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Universal Access in Human Computer Interaction

Coping with Diversity

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Foreword

The 12th International Conference on Human-Computer Interaction, HCI International 2007, was held in Beijing, P.R. China, 22-27 July 2007, jointly with the Symposium on Human Interface (Japan) 2007, the 7th International Conference on Engineering Psychology and Cognitive Ergonomics, the 4th International Conference on Universal Access in Human-Computer Interaction, the 2nd International Conference on Virtual Reality, the 2nd International Conference on Usability and Internationalization, the 2nd International Conference on Online Communities and Social Computing, the 3rd International Conference on Augmented Cognition, and the 1st International Conference on Digital Human Modeling.

A total of 3403 individuals from academia, research institutes, industry and governmental agencies from 76 countries submitted contributions, and 1681 papers, judged to be of high scientific quality, were included in the program. These papers address the latest research and development efforts and highlight the human aspects of design and use of computing systems. The papers accepted for presentation thoroughly cover the entire field of Human-Computer Interaction, addressing major advances in knowledge and effective use of computers in a variety of application areas.

This volume, edited by Constantine Stephanidis, contains papers in the thematic area of Universal Access in Human-Computer Interaction, addressing the following major topics:

- Designing for Universal Access
- Universal Access Methods, Techniques and Tools
- Understanding Diversity: Motor, Perceptual and Cognitive Abilities
- Understanding Diversity: Age

The remaining volumes of the HCI International 2007 proceedings are:

- Volume 1, LNCS 4550, Interaction Design and Usability, edited by Julie A. Jacko
- Volume 2, LNCS 4551, Interaction Platforms and Techniques, edited by Julie A. Jacko
- Volume 3, LNCS 4552, HCI Intelligent Multimodal Interaction Environments, edited by Julie A. Jacko
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- Volume 6, LNCS 4555, Universal Access to Ambient Interaction, edited by Constantine Stephanidis
- Volume 7, LNCS 4556, Universal Access to Applications and Services, edited by Constantine Stephanidis
- Volume 8, LNCS 4557, Methods, Techniques and Tools in Information Design, edited by Michael J. Smith and Gavriel Salvendy
- Volume 9, LNCS 4558, Interacting in Information Environments, edited by Michael J. Smith and Gavriel Salvendy

- Volume 10, LNCS 4559, HCI and Culture, edited by Nuray Aykin
- Volume 11, LNCS 4560, Global and Local User Interfaces, edited by Nuray Aykin
- Volume 12, LNCS 4561, Digital Human Modeling, edited by Vincent G. Duffy
- Volume 13, LNAI 4562, Engineering Psychology and Cognitive Ergonomics, edited by Don Harris
- Volume 14, LNCS 4563, Virtual Reality, edited by Randall Shumaker
- Volume 15, LNCS 4564, Online Communities and Social Computing, edited by Douglas Schuler
- Volume 16, LNAI 4565, Foundations of Augmented Cognition 3rd Edition, edited by Dylan D. Schmorrow and Leah M. Reeves
- Volume 17, LNCS 4566, Ergonomics and Health Aspects of Work with Computers, edited by Marvin J. Dainoff

I would like to thank the Program Chairs and the members of the Program Boards of all Thematic Areas, listed below, for their contribution to the highest scientific quality and the overall success of the HCI International 2007 Conference.

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April 2007

Constantine Stephanidis
General Chair, HCI International 2007

HCI International 2009

The 13th International Conference on Human-Computer Interaction, HCI International 2009, will be held jointly with the affiliated Conferences in San Diego, California, USA, in the Town and Country Resort & Convention Center, 19-24 July 2009. It will cover a broad spectrum of themes related to Human Computer Interaction, including theoretical issues, methods, tools, processes and case studies in HCI design, as well as novel interaction techniques, interfaces and applications. The proceedings will be published by Springer. For more information, please visit the Conference website: http://www.hcii2009.org/

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Fundamentals of Inclusive HCI Design

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Abstract. In this paper authors review several fundamental issues necessary for the design of inclusive human-computer interaction systems. The main objective is to vindicate the adoption of the Universal Accessibility paradigm in the design of main stream applications. Given that the authors think that current technology and design methods and tools are mature enough for inclusive design, they studied the conditions for its full deployment and propose the elimination of the found obstacles. In this paper, after justifying the importance of the Design for All, the main restrictions to inclusive design are reviewed and the need for a user oriented approach is showed. Other crucial matters to ensure inclusive design, such as user full participation and ethical and social impact avoidance, are analyzed. To finish, the role of the Assistive technology, in relation to Design for All is discussed.

Keywords: Universal Accessibility, Inclusive Design, Design for All, Ethics, Users with disability.

1 Rationale

Experience shows that a large amount of human-computer interaction systems are designed for someone conceived as the "standard man" leaving out the scope all the people with different physical, sensory or cognitive features. Having in mind that the most common human characteristic is just variety, most designs do not completely fit individual user’s needs.

The problem of matching product features with users' characteristics is most frequently addressed by the own user adapting himself or herself as much as possible to the interface. As a consequence, people that are no able to adapt themselves are simply left out of the possibility of use these products or services.

There currently exist design techniques and methodologies able to address users’ diversity, by means of modelling and adaptation [1]. Nevertheless, they are not enough known and used. In fact, the marginalization of large sectors of users was – and frequently is– justified by limitations of technology. Nowadays we know that

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technology can be designed in a most inclusive way avoiding the inclusion of unnecessary barriers.

Inclusive Design aims to consider the needs of all the users in main stream applications and not only in the systems especially designed for people with physical, sensorial or cognitive restrictions.

2 Advantages of Inclusive Design

Inclusive Design is based on the convincement that humans are naturally very diverse. The partition into "normal users" and "other users" is artificial and the frontiers between both populations are arbitrary. In fact, there are abundant examples where technology eliminated or alleviated these frontiers. Something as simple as glasses – nowadays of common use– allow several people with eyesight restrictions to enhance their vision. More complex technologies, such as computers, give people with motor and speech impairments a way to personal and remote communication, and to control their environment.

Evidently, Inclusive Design has ethic and social fundaments. Universal Accessibility is supported by the convincement that all the human beings have the same rights. In practical terms this means that they should be able to access to the same services and to enjoy the same opportunities. Technological designs that unnecessarily establish barriers to universal use effectively exclude users with physical, sensory or cognitive restrictions.

In addition, to its ethics roots, inclusive technology is highly practical and useful. It frequently has a higher impact over the market because accessible products are directed to a broader population of potential consumers. In fact, people without disabilities usually find inclusive technology easier and more usable. On the other hand, the new ways to interact with mobile and ubiquitous technology frequently require hand and sight free interaction, and as a result they can very much benefit from Inclusive Design. For instance, people wanting to read their email while they drive to work do need auditory interfaces, similarly to several vision impaired people. In addition they will need voice input to enter commands to the system, similarly to many people with severe motor restrictions.

It is frequently argued that Inclusive Design (for instance accessible web design) is not more expensive that standard design. We cannot deny that accessible design requires higher effort from the designer. That means the need of knowledge and experience on this kind of design, longer development periods, etc. Nevertheless, it is proved that accessible products are of higher quality. In fact, usability and accessibility are included as quality measurement figures of merit in a number of software methodologies.

3 Current Restrictions to Inclusive Design

Even if Inclusive Design advantages have been frequently acknowledged, there is little advancement in Inclusive Design of commercial ICT products. This may be due to a combination of factors. Let us discuss some of them.

- *The lack of awareness of universal design.* Numerous HCI designers frequently ignore that they can design for a broader population simply avoiding the inclusion of certain features that put difficulties to the accessibility by a number of users.

In order to avoid this problem there exist a number of initiatives that promote the Design for All, such as the European Design for All e-Accessibility Network[1]. EDeAN produces resources to enhance the awareness among designers of the need for universal access. In particular, they provide links to diverse initiative to promote accessible design, such as The Centre for Accessible Environments, CAE[2], were useful references [2], can be found.

In addition, it is necessary to educate current and future designers in the use of methods and tools for Design for All. Universal Accessibility aims, techniques, tools, etc., should be well known by engineering students, in order to avoid this lack of awareness in their future professional activity. To this end, the Inclusive Design Curriculum Network, IDCnet[3], produced a number of comprehensive documents addressing the needs of industry for the graduate profile and analyzing what constitutes Design for All knowledge. ICDnet studied a DfA core knowledge and analyzed the needed skill sets in order to propose a model curricula and recommendations to teach it. In addition, the current situation in USA and Europe was reviewed and policy recommendations on Design for All related higher education for EU countries were issued. IDCnet results have been summarized in [3].

- *The lack of knowledge about user needs.* Most HCI professionals usually design without having a previous analysis of the users needs. Their designs are frequently based in their own mental model of the task, their own capabilities and likes, etc.

In order to prevent this approach, there exist user-centred design methodologies [4]. They give special attention to early user features gathering, and to usability evaluation thought the complete design process. Therefore it is crucial to instruct HCI designers to use user-centred design methodologies.

When speaking about Universal Design, people having physical, sensory or cognitive restrictions should also be taken into account, although most designers ignore their characteristics and needs. For this reason, it is highly recommendable to use Inclusive Design guidelines. Design guidelines usually collect recommendations for good practices in design collected by experts or coming from previous successful developments. More information about the use of Inclusive Design guidelines, and methodologies and tools for they application can be found in Nicolle 2001, Abascal 2001 Abascal2005 [5, 6 , 7].

In addition, it is important to emphasize that the use of Inclusive Design guidelines do not exclude the need for sound evaluations by real users as demanded by user-centred methodologies.

4 Conditions for Inclusive Design

There are numerous "side" key issues that must be taken into account when Inclusive Design paradigm is adopted.

[1] http://www.education.edean.org/
[2] http://www.cae.org.uk/index.html
[3] http://www.idcnet.info/home

4.1 User Integration in the Project

Inclusive Design is hardly possible without the full participation of the users in de whole design and development process. That means that the users must be present:

- *In all the phases of the process:* not only when the product or service is finished and there is not opportunity to influence its redesign
- *As full participants*: with capacity to influence the decisions.
- *Being paid*: Frequently users are consulted about the results of a project. They knowledge and experience is not given any value, and they are expected to give their opinion free, just because this is good for them.
- *Under a code of conduct for experiments*: experiments must be ethically conducted. Personal unnecessary data shouldn't be collected. In case that private information is strictly necessary for the experiment, it should be coded in a way that the user can not be identified. Personal information must be erased after its use. In addition, frequently users feel that are they who are examined and not the product. Failures are assumed as their own limitation and not as product malfunction. To avoid several frustrating experiences that conduct to rejection to participate in ulterior users tests it is important to show to participants that malfunctions found in the experiments are most frequently due to the provisionally of the system, and to found them is just the objective of the experiment.

4.2 Ethical Risks Avoidance

- *User autonomy: Avoid taking automatic decisions about the user without her or his consent.*

The system should take decisions about matters concerning the user only with it is strictly necessary, for example in risky situations. Even for pre-programmed low importance tasks, such as heating or lighting control, the user should maintain the control and have the possibility of override system decisions. Systems that automatically or remotely take decisions that affect the user autonomy must count with her or his informed consent [8].

- *User privacy: Avoid to store, transmit or process data about the user or his/her activities that are not strictly necessary for the current application.*

Today's technology allows easy and cheap user data gathering. Collected data are frequently not needed for the application and are taken "just in case" or for statistical purposes. It is important only to collect the needed data. In addition, this information must be deleted when it is not more necessary. If it is stored for statistical purposes, it must be guaranteed that it is not possible identify the user from these data [9, 10].

- *User consent: always ask for the informed consent from the user.*

In case that sensible information has to be collected, for instance by health surveillance systems, or when the systems takes decision affecting them, for instance triggering an alarm when going out home, the users must previously know it and give their consent. In this case, there must exist alternatives –not merely disruption of the access to the service– for people not prone to give their consent. Otherwise the informed consent leads to something similar to coactions: if users do not give their consent they have to renounce to the whole service.

4.3 Social Risks Avoidance

- *Compensate the social impact of services that produce isolation.*

A number of remote services and applications may reduce human contact and socialization especially to users with mobility or communication restrictions. For instance, tele-care, tele-work and tele-learning provide good opportunities to people living in remote places or having motor disabilities to access to health, labour or formation services. Though, some people with disabilities would have fewer occasions for interpersonal relationships. Even if the creation of alternative actions to enhance the opportunities for human contact should be developed by policy makers, designers must be conscious of the likely social impact of their products and try to as much as possible reduce isolation effects caused by them [11].

5 Inclusive Design vs. Assistive Technology

The aim of the Assistive Technology is to develop equipment specially adapted to the specific characteristics of users that cannot utilize standard input/output devices, such as keyboards, mice, screens, etc. Special interaction devices, such as one-key-scanning systems for severely motor impaired people or output devices such as Braille rows for blind people, allow computer use only if standard hardware and software in the computer is designed barrier-free [12]. That is, if it is designed for all.

Universal Design recommends adding textual comments to the figures in the designing software applications, for instance. When interacting with these applications blind people are still unable to see the figures, but they can read the explanations in Braille or hear the output of a text-to-voice synthesizer.

In addition, Universal Design requires that the own computer is accessible. If, for instance, the hardware puts barriers to the installation of non standard input/output equipment and its drivers, or the software prevents this equipment to capture standard input/output, assistive devices are useless.

Therefore Design for All does not make unnecessary the development of special equipment for people with disabilities. On the contrary, even if the *Design for All* paradigm would be universally embraced and accessibility barriers were removed from all the designs, numerous people with disabilities would still need special input/output devices to be able to use computers and its applications [13].

5.1 The Need for a Model Leading Technology Development

The design of technology is always framed in a model. Even if technologists are not aware of it, the subjacent model very much conditions starting points, methodologies and results. The absence of an explicit model frequently means that the research and development process is driven by technology availability. Designers having interest in developing such a technology imagine its application to the needs of a collective of people (mostly unknown for them). These experiences frequently produce good devices or services from the point of view of the technology but hardly successful from the users' point of view because they are expensive, difficult to be operated incompatible with other technologies needed by the same user, etc.

Having into account the issues previously analyzed in this paper, the use of an inclusive model for HCI development means:

- Directing the process to a verified exiting problem
- Knowing the actual needs of the potential users
- Having into consideration the whole users: all their needs, their environment, the tasks performed, their likes and their physical, sensory and cognitive features
- Verifying the successive design decisions with real users
- Using technology proportional to the problem. Avoiding not really needed expensive fancy technology
- Analyzing and avoiding any risks of ethical and social impact

All these matters, considered as a whole, should be included in the standard software development methodologies, in order to be systematically addressed. The existence of associated development tools would also be very useful.

6 Conclusion

Current advancements in technology, and present design methodologies and tools allow an inclusive approach to HCI design that impedes the creation of barriers for users with physical, sensory or cognitive restrictions.

To move forward in this direction it is necessary to enhance the awareness among designers on user diversity, to provide them with inclusive guidelines and user centred methodologies and design tools. User participation in the whole development process must be also seriously implemented. All these issues must be framed in a model that takes into consideration all the factors affecting the process: users, their environment, expected tasks, the economical and social context, etc.

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Ensuring Access to the Information Society for People with Disabilities Through Effective Use of Design for All Methodologies

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Abstract. Since the European Commision's Information Society Technologies Program Advisory Group (ISTAG) coined the phrase "ambient intelligence" [1], [2] a much anticipated future has been considered. That future would involve people with disabilities living in a world populated by interconnected networks of intelligent devices, providing the means for communication, information retrieval, entertainment. A responsibility now exists to include people with disabilities in the debate and discussion of what such a future will mean to them, how it will improve their quality of life and how the potential of future technologies can be appropriately exploited. This paper outlines a collaborative process undertaken by the Central Remedial Clinic, providing a total of 34 people with different disabilities with an opportunity to reflect on and discuss the ISTAG scenarios and envision their own future as citizens with disabilities in a world surrounded by and supported by, as yet unrealised, ambient intelligences.

1 Introduction

The European Commission's Information Society Technologies Program Advisory Group (ISTAG) in 2001 published a set of four separate scenarios articulating a vision of how technology interconnected by ambient intelligences would practically influence and affect the lives of people [2].

Such a vision of the future promises much to people with disabilities who are currently limited in their ability to participate in society by the barriers and limitations they experience. Although to date, technology has provided people with disabilities with new opportunities for education, employment and leisure, much of this technology has been specialised, expensive and at times socially isolating [3].

Facilitating the participation of people with disabilities in defining a vision for a new society will involve ensuring that they are at the forefront of discussion and have opportunities for inclusive articulation of their own vision of how such technologies can be exploited. Historically however, regulatory, social and ethical standards have tended to follow rapid technological proliferation [4].

A Design for All approach encourages the full inclusion and participation of people with disabilities in the design and development of new technologies [5].

The purpose of this paper is to report on and present the results of a project which involved providing people with disabilities with a forum to discuss the ISTAG scenarios and to discuss how they saw future technologies affecting their own lives.

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It was also intended that this group, by engaging in this, educational process, would coalesce into a group of people with disabilities with the skills and knowledge to participate in future inclusive design processes, thus influencing the future of technology development.

A series of information sessions, involving the participation of a total of 34 people with physical, sensory and cognitive disabilities. These information sessions provided participants with a brief overview of the areas of ambient intelligence, ubiquitous technology and natural interfaces. These also provided the opportunity for participants to gather and individualise information. All sessions were followed by a series of focus groups where participants were given the opportunity to identify and articulate their own vision of what ambient intelligent technology in the future will constitute, and more importantly how it impacts upon their own participation in society.

2 Method

A total of 34 people with disabilities who work in or use the services of the Central Remedial Clinic participated in a series of formal and informal information sessions aimed at presenting current research in the area of Ambient Intelligence and Design for All over a period of nine months, from March 2006 to November 2006.

The aim of these sessions was to increase the first hand knowledge people with disabilities have of current research and thinking in the area of Ambient Intelligence and to facilitate the articulation and discussion of their vision of a future where they could exploit the potential of such technology.

All participants were taking a short course in Assistive Technology, which was developed and delivered by staff of the Central Remedial Clinic, where one module from six was dedicated to “Future Trends in Technology”.

All the participating students with disabilities were taking the course in order to increase their own awareness and knowledge of new technology. The particular profiles of participants with disabilities are outlined fully in the Results section that follows this.

This module comprised a total of twelve hours of direct tuition, followed by a series of facilitated web discussions based on the materials presented during the face-to-face sessions. The central vehicle facilitating these discussions was the ISTAG case study scenarios [1], [6], these case studies were developed as a means of presenting a vision of the future based on new developments in technology and society. This vision is based on a future in which Ambient Intelligence in integrated seamlessly into the fabric of society and as part of the day-to-day lives of citizens.

As mentioned previously, these were selected as a means of providing a focus for the discussion and reflections of students participating in the course module outlined above.

Students were asked to discuss the four scenarios under the following headings, the results of these discussions are summarised in the Results section of this paper. Based on these discussions, a questionnaire was developed specifically to examine the opinions of participants with disabilities regarding a future based on a society of services and technology integrated by Ambient Intelligence.

After completing the online discussion of the ISTAG scenarios, students were provided with a further four hours of lectures in the area of Design for All and the effective inclusion of people with disabilities in the process of product and technology design.

This process was modelled on a previous study with people with disabilities conducted by the authors of this report in a similar educational process [6].

Online discussions took place using the Learning Management System, MOODLE (www.moodle.org) Moodle, a free online resource was used by the author to provide project participants with a range of collaboration tools, including, asynchronous discussion board, synchronous chat, and a file publishing and sharing facility.

Although dedicated Virtual Learning Environments, such as Blackboard™ and WebCT™ are commercially available, the costs associated with buying and maintaining such a system are prohibitive for many schools. This and the advantage of being able to tailor an online environment for the participants involved have resulted in a rise in popularity of "do it yourself" [8] systems such as MOODLE which is used here.

3 Results

3.1 Description of Project Participants

As mentioned previously, a total of 34 participants with disabilities were involved in this project, the distribution of male and female participants is presented below in Figure 1.

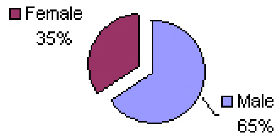

Fig. 1. Distribution of male and female project participants

Participants had a broad range of physical and sensory disabilities with several presenting with a learning difficulty. The chart below describes the representation of disabilities within the group participating in this project.

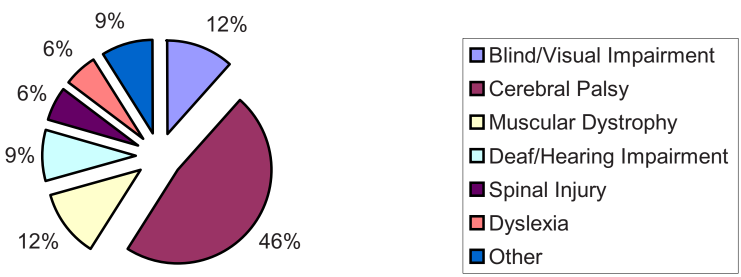

Fig. 2. Distribution of disabilities amongst participants

As can be seen from Figure 2 above, Cerebral Palsy is the condition most significantly represented among participants in this project, this is reflective of the service users of the Central Remedial Clinic, which as a service primarily deals with people who predominantly have physical disabilities.

As stated previously, participants were surveyed in terms of the technology that they most commonly use, so as to present a profile of the technology use of this particular sample of people with disabilities.

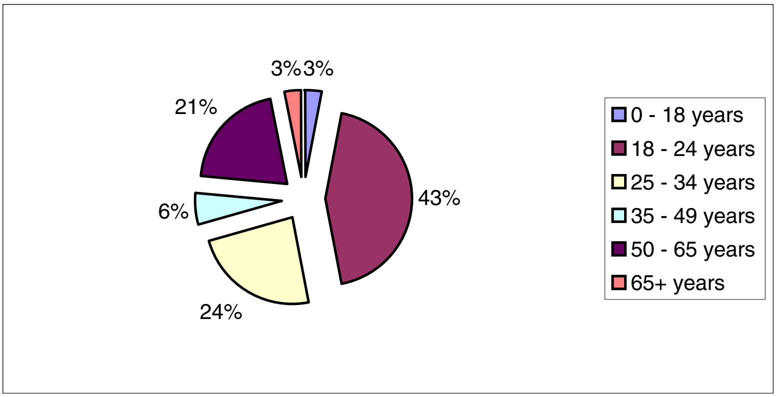

Fig. 3. Age profile of participants

3.2 Presentation of Student's Online Discussion

Participants in this project were asked to discuss the four ISTAG scenarios presented using an online learning platform, which captured all student discussions.

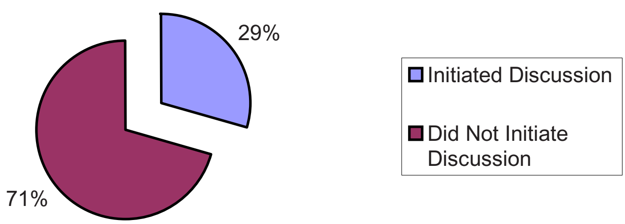

Fig. 4. Representation of Student discussions, highlighting the number of participants who actively initiated discussions during the online process

As is obvious from the above many participants were slow to initiate online discussion and express opinion without the prompting or support of others. However, as can be seen below, the majority of those participants in the discussion took an active role in the ongoing discussions of the four ISTAG scenarios.

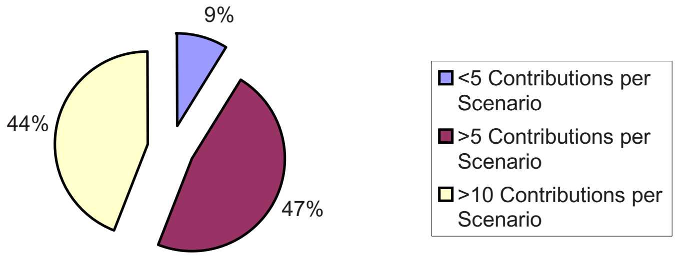

Fig. 5. Percentage of Discussion Contributions per Scenario by each student participant

From the above it is clear that the majority of participants actively involved in discussion of the ISTAG scenarios, thus reflecting a greater level of reflection and analysis on the part of each individual person with a disability participating in this process.

During the discussions all participants were asked read each story and comment on how the technology in the background of each scenario might impact on their lives as people with disabilities. Participants were also asked to comment on what they saw as their "difficulties" or issues with these scenarios. Several of the responses were interesting and in a qualitative way informed the discussion in this paper.

Some of the user comments drawn from these discussions are outlined below in conjunction with a short summary of the authors' summary of these discussions.

Within the scope and context of this paper it is impossible to present all of the discussions in a complete and quantitative manner, rather, a snapshot of each of the sets of discussions will be captured with the author paraphrasing and summarising the full discussions for the purposes of illustrating the overall themes that emerged from student's reflection and their discussions.

3.3 Summary of Student Discussions

Scenario 1: Maria - Road Warrior

The overall impression presented by all participants was of a life supported by a range of yet to be realised *navigation technologies*. This scenario facilitated a large amount of discussion amongst participants, where the majority expressed the view that such technology could be of great benefit to people with disabilities. Of particular interest to note was the enthusiasm with which people with visual impairments embraced the potential of such technology, with several accounts of extending current technology being envisioned during the discussions;

> "*…a lot of GPS and navigation aids are too simplistic right now, and need to be hooked up to a bigger number of satellites and other systems for Blind people, it would be good to imagine a system that made travelling much more 3D…*".

Of further interest in these discussions was the fact that many participants felt a level of cynicism toward a technology that could provide navigational support to people with disabilities. Many participants pointed to the difficulties that Maria would continue to experience in the physical/built environment regardless of her ability to use Ambient Intelligence to navigate around any environment.

> "…*a navigation tool is not much good unless it can spring out a ramp when you get to a flight of stairs*!"

Positively, the discussion highlighted the benefits of a "personal communicator" providing people with a disability with a single point of access to many different sources of information, support and guidance, although some did comment on the potential obtrusive nature of such a technology.

> *"… we are not far from having personal communicators now, my mobile phone has almost all the functions that I imagine that I need, it is important though to know when I can switch it off…"*

Scenario 2: Demitrios – Digital Me

This case study/scenario generate less discussion than that of Maria, although some of the discussion did highlight two particular areas of interest to people with disabilities. Firstly, having a "communication agent", able to communicate differently to different people and secondly, the idea of being able to adopt a great many "digital personae".

How people with disabilities understood the concept of a communication agent during this process may have been somewhat misunderstood, with many of those participating in these discussions articulating a communication agent as being an immediate technology that facilitates communication for those with difficulties interacting with others, much as current Alternative and Augmentative Communication is intended to do.

> *"….Dimitrios, if he had a stroke, could get one of his Mini-Me's to go back and do the talking for him after his stroke…."*

Some discussion was dedicated to the usefulness or otherwise of a "universal translator" – this was seen of particular relevance to people with difficulties with text, such as those whose first language is sign, or indeed for those who communicate using symbols/symbolic representations.

> *"…I cant see a communicator like this being able to interpret or translate different types of sign language, you would have to have video on a screen or his videoconferencing system and the translation to happen straight away….I just cant see it being fast enough…"*

It is interesting to note that most participants did focus on the communication agent as a stand alone piece of technology, with little reference to any Ambient Intelligence that it may be part of. Exploring this further may indicate how people with disabilities currently consider the technologies that they use.

Some participants speculated about the relevance of creating multiple "digital personae" for people with disabilities, thus ensued some discussion of the merits of online communities, such as BEBO (http://www.bebo.com). One participant speculated on the merits of people with disabilities being able to experience alternative experiences of interaction with people in such circumstances, where he considered that an online, avatar agent could represent him in a way that may not be possible when he interacts with people on a face-to-face basis. Although this was from a social perspective an interesting turn in the discussions, no other participant took up on this particular thread.

Much of the discussion regarding the impact of the Ambient Intelligence surrounding Dimitrios would certainly merit more in-depth sociological analysis, well beyond the scope of this project.

Scenario 3: Carmen – Traffic, Sustainability & Commerce

Interestingly, the students using wheelchairs participating in these discussions, related to this story by interpreting their own wheelchairs as part of an overall "city system", where they envisioned themselves moving throughout the city receiving regular updates regarding the accessibility of buildings etc.

> *"…even if we could get information going into town about a new set of stairs or a broken lift, that would be great, and if the chair brought us automatically to a new accessible place that would be better…."*

Many participants spoke of the benefits of online shopping services for people with disabilities with several speaking of their own experiences of using e-commerce sites and how this eliminates some of the environmental barriers they experience in the community.

Other participants discussed the limitations of their home environmental control technologies and expressed the need for further connectedness between the technologies that they are using.

> *"…its not that crazy that you could shop from your own home, even now all you need is the computer and the Internet, the only problems at the moment are switching the computer on and paying the bills…"*

It is interesting to note that this scenario, on initial review by the authors of this paper, would appear to promote most meaningful discussion regarding the concept of Ambient Intelligence, this may be because the participants in this project had first hand experience of technology supporting them in the home, supporting them for activities such as shopping and with mobilising independently around a urban landscape.

Scenario 4: Annette & Solomon – A Context for Social Learning

Scenario four generated most discussion, possibly because all of the participants were engaging in a social learning activity mediated by Internet technologies, so a certain relevance could be drawn between the scenario and the immediate experiences of the participants in this project.

The major theme that emerged during these discussions was related to how Ambient Intelligence in an educational context could compensate for the gaps people felt they had in their education to date, how poor literacy or memory difficulties could be supported by Ambient Intelligence, or at least a collective knowledge repository that people could be connected to at all times.

> *"…imagine, not having poor spelling stand in the way of doing an essay or assignment…"*

Some of the participants speculated that access to Ambient Intelligence within education would eliminate the need for education completely, leading to lives dedicated to leisure;

> *"… if technology did all the learning for me, I'd have the time just to enjoy myself with my friends…"*

One further issue of note here was that of how Ambient Intelligence could change the process of learning away from one that is dependent on interaction with text, either in terms of reading/listening/writing etc., and whether or not technology could replicate practical learning opportunities. Some speculation was made as to whether virtual reality type technology could harness Ambient Intelligence to provide people with real life experiences of different learning opportunities with one participant speculating that;

> *"you could try out what it was like to be a nurse or fireman without becoming that person, and you'd always be able to go back to normal again…."*

These findings will be discussed in more detail in the next section of this paper.

4 Discussion

Imagining a future of ambient intelligences supporting us as we go about our day to day lives can often be difficult, in particular establishing a consensus on what that future will be like requires a great deal of thought, discussion and planning.

As mentioned previously, such a future can provide opportunities for greater participation at all levels of society for people with disabilities.

For researchers and designers, a continuing challenge is that of providing a platform from where people with a disability can be involved in the process of planning and envisioning a world where they can exploit the potential of future ambient intelligences and other technologies.

Using the ISTAG scenarios as a starting point from which to facilitate people with disabilities articulating their views of ambient intelligence and how these could potentially

One major limitation of this process, was the time that was dedicated to the discussion process, each participant had only four weeks to complete his or her discussions of the four ISTAG scenarios. This meant that for some of the scenarios, students limited their discussions to statements of how they felt each of these related to their own lives. Pressure of time meant that there was little time to clarify issues and misunderstandings that arose from different participants understanding of the scenarios.

Further moderation by course tutors would also have been invaluable in facilitating a greater level of reflection by students and would have encouraged a greater degree of collaborative and peer learning during the process.

Furthermore, for future work using this process, it would be important to create inclusive online communities, such as those proposed by Brufee [9].

Notwithstanding these limitations, the process was a rich and valuable one on the part of the students and tutors. A great deal of insight was gained into how people with disabilities envision a technology supported future for themselves, and it provided students with a much greater appreciation of how they can engineer the future more directly.

Student's comments and discussion elicited during this merit further and more in-depth analysis, which is beyond the scope of this paper, which is focused only on reporting on the process. Future work however, would be greatly enhanced by a more rigorous pedagogy emphasising increased collaboration between students and opportunities to discuss the scenarios both in face to face sessions and mediated by online technologies.

The purpose of this project was twofold; firstly to establish a starting point from where people with disabilities could be facilitated in the process of imagining a world with ambient intelligences. Secondly, to provide them with a practical knowledge base from which they can, in the future, practically participate in realising this future.

The intended outcome for participants in this process was that they would acquire the skills necessary to participate in inclusive design process for new technologies and new systems. For an organisation such as the Central Remedial Clinic, establishing such an expert user group will prove an invaluable tool in future Design for All projects.

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Investigating the Use and Adoption of Self-service Technology in China

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Abstract. Self-service technology use and adoption can be seen as an evolutionary process. From a conceptual perspective, evolution delivers the growing advantages of self-service. From a practical perspective, evolution is based on user perceptions and attitude toward adopting the technology. Based on the latter perspective of technology adoption, this paper presents an analysis of three empirical studies exploring self-service solutions for Chinese customers. These studies involve several user-centred research methodologies. The studies were carried out as a result of research collaboration between Sino-European Usability Centre (SEUC), Dalian Maritime University, China and Advanced Technology and Research (AT&R), NCR, U.K. The first study investigates the introduction of a basic automated teller machine (ATM) accommodating Chinese user requirement. Findings indicate that the relationship between individuals' pre-adoption and post-adoption perceptions of ATMs was a critical determinant of its continued use. The second study focussed on the functionality of ATMs in terms of using cash deposit solution. The study reports that the successful use of cash deposit was evaluated on the basis of users' understanding of deposit solution. The third study addressed biometric technology use for enhanced security on ATMs. Consistent with previous findings, user perceptions emerged as an important determinant of biometric technology adoption in the Chinese financial market. Based on user perceptions, these studies provide an understanding into the self-service future in China. Several user-centred design guidelines to adapt self-service technology to Chinese user requirements have emerged. Also, these studies offer valuable outcomes in terms of useful insights into the current Chinese banking culture. These insights provide Chinese financial institutions a basis to strategically introduce self-service technology on a broad scale.

1 Introduction

In the past decade, the evolution of self-service technology from a practical perspective has been greatly influenced by the focus of research on customer experience with the technology. Previous research also highlights the significance of user experience upon the potential diffusion of self-service technology in the Indian market (Angeli De et al. 2004). Therefore, it is important to analyse the evolution of

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self-service technology from a user viewpoint in terms of various functionalities, convenience, security and efficiency the technology offers. In this study, the evolution of self-service will be analysed in the context of Chinese financial market. The Chinese market provides a platform to explore competitive opportunities for introducing self-service technology. Also, the fast growing Chinese economy has focused on the process of globalisation which has led to an increase in the practice of usability and user experience methods (Liu et al. 2005 and Wang 2003). Three user studies will be presented with a focus on various financial self-service technologies for Chinese customer.

The paper begins with a brief introduction to self-services solutions and their gradual growth in the financial market. The section also discusses the long-term close alliance between industry and academia at Advanced Technology and Research at NCR, U.K. and Sino-European Usability Centre at Dalian Maritime University, China, respectively. The alliance has provided a basis to design and carry out the three studies.

Section 3 reports on the first study which began with an in-depth analysis of Chinese individuals' requirements of using an ATM in terms of their perceptions. The study comprised two phases. The first phase carried out a preliminary investigation into user perceptions on the basis of focus groups and interviews with individuals with different levels of experience with ATMs. The second phase involved a comprehensive usability evaluation of an ATM. The usability evaluation began with experts to identify important areas of usability investigation. The expert evaluation was followed by regular users and non-users of ATMs, which provided useful insights into their preferences and concerns regarding the ATM use. The results of the research provided guidelines for the design of and interaction with ATMs. Positive user attitude toward using ATM technology evolved the process of introducing self-services in China. Since a strong preference for a richer functionality within ATM was expressed by users, the next user study analysed user requirements of cash deposit technology within ATMs in China, which is reported in Section 4.

The study on deposit technology was based on a questionnaire survey and usability evaluation of deposit technology to address user perceptions toward and difficulties with using the technology. The major findings from the study emerged in terms of users' perceived security, efficiency and ease of use of deposit technology use. With increased functionality, the security of self-service technologies becomes more critical. Therefore, the security issue was addressed in the third study which is discussed in Section 5.

In order to analyse user perceptions of ATM security, a two-phase project on biometric technology use for identity authentication within ATMs was conducted. In the first phase, usability methodologies such as interviews and survey were used in China to determine initial user perceptions of fingerprint technology use. In the second phase, an in-depth experimental study was conducted to investigate issues related to the actual use of fingerprint technology. The results of the second phase analysed user preferences for various fingerprint sensors, which further help understand how users measured efficiency, interactivity and feedback from sensors. The study concludes with a discussion of the findings of the three studies.

2 Background

In the financial sector, self-service technology was introduced in the form of an automated teller machine (ATM). The strength of ATMs was in dispensing cash and offering basic banking functions. With the advancement of online technology and self-service solutions in sectors such as retail, a need to enhance ATM capability has been felt. Therefore, enhancing the functionality of ATMs has promised financial instituted business value in terms of its operational efficiency and low cost maintenance and reliability. It is also important to note that the success of self-service technology has been assessed in terms of convenience, consistency, effectiveness and control from a user's viewpoint. Therefore, kiosks are deployed for banking, airport check-in retail store check-out and at cinemas and railway stations. Self-service technology is provided via the web, phone and kiosks. Individuals have been able to perform transactions by avoiding queues, during non-working hours and even at home online at their own convenience. Hence the user-centred self-service technology has contributed immensely to its widespread use. The introduction and deployment of self-service solutions has attracted many emerging markets in the past decade.

The success of self-service technology is of key interest for financial institutions in China which is potentially the largest future market in the world for the self-service technology. The collaboration between AT&R, NCR and SEUC, Dalian Maritime University has set forth several successful projects aiming to investigate self-service technology such as automated teller machines (ATMs), cash deposit solutions and biometric technology use for identity authentication. The aim of these projects has been to evolve the self-service technology in China by exploring the requirements and the usability of the technology in terms of customers' perceptions and experience. The collaborative work between SEUC and AT&R has involved several researcher visits for each study between the two centres. These visits have placed an emphasis on defining the scope and design of longitudinal studies and the provision of materials and supervision. The projects also involved secondments of SEUC students at AT&R to obtain first hand knowledge and experience with technology and interaction with researchers in AT&R. Continuous progress of all projects has been maintained through regular conference calls between SEUC and AT&R on a weekly basis. The success of these projects has provided academia a valuable opportunity to real-world exposure of user problems associated with self-service technology. These studies have put together a compendium of ideas to further explore avenues of collaboration between SEUC and AT&R.

One of the major factors contributing toward the success of the self-service technology is its design based on Chinese users' perceptions. The importance of user-centred technology design in general and self-service in particular has been realised in China for over a decade. However, it is still relatively a new discipline and has been practised in industries such as Microsoft, IBM, Nokia, etc., and some large scale local companies, such as Lenovo and Huawei (Wang 2003). However, user-centred design provides a strong foundation to identify and analyse critical user perceptions that determine the acceptance of technology. In the next section, the first study investigating the use of a customised ATM is analysed on the basis of Chinese user perceptions.

3 Self-service Technology – Automated Teller Machines

China has been seen as one of the biggest markets for the adoption of automated self-service solutions in the financial market. In order to obtain an understanding of how Chinese individuals perceived self-service technology, a study was initiated with a focus on the use of an ATM. The ATM was customised to Chinese users' requirements. The main aim of the study was to analyse user perceptions and attitude towards and any difficulties when using the customised ATM. The study included two main phases starting with a preliminary investigation based on focus group sessions and interviews, which then led to the usability evaluation of the ATM.

3.1 Phase I – Preliminary Investigation

Preliminary investigation began with eight focus groups with eight participants in each session both in Dalian and Shanghai. Participants were grouped on the basis of their experience/no-experience and higher/lower income. Several factors ranging from user expectations for the design of ATMs to the perceived use emerged as a result of focus groups sessions. These factors provided a basis to conduct interview with 100 Chinese individuals. 50% females and 50% males participated in the interview. Their age ranged between 18 and 54.

Individuals were divided into two groups. In one group, 60 individuals were approached when they finished using and ATM and were asked to participate in an interview. The participation was voluntary. In the other group, 40 users were asked to take part in the interview who had not used an ATM before the interview. Consistent findings emerged from data analysis of both user groups. Findings showed that a general positive perception of ATMs was expressed by users for its convenient use. Several preferences for the design of ATMs also emerged in the analysis of interview data. Certain concerns regarding the security were highlighted and users showed their interest in more financial operations to be automated in ATMs such as paying bills. The findings of the preliminary investigation provided an initial understanding of user perceptions of ATM use in general. To further address the actual use and user preferences of ATMs, a usability evaluation of a customised ATM was carried out in the next phase.

3.2 Phase II – Usability Evaluation

The phase began with the evaluation of an ATM by three usability experts from Dalian Maritime University. The purpose of conducting a heuristic usability evaluation with experts was to identify important factors to shape the usability evaluation with regular users of ATMs. Based on interview findings in Phase I and experts' feedback on ATM use, the evaluation of ATM was carried out with 30 Chinese individuals of whom 20 had experience and 10 had no experience of using ATMs. Users were asked to perform several typical tasks with the ATM.

Several physical features of the ATM design along with the information presented were evaluated. Despite the level of experience with ATMs, users generally presented a positive attitude toward the physical design of the ATM. Most features were perceived to be unambiguous and easy to use. These findings indicated that users generally had a positive attitude toward features which gave them a sense of control. However, certain factors highlighting users' concerns with understanding the processing of transactions emerged. For example, the presentation of a screen saver (a welcome screen) during the inactivity of ATM was seen as confusing. Users also found decimal entry ambiguous during fund transfer. However, strong preferences for choosing a language for interaction were expressed. The aspects of ATM use which were reported to be confusing were used to modify the design. The comprehensive usability evaluation provided several useful design guidelines based on user perceptions and preferences of ATM use.

As identified in the study, users expressed a strong preference for more financial operations such as cash/cheque deposit to be incorporated within ATMs to enhance its functionality. In order to take this into account, a second follow-up user study was designed and conducted with Chinese users in Dalian. The study focussed on user perceptions and evaluation of the use of automated cash/cheque deposit technology within ATMs. The design of the study along with its major findings in terms of user perceptions toward accepting the technology is discussed in detail in the next section.

4 Operations – Cash Deposit

The success of cash withdrawal at ATMs has increased the demand for cash/cheque deposit automation within ATMs over the years. Therefore, automation of cash/cheque deposit solutions is on the rise in the financial sector. The acceptance of deposit technology not only depends on its technical proficiency but also on user perceptions and attitude towards its use. User perceptions in the evaluation of deposit technology acceptance become important due to a number of security and usability issues such as bank notes quality and validity, verification of deposits and the ease of use of the technology. In order to look into user perceptions and concerns regarding the use of deposit technology in China, a study was carried out in two major phases. The first phase involved a survey of Chinese individuals in Dalian, which provided a basis to address the emerging issues in the evaluation of actual use of deposit technology.

4.1 Phase I – Survey Enquiry

The survey began with a questionnaire design, which involved interviews with seven staff members from five different banks and discussion sessions with individual with and without deposit technology experience. 78 individuals participated in the survey. Data from 66 responses (59 males and 41 females) was found to be complete. Data analysis showed that security and ease of use were seen as most important factors associated with the use of deposit technology by both user groups (users with and without deposit technology experience). Overall users showed a positive attitude toward using deposit technology based on their perceived security and ease of use of the technology.

The preliminary survey investigation of common user perceptions of self-deposit technology led to the design and evaluation of the usability of a cash deposit prototype. The usability evaluation was based on the walkthrough method with both experts and regular users of financial services.

4.2 Phase II – Usability Evaluation

The evaluation of a deposit technology prototype began with four academic experts in the usability domain. The usability evaluation involved a screen flow of the prototype for interaction highlighting several issues. The usability issues were categorised under design aesthetic, user behaviour and information processing. The design aesthetic analysed user expectations from the interaction in terms of its presentation. Several factors such as screen layout, colour and font indicated how the interaction was perceived by users. User behaviour indicated how the use of cash technology was assessed in terms of its functionality. Information processing provided insights into user understanding of cash depositing function. Based on the data analysis, several suggestions were made which were incorporated in the prototype design. The prototype was then tested by regular users of financial services.

Eight individuals volunteered for an in-depth usability evaluation. The individuals were divided equally into two groups based on their experience and no experience with deposit technology. The experienced user group evaluated the original prototype and the no-experience group evaluated the revised version of the prototype.

As a result of evaluation, several issues related to the screen and message presentation emerged. The analysis of data showed that prototype was evaluated with a focus on the processing of information to ensure successful completion of cash deposit. Another important finding was the positive effect the design aesthetics had on the actual use of deposit technology.

The findings of the survey indicated a positive user preference for the automation of cash/cheque deposit operation for better security and ease of use measures. The usability evaluation study, however, indicated several factors determining the security and ease of use of deposit technology. The study produced design implications based on the significant insights into user perceptions and preferences of self-service deposit technology. To further explore user perceptions of ATM security, a study was carried out involving the use of biometric technology.

5 Enhanced Security – Biometrics

With an increasing demand of better security features on ATMs and maturing of technology, biometrics are seen as a reliable and robust way of improving the security of ATMs. The prevalence of biometric technology has promised better security and reliability in the self-service solutions. The biometric technology has also allowed financial institutions to expand their customer base in emerging markets such as China. However, introducing biometric technology in Chinese market faces several challenges such as understanding user perceptions and attitude toward using biometrics. In order to investigate user perceptions and concerns toward using biometric technology, a preliminary study was conducted in Dalian, China.

The study was comprised of two major stages, namely survey enquiry into Chinese individuals' general awareness and perception of biometric technology and testing of fingerprint and palm-vein sensors with Chinese individuals in Dalian.

5.1 Phase I – Survey Enquiry

In the first phase, the questionnaire was designed on the basis of several interviews conducted with nine usability experts both in industry and academia. The questionnaire was distributed to individuals both with and without experiences of biometric technology use. 152 complete responses were received out of which 118 participants had no experience with biometric technology and 34 reported to have some degree of experience with biometric technology. Out of 118 participants without any experience with biometric technology, 60 were female and 58 were male participants. In the group of 34 participants with biometric technology experience, 11 were females and were 23 males. The data analysis showed that more than half of participants with no biometric technology experience perceived it to be easy to use.

Participants with no experience with biometric technology perceived security as the most important feature of the technology. However, participants with experience with biometric technology expressed their preference for biometric technology for its convenient use. Findings indicated that participants' level of experience had a positive impact on their attitude toward biometric technology use. However, it was important to note that overall all participants showed a positive attitude toward using biometrics.

Phase I led to the design of a preliminary study investigating user perceptions and attitude based on biometric technology use. A pilot study was conducted with 40 UK participants in order to prepare the materials for conducting the actual study in Dalian with Chinese individuals.

5.2 Phase II – Sensor Testing

Three fingerprint sensors and one palm-vein sensor were used in the study with 46 female and 40 male Chinese individuals. Their age ranged between 16 and 65. Participants filled in a questionnaire before and after the use of sensors. The questionnaire looked into their perceived advantages and concerns related to biometric sensors use. The use of the sensors involved enrolling as a new bank customer and logging in with the new biometric identity.

The data from pre-test questionnaires showed that users perceived efficient use of biometric sensors as the most important feature provided by them. However, post-test questionnaire data indicated a change in user perceptions in terms of perceiving ease of use of biometric sensors as the most important feature.

The findings of the study highlighted a positive attitude of Chinese individuals toward using the biometrics technology. In the light of findings, it can be argued that there was no significant change in user attitude before and after using the biometric technology. The understanding of Chinese user perceptions and attitude toward using biometric technology set a basis for the design of a better training method for enrolment and interaction for the actual use of fingerprint technology.

6 Discussion

The research into exploring the acceptance of self-service financial technology in China can be seen as an evolutionary process. The process began with investigating how a customised ATM was perceived and use by Chinese individuals. The study highlighted a positive attitude of Chinese individuals toward using the technology, which evolved as a strong preference for additional function of cash/cheque deposit within ATMs. In order to address user preference and analyse the use of emerging technology of cash deposit automation, second study was conducted in Dalian. The study showed that users preferred the deposit technology over the teller service for convenience and efficiency. User perceptions toward using deposit technology were then tested in a usability study of the technology. The usability evaluation indicated that users welcomed the technology and expressed willingness toward using the technology. However, due to sensitive nature of deposit technology, users expressed their expectations from the technology in terms of better security measures. This issue provided a basis to carry out the third study looking into the use of biometric technology use for identity verification on ATMs. Despite the awareness and level of experience with biometric technology, users showed an interest in the use of biometric technology. The actual use evaluation of biometric technology revealed certain issues the users had with the technology use. However, consistent with previous studies findings, positive user perceptions toward the introduction and use of biometric technology within ATMs emerged.

The findings of the three studies show consistent positive user perceptions toward using financial self-service. Use perceptions play a critical role in determining user attitude, which form user intention that determines diffusion of technology (Davis 1989). Several key factors that contribute toward user positive perceptions such as availability, efficiency and effectiveness of technology according to the requirements of Chinese individuals were highlighted. An in-depth understanding of Chinese user expectations and concerns will ensure the successful deployment and use of technology.

The importance of these studies can been seen in terms of several design guidelines that have emerged on the basis of users' opinions, expectations and requirements from the self-service technology. These findings will enhance the promotion of traditional self-service technology accommodating specific requirements of Chinese users.

The findings of these studies also offer a glimpse into the future of Chinese banking. The advancement of modern technology particularly in the emerging markets is breaking new ground in the area of financial services. The self-service concept developed specifically for the Chinese customers as a result of the collaboration between SEUC, China and AT&R, NCR help Chinese banks break into the highly competitive financial sector. With a consistent positive attitude of Chinese customers toward self-service technology, it can be argued that the technology will spread in this country faster than anywhere else.

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Determining Accessibility Needs Through User Goals

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Abstract. Access to information remains a major challenge for people with disabilities. In this paper, an approximate model of how people access information is proposed. This model is presented in the context of the sequence of goals that must be completed by a user to access an information source. This model has led to the development of a tool, the Accessibility Information Matrix that can be used to guide the design of technologies and techniques for information access.

1 Introduction

The field of accessibility has advanced substantially over the last 10 years. With innovations in assistive technologies, along with the provision of various guidelines for accessible content, it would seem that many of the problems faced by those with people with disabilities should be solved.

However, despite these advances, and the increased awareness regarding accessibility that has come with them, there are still enormous challenges for people with disabilities when interacting with information. Examples can be seen in the report by Burton 1 regarding the use of cell phones by people with visual disabilities where, even though screen reader functionality was outstanding in its performance, users frequently experienced problems with advanced functionality such as audio note taking. Similar reports are seen in the experiences of blind users navigating table renderings on websites. This is a prime example of where information can be perceived but not navigated, and thus unique browsing solutions are required 2. Finally, there are experience reports of deaf learners having challenges participating in class discussions, even when an interpreter is available to assist them with communication 3.

From these examples, it becomes clear that accessible information is not a simple on and off proposition. It is not the case that once a user can perceive the information, he/she will have complete access. There is a broad range of activities that occur after the initial perception that a person must undergo to fully comprehend and then interact with information.

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The paper provides an approximate model of information access that describe the types of goals that a person completes when working with an information source. Each goal presents new accessibility challenges and new needs for particular groups with disabilities.

Additionally, presented in this paper is a tool based on these goals: the Accessibility Information Matrix (AIM). This tool indexes accessibility needs and solutions by both the goal and a disability group.

This paper begins with an introduction to Norman's stages of action 4, which is then related to eight distinct goals of information access. These goals are then described and an example of their use in organizing the needs of people with visual disabilities is presented. The paper concludes with directions for future work, such as the inclusion of the AIM in scenario based design and other design projects.

2 Norman's Stages of Action

Don Norman's high-level schema of human actions 4 is intended to support discussions and design concerns of the interactions of people with artifacts in their world. Two key concepts from Norman's model are *goals* and *intentions*. He defines a goal as "…something to be achieved…" and an intention as being "…a specific action taken to get to the goal…"

Using these definitions, Norman's model starts with the setting of a goal, and then the execution of intended actions that allow the person to reach that goal. Finally after performance of those actions a person must perform evaluation of the state of the world to see if the desired result was achieved. This continues in a cycle until the original goal has been completed to the satisfaction of the user. The execution stage can be further broke down into three steps:

1. The user forms an intention to act to achieve the goal.
2. The user builds a sequence of actions planned to achieve the goal.
3. The user physically executes the intended actions to achieve the goal.

Similarly, the evaluation stage can be broken down into three parts:

1. The user perceives the state of the world after the performance of some actions.
2. The user interprets those perceptions according to the expectations resulting from the actions.
3. The user must examine the current world state with respect to both his/her own intermediate expectations and his/her over-arching goal.

Therefore, the seven stages of action are comprised of the goal step, the three steps of execution and the three steps of evaluation.

It is important to note that goals are not necessarily atomic. In many cases goals can be broken down into sub-goals, each of which must each be executed and evaluated. The model of information access presented in this paper uses this feature of Norman's model to break down the goal of acquiring access to information into a set of sub-goals required to fully interact with a particular information source.

As an initial example of how this discretization of goals can occur, consider a person who is blind wishes to understand educational material for a class. Her first step is to generate a goal: to comprehend the contents of a lecture on Shakespeare. Then, she makes a plan to get a copy of the slides and read them. She breaks this into the steps of calling her professor, accessing the slides on a file server and having her computer speak the slides to her. After contacting the professor and downloading the slides, she has her computer use a voice synthesizer to speak the notes to her. When she is done, she recognizes that several plays are missing from the notes, as the table of contents covers all of the plays of Shakespeare. Realizing this, the student decides to call the professor to see if she is missing some lecture slides.

When looking closely at the example, it can be seen that there are several sub-goals that are implicit in the student's actions. Before she could comprehend the materials she had to acquire the information source, and then had to find a way to perceive the contents of that source. These sub-goals in themselves are not unique to people with disabilities; indeed they are what all people wanting to achieve the overall goal must do implicitly to access information. What is important is this: for people with disabilities, these implicit sub-goals are often places where accessibility problems appear.

3 Goals of Information Access

In order to address the various goals involved in accessing information, consider a further example of a person researching a topic from an encyclopedia.

First the person must obtain the encyclopedia. This is where the first challenges could be presented to a person. For example, the goal of *acquisition* of a resource has associated with it commonly faced challenges by people with physical disabilities. This might involve physically obtaining a book from a very high shelf, or turning on a computer to visit an encyclopedia website. Such challenges can be overcome by personal assistants or through technology (e.g. sip/puff interface). Despite resources regarding the need for accessibility in this goal 5, one can see examples everywhere of this type of accessibility need being overlooked, such as terminals at rail stations that are too high or two low to be useful to someone in a wheelchair.

After the resource has been obtained, the user must *perceive* the information contained within. This is possibly the most common goal that is addressed by current accessibility efforts. Screen-readers, sign language interpretation of speech and colour contrast adjustments are all examples of services designed to improve the perception of information.

With the perception of information complete, the person must undertake *cognition* of the information to become aware of and understand its meaning. An example of an accessibility tool intended for use in this state is word-highlighting enhancements used to aid people with dyslexia 6.

Once the information has been found and understood, there is an *integration* step where information must incorporated into the body of knowledge that the person already possesses. Challenges in this area, in particular regarding the management of a potentially large group of resources, are often encountered in people with a variety of learning disabilities.

Understanding the *intent* of the author is often a challenge when working with information. In spoken language, comments can be meant in humour, or in irony. In text, the typesetting of emphasis through italic text or underlining can provide key information regarding the original intent of the material.

When these goals have been completed, a person can now *navigate* through an information space, he/she can *interact* with existing materials or participate in the *creation* of new materials.

The order that these goals are taken in is as they were presented in this section, with a diagrammatic representation of this ordering presented in Fig. 1.

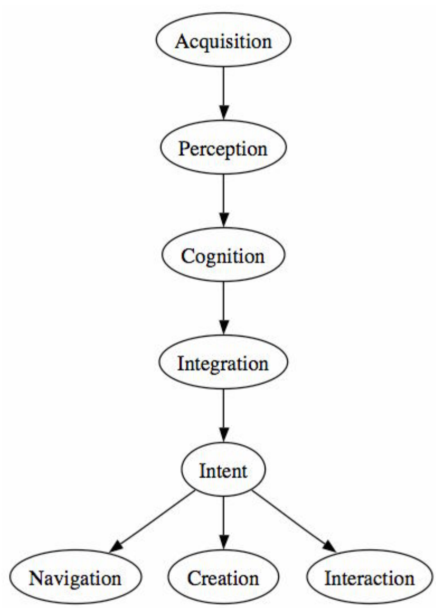

Fig. 1. The ordering of goals for information access

4 Goals and Accessibility Needs

The types of challenges that can be encountered in each of the above goals will be unique to any individual person; however, there are several challenges in accessing information that have been identified to be present in common to people in a particular disability group. In this section, a set of accessibility needs for one group, people with visual disabilities, is discussed. In each case the accessibility needs are associated with the goal that is to be accomplished in gaining access to information.

Acquisition
The acquisition of resources that are in appropriate formats remains a challenge for people with visual impairments. Whether this is related to tactile or audio materials, resources are often not available 7.

Perception

The perception of printed text and graphics is perhaps the most obvious of the challenges presented to people with visual disabilities. As a result, this is perhaps the most addressed in terms of assistive technologies/techniques, be it Braille, tactile diagrams, audio presentation of text, or multi-modal diagrams 8.

Cognition

For those who are unfamiliar with tactile or audio information sources, such information can be difficult to comprehend. While such challenges are sometimes overcome with practice, the proper design and organization of data can also assist with these challenges. For example, many of the guidelines for tactile pictures are designed to limit those features that are confusing to people with visual disabilities; such as avoiding large amounts of empty space between objects or the consistent mapping of symbols.

Integration

One of the integrative challenges associated with visual disabilities is the problem associated in dealing with multiple sources. Having to cross-reference knowledge from one audio source with another can be difficult due to the serial nature of the information.

Another associated problem with this goal for people with visual disabilities is the lack of information available for integration. In some cases, information sources assume prior knowledge regarding a topic. That prior knowledge must itself be accessible for the new knowledge to have meaning.

Intent

The use of emphasis notation in text can be perceived through screen reader technology if properly indicated through document markup; however, with this perception there needs to be an understanding of why such emphasis is being used may be lost without proper context information surrounding it. Other examples of challenges in this area are the understanding pictorial irony or humour.

Navigation

There are several distinct challenges faced by people with visual disabilities in navigation depending on the medium a resource is presented in. Due to the serial nature of both audio and tactile presentations, the lack of a proper table of contents or index can make a large source unmanageable 9. Indeed, similar arguments are made regarding the need for proper use of headings/semantic markup in web pages for navigation purposes 10.

Interaction

For people with visual disabilities the ability to manipulate documents and other types of materials remains a challenge. Examples can be seen in the World Wide Web where web forms cannot be followed properly due to incorrect tabbing order. This type of problem can be overcome by explicit ordering of interaction rules and proper adherence to best practices for the interaction medium.

Creation

The creation of materials by the visually impaired for other users remains a challenge. While there are some aspects, such as Braille transcription into ASCII/Unicode text, that are well understood, solutions for other types of creation, such as self-made tactile diagrams, are still lacking 11.

5 The Accessibility Information Matrix

The above (far from complete) set of challenges encountered by people with visual disabilities in accessing information begins to demonstrate how complex addressing accessibility needs can be in any given design. This model of information access provides a way of parameterizing accessibility needs by the goals of the individual and by disability group. This cross-referencing creates lookup table: the *Accessibility Information Matrix* (AIM). The cells of an instance of the AIM are populated by accessibility needs of the users, and possibly a list of solutions, either technological or otherwise, that address those needs.

While a complete matrix is beyond the scope of this paper due to its size, an example layout of such a matrix is presented in Table 1. The AIM has the sub-goals for information access on the vertical axis, with the various groups of users across the horizontal axis. In Table 1, four broad categories of users are presented: people with learning disabilities, people with physical disabilities, people with auditory disabilities and people with visual disabilities. These are not the only categories that could be included, with more precise groupings possible (e.g. colour-vision deficiencies etc.), as well as other people with disabilities (e.g. cognitive disabilities).

Table 1. The layout of the Accessibility Information Matrix (AIM)

Sub-Goal/Group	Learning Disabilities	Physical Disabilities	Auditory Disabilities	Visual Disabilities
Acquisition	…	…	…	…
Perception	…	…	…	…
Cognition	…	…	…	…
Integration	…	…	…	…
Intent	…	…	…	…
Navigation	…	…	…	…
Creations	…	…	…	…
Interaction	…	…	…	…

The AIM can be used in a variety of ways in the design process. If a designer has an existing design, he/she can identify the set of sub-goals within the matrix that applies to the user tasks performed in it. These goals can then be used to reference the needs of each disability group, with the intention of identifying if the design satisfies the needs therein, or if not, what appropriate solution to those needs is available.

6 Discussion

It is important to note that this model of information access, much like Norman's original model of human action, is only an approximate model of the behaviour of information access; it is not a complete psychological theory. There are many ideal assumptions made regarding the progress of a user through the various sub-goals. In particular, there are occasions where a person will need to repeat a sub-goal several times before finding an adequate solution. An example of this would be a person who is blind using a screen reader and Braille to perceive information. In the same way, it is difficult to put firm boundaries on when a particular sub-goal ends and another begins, such as perception and cognition.

The model was validated through the examination of the experience reports by people from a variety of disability groups, in particular those from the groups of people with learning disabilities and people with visual disabilities. From these experience reports the authors reconstructed the common sub-goals that cause barriers to information.

Despite the fuzzy boundaries between the various sub-goals, this model has already proved useful in design settings. The AIM was applied in several scenario-building exercises by the authors 12. When completing the problem scenarios for a person completing an information access task, the various sub-goals clearly identified the points where barriers to information occurred. This gives some evidence that the AIM could be used throughout the scenario-design process.

Future work on validating the AIM includes its use in several more example scenario-building exercises, with its use being applied through to a final design evaluation. The AIM will also be used in identifying the needs of real users based on large-scale interview and surveys in relation to the participation of people with disabilities in learning settings.

7 Conclusion

In this paper an approximate model regarding how people interact with information has been presented. This model has been demonstrated to break the overall goal of information access into sub-goals, as proposed by Norman in his work on the stages of human action.

These sub-goals have been used to breakdown and understand the types of accessibility problems that occur for people with disabilities. With this model, and its related tool the Accessibility Information Matrix, designers, practitioners and researchers will be able to more accurately identify those places where accessibility needs are not met in their designs. This analysis will result in better designs that provide better access to information for all users.

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"It's Not What You Do, It's the Way That You Do It": The Challenge Workshop - A Designer-Centred Inclusive Design Knowledge Transfer Mechanism for Different Contexts

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Abstract. This paper will look at the Challenge Workshop, a knowledge transfer model on the inclusive design process based on the seven DBA Inclusive Design Challenges organised at the Royal College of Art (RCA) since 2000 by the author in collaboration with the Design Business Association, the leading trade association for designers in the UK. This mentored annual competition sees leading UK design firms work with consumers with severe disabilities to develop innovative, inclusive and aspirational product and service prototypes for the mainstream market. It will focus on how this collaborative model has been further developed into creative workshops of varying lengths and iterations in different contexts in the UK, Japan, Israel and Singapore to inspire and inform designers, engineers and others of the innovative possibilities of inclusive design and in the process change their perceptions. The paper will also describe how the workshop has been adapted to and addressed the different knowledge transfer challenges of each cultural context and will show examples of some of the outstanding design proposals that have emerged.

Keywords: inclusive design, knowledge transfer, disability, design innovation.

1 Introduction

Inclusive design is based on the simple principle that if you include those most affected by design failure in the design process from inception to finish, your design is likely to work for them and other consumers who may experience similar difficulties with the product or service in question, albeit to a different degree.

Understanding why things fail and working with others across the design and engineering disciplines as well as experts from other fields, who can supply the missing information in the right dosage and at the right time is a powerful route to better design. Holistic principles such as these are simple to grasp theoretically, but implementing them into the time-pressured commercial design process is notoriously tricky. For collaboration means dealing with partners from different disciplines each of whom has their own time lines, definitions, vocabularies and modus operandi – an

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HCI engineer, for example, may judge whether a design is good or bad according to different criteria to those of a product or visual communications designer. To design effectively, each will need information of a different kind and may prefer it in different formats, media and through different routes.

But collaborate we must if we are to create products and services that work better for all. Fundamental to this collaboration is the sharing of ideas not in the fragmented manner that characterizes many product and service development projects but in a cross-disciplinary way. One that recognizes the special skills that each partner can bring at each stage of the operation yet nevertheless integrates them in a creative brainstorming process where user, designer and engineer meld their skills and expertise to jumpstart the innovation process and then work together to realize the potential of the ideas they jointly generate.

1.1 The DBA Inclusive Design Challenge

The annual DBA Inclusive Design Challenge now in its seventh year, is framed around such a process. It was conceived as a knowledge transfer mechanism in the form of a mentored competition aimed at the professional design community in the UK. The aim is to alert them to the innovative possibilities of the inclusive design process and enable them to integrate the skills they acquire through participation into their working practice. Designers were targeted primarily because they are poorly served in information terms by existing conventional text-based formats and guidelines on inclusive/universal design. They find that such guidelines are unnecessarily prescriptive and do not address their need for stimuli – the all-important and often unconventional creative triggers that inspire new design ideas and avenues of exploration and encourage them to engage with the subject in the first place.

The high levels of dyslexia in the creative industries [1] underscore the importance of such alternative ways and formats for designers where knowledge of the subject is delivered experientially rather than theoretically.

Age and empathy are two other issues – how can designers be encouraged to engage with those who do not fall within the conventional marketing-driven focus of their work - the able-bodied 18-35 year-old market segment of consumers who are so much like themselves? The design profession in the UK is overwhelmingly youthful with 62 percent of designers aged under 40 with 30 percent of these in their twenties. A further 62 percent of the total are men with only six-percent from minority ethnic groups [2]. It is not a recipe for inclusive thinking particularly where age or disability are concerned. The associated discipline of marketing is similarly youth-centric with only five-percent of overall marketing in the UK is targeted at older consumers. Another factor underlying this designer focus is the dominance of the UK design industry by small independent companies working with national and international clients with high rates of mobility [3]. Since it is their job to simultaneously 'pitch' for work, respond to a client's brief and provide design solutions to it, designers have the potential to play a key role as continuing advocates of inclusive design, irrespective of the design firm that employs them.

1.2 Disability as Creative Trigger

Seven full-scale challenges have been held since 2000 involving over 350 designers. A key element is the involvement of disabled people, not their traditional, limited role as ergonomic test subjects but as design partners. Disability is viewed not as a restrictive status quo but as a creative state, that can supply designers with a set of stimuli and creative triggers alongside the essential ergonomic and contextual information they require. The routine difficulties experienced by disabled people in their interactions with the designed world; the strategies they adopt to circumvent them and their aspirations regarding design have proved to be treasure house of ideas which have inspired the participating designers to think laterally and innovate significantly even in such areas as mobile phones where the saturation point for new design ideas would appear to have been reached long ago.

1.3 The Challenge Format

The Challenge takes place over a period of five months, replicating the span of the average design project. Until 2006, the brief was general rather than prescriptive and focussed on mainstream solutions in areas that the designers wished to investigate and were pertinent to their design speciality. In this way, any lessons learned are immediate and applicable. In the 2006/7 Challenge a further brief relating to 'Slips Trips and Turns (STATS) was set by the National Patient Safety Agency (NPSA), a branch of the National Health Service in the UK. The shortlisted design teams are obligated to produce a six-minute final presentation in any media for public presentation at the Awards event that marks the end of the process. Many have gone on to produce display prototypes to accompany their presentations. It is here that the designers have professed a sharp learning curve since in larger firms briefing clients or 'pitching' new ideas to them may be the responsibility of the creative director or new business manager not the designers. However, it was felt that by emphasizing the importance of communicating inclusive design alongside designing inclusively:

1) Designers, creative directors and business managers could become effective advocates to their future clients of inclusive design strategies and solutions.
2) The restrictions imposed by a time limit of six minutes for the final presentation would be a self-editing mechanism to ensure focus on the key design issues which would in turn eliminate the tendency to produce complex solutions that were unworkable in mainstream product, service or latterly visual communication terms.

2 The Development of the Challenge Workshop

In January 2005, the author was asked to work with Sieberthead, a specialist in structural packaging design and branding and the Henley Centre, the strategic futures and marketing consultancy to devise a three-day innovation workshop for staff of the multinational giant, Reckitt Benkiser. Sieberthead had participated in the Challenge twice [4] [5] and been impressed by the creative stimulus, rapid knowledge transfer and internal teamwork the experience engendered. They felt that this was directly transferable to other contexts and would benefit Reckitt Benkiser's internal design team and their new business, marketing, sales and R & D teams. The focus was more on packaging innovation than inclusive design per se and the workshop was structured accordingly:

Day 1. (Background)
a) The business case for inclusive design - demographics and marketing trends and forecasts (Henley Centre)
b) The creative rationale for working with extreme users. (HHC)
c) Case studies (HHC)
d) A Reality Check' video recorded previously showing six 'extreme users' interacting with and commenting on Reckitt Benkiser products. (HHC)
e) A simulated experience of disability in a restaurant context. (The menu was printed in an ornate nine point font in white on pale grey. Participants exchanged spectacles or wore 'sim specs' to order their meal, which they ate in dim light wearing thick rubber gloves to hamper dexterity).

Day 2. (Idea Generation)
a) Facilitated team workshop with extreme users with different disabilities (HHC + S)
b) Brainstorming and evolution of new product ideas (HHC + S)
c) Presentation of concepts (HHC + S)
d) Joint critique of ideas by users, experts and participants (HHC + S)

Day 3. (Refinement of concepts)
a) Refinement of the concepts (All)
b) The six 'Reality Check' users critiqued the concepts and selected 18 for potential future development.
c) Feedback on workshop content.(All)

2.1 The Role of Visualizers

This workshop established the basic blueprint for the company context viz; elucidation of the business case; experiential simulation of disability; observation of product use by and brainstorming with extreme users and the visualization and presentation of new concepts. One element was lacking. Of the 30 employees present only one was a designer. The brainstorming sessions with users produced a large number of ideas but none of the participants bar the designer could sketch them convincingly as they were generated and then amend and refine them sufficiently for assessment and further development. For the user forums held for the DBA Inclusive Design Challenge, the design teams sketch or storyboard ideas and are able to progress concepts significantly during these two-hour sessions. The lack of such 'visualizers' in the Reckitt Benkiser workshop hampered progress. Their involvement is now integral to collaborative workshops involving participants from disciplines other than design but with expertise in other areas. Cross-disciplinary knowledge sharing is vital to the development of broad-based inclusive design concepts but participants may not share a common conceptual language or focus. The ability of designers to synthesize and visualize overall concepts, storyboard them and generate multiple scenarios has proved invaluable to this ideation process, irrespective of who is involved. It has enabled concepts to be explored with a greater degree of sophistication and detail than might otherwise have been possible and lifted them from the realm of theory to explored and practical possibility. It is now a key element of the Challenge workshop format.

2.2 The 24 Hour Inclusive Design Challenge

A further element was trialled at the INCLUDE 2005 conference at the Royal College of Art. In the design industry, inclusive design is widely perceived as a time-consuming process centred exclusively on age and disability that rules it out of consideration for many short-term projects with a different consumer focus. This begged the question as to whether a quicker format could provide an effective way of generating innovative ideas and signal the advantages of an inclusive approach to designers and design managers from a broader innovation perspective, irrespective of the project at hand. Five teams covering product, telecommunications and interaction design entered the 24-Hour Inclusive Design Challenge. Although led by single DBA member firms, the teams included freelance designers and others. Each worked with a single disabled user and had to present their response to a prescriptive brief within twenty-four hours to an audience of three hundred of their peers with the winner decided by audience vote.

The brief centred on solving ‘a clearly defined public transport issue that currently limits or excludes a disabled or older person from using it.’ The design teams could meet their assigned user in advance to document contextual information but did not know the theme of the challenge. The users represented a spectrum of disability to ensure a breadth of design solutions. The winner by popular vote was the Applied Information Group (AIG) team who had worked closely with a visually impaired composer and his guide dog to develop a wearable navigation device called Babelfish that would give sonic clues and feedback in large transport termini and form part of a wider service accessed via the Internet and mobile phone. Other entries included a modular suitcase system, a gel-filled rubber device to bridge the gap between platform, curb and vehicle, a smart ticket holder and PET –a Personal Excursion Ticket that would allow travellers to access plug-in services [6].

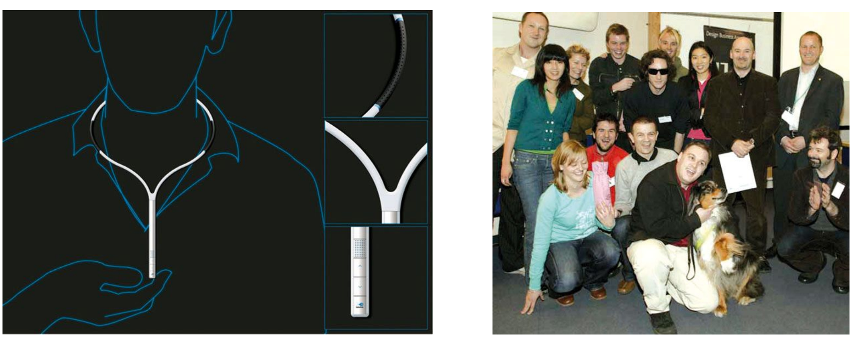

Fig. 1. Babelfish and the winning team with their lead user at the INCLUDE 2005 24 Hr Inclusive Design Challenge

2.3 Mixed Discipline Collaborative Workshops

To further explore the effectiveness of this evolving Challenge model a one-day workshop was organized in January 2006 in collaboration with the College of Occupational Therapists (COT) – the 20,000 strong body for a profession in the UK. Its aim was to bring together occupational therapists and the aids and equipment manufacturers who supply their clients. [7] The sector is characterised by low levels of R & D, small profit margins and low design standards. The participants were well versed in the importance of the functional aspects of design and the specific needs of their disabled clients but less aware of the impact and stigma of poor aesthetic design or of how to mainstream their products.

The day was divided into two discrete elements – a morning devoted to presentations which emphasized these aspects and delineated the business case for inclusive design through case studies of good practice from industry. In the afternoon five teams had ninety minutes to come up with an inclusive product solution to the design problem set by the disabled consumer on their team. Assisting them were 'visualizers' – RCA/HHC graduate designers who could help the team evolve their ideas. The ideas presented ranged from the 'Loomerang' – a portable, inflatable toilet seat, to the winning design for reconfigured CD packaging. The crucial role of the visualizer in this attenuated time frame was unequivocal – their ability to synthesize ideas given by team members with different backgrounds, viewpoints and expertise enabled credible design solutions to be evolved and presented in a short period of time.

2.4 Immersive Workshops for Students

Since then, three further workshops have been held for industrial design students in Israel and Human Computer Interaction (HCI) and students of other design disciplines in Japan. The basic framework mirrored that of the Reckit Benkiser workshop but the contextual content was changed to reflect the different needs of the participants and their lack of design and design management expertise. There was less emphasis on the business case for inclusive design and more on methodologies and process but with major stimuli provided as before by users.

In Japan, the students worked with users with severe disabilities while in Israel they were required to go out and find individuals or groups whose situation encapsulated design problems they could address. The three-day workshop centred on a concentrated experience of user-centred research methods culminating in a group design project by each team.

While the basic elements of the workshop remained the same, it was structured to take account of the students' inexperience in design and project management and move them through the different stages of understanding so that they could arrive at a viable solution within a strict time frame and communicate it effectively. The Japanese student teams had a balance of participants from engineering and design including visual communication to ensure that the latter aspect was covered.

The following activities were preceded by presentations by the author covering the context of inclusive design, 'quick and dirty' ethnographic research methods, multiple scenario-building and presentation techniques. The students were required to:

- Analyse design failure
- Reconfigure or enhance existing products to become more inclusive

- Source and document vital contextual information from diverse users and contexts
- Isolate design opportunities from this information
- Develop multiple scenarios and the ability to storyboard them
- Effectively present their ideas within a strict time limit.

The workshop culminated in presentations by the students with two prizes awarded – one for the best idea, one for the best presentation. For the latter, the students were shown examples of effective presentations from previous Challenges and the author's template of a Powerpoint presentation that combined simple but striking imagery with a minimum of text. Throughout the three days, team members were required to take turns at presenting their findings at each stage and given critical feedback on their effectiveness. In both Israel and Japan, this tactic resulted in the rapid improvement of their presentation skills.

2.5 Problem Areas

One difference noted was while the Japanese students were able to isolate and document problem areas related to their individual user in great detail, extrapolating a design direction from the mass of information gleaned and then creating multiple user scenarios around it in order to arrive at a mainstream product or service idea proved difficult. (This was also the case for the teams of inexperienced designers competing in the 48 Hour Inclusive Design Challenge in Singapore described in Section 3.) The Israeli students were more flexible in their approach, which may be due to the cultural complexity of their society in contrast to the more homogenous nature of Japan and the prescriptive nature of its education system, the latter of which is also true for Singapore. The Israelis were not assigned extreme users but were free to choose their own, thus there was a level of selectivity compared to the more stringent conditions of the Japanese workshops and the Singapore 48 Hour Challenge.

Cultural differences aside, however, this stage has proved the most difficult for all groups where the participants lacked professional design experience or were experienced but with only a single element of the design process not the whole project span. However, it has not been the case for teams led by experienced designers in any of the Challenges or Challenge workshops to date.

3 The 48 Hour Inclusive Design Challenges - Japan and Singapore

In October 2006, the author organized a 48-Hour Inclusive Design Challenge as a keynote event at the 2nd IAUD International Conference on Universal Design in Kyoto. This was followed in January 2007 by a similar initiative to launch the Singapore Fringe Festival. Both were based on the model of the 24-Hour Inclusive Design Challenge at INCLUDE 2007 in which competing teams of designers worked with a single disabled user. Identical in structure bar one important element, the two events nevertheless had quite different results. In Kyoto the five teams were composed of young in-house designers from IAUD member firms with each led by a highly experienced veteran of the DBA Inclusive Design Challenge. Four of the five lead designers ran their own design consultancies in the UK and despite the different cultural context and language barrier, steered their teams to a set of innovative solutions and accompanying presentations of a high quality. In Singapore only one of the eight teams, a leading advertising agency, was similarly experienced and they won the event. The qualitative difference between theirs and the other projects was striking. Their subject was a female amputee and wheelchair user on dialysis and their six-minute film on their design of easy-to-wear underwear with an accompanying communications campaign to launch the range was of an equivalent standard to the Kyoto proposals. It demonstrated what is possible within a short period of time where experienced designers are in charge, with one proviso. Of the five designers invited to lead the teams in Kyoto, two were product design specialists, one an interaction designer and the final two worked in visual communications and branding, disciplines which are more culturally specific in terms of content development and less process-driven than product design. The visual communications designers found the different cultural and linguistic context challenging and experienced difficulty in pacing their teams to reach a final result.

Figure 2 shows some examples of the 48 Hour Inclusive Design Challenge. The top left is Audio Sphere, a communications device inspired by a hearing impaired user. The top right is 'u-control', a customizable remote control. The bottom right shows a Tag Wear system, an embossed clothing tag system indicating size etc, both projects inspired by blind consumers. All three projects are from the 48-Hour Inclusive Design Challenge in Kyoto. On the bottom left are Wunder panties with a side fastening and removable crotch that won the 48-Hour Inclusive Design Challenge in Singapore.

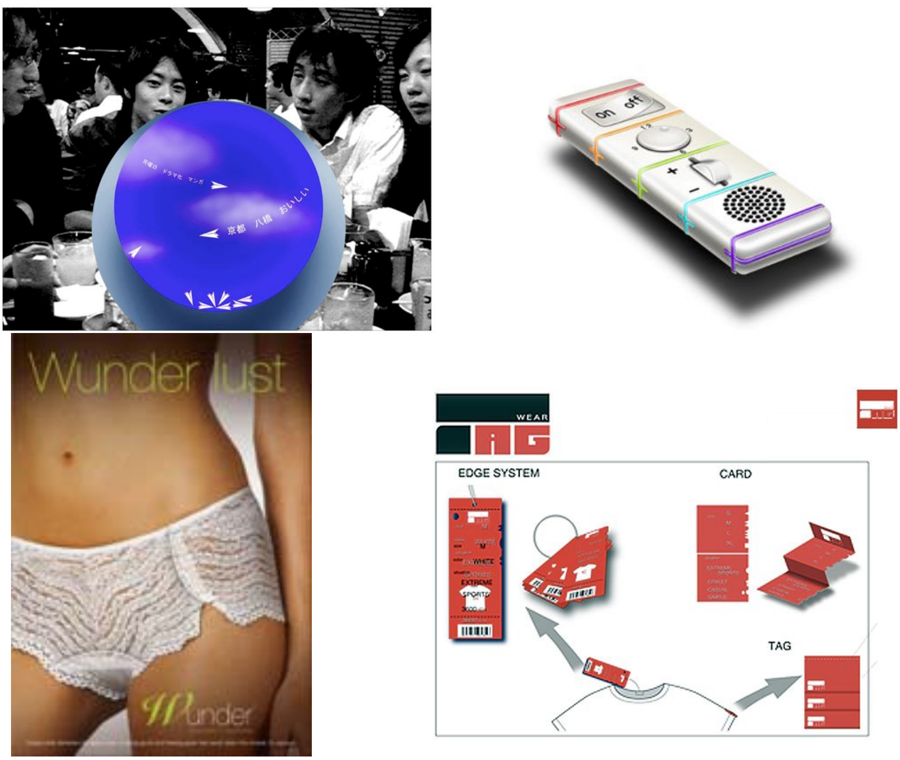

Fig. 2. Exemplars from the 48 Hour Inclusive Design Challenge in Japan and Singapore

4 In Conclusion

In its different iterations, the Challenge model has proved effective for concentrated knowledge transfer irrespective of cultural context where the process is well-structured and pertinent to the participants' situation. The original five-month long DBA Inclusive Design Challenge centres on professional designers in the UK. The mentored input consists of designer briefings, a joint workshop for the shortlisted teams, a project-specific user forum for each team and visits to them by the author at different stages to monitor progress and give critical feedback. The production of a convincing six-minute film of their design process and prototype constitutes a communications challenge in its own right particularly for product or industrial designers for whom it is unfamiliar territory. However, the need to create a convincing narrative around the design proposal reinforces the team's own research into inclusive design and ensures that the greater context is grasped and detailed information sourced and retained on the project area. As a result, the ability of team members to be formal advocates for inclusive design to their clients rises accordingly. This is clearly not feasible within the time constraints of the 24 or 48 Hour Challenges whose value lies more in shifting the focus of inclusive/universal design away from age and disability alone (Japan/UK), repositioning it as an innovation process (Japan/UK/Israel) demystifying and raising awareness of it(Singapore, UK, Israel) and positing a new relationship with disabled users (All).

The prototypes that result from the five-month Challenge reflect high levels of sophistication and detail and the winning proposals set new standards for inclusive innovation. Some of the concepts generated in the 24 and 48 Hour Challenges are of an equivalent standard even where they understandably lack fully realized detail. It could therefore be argued that the longer time frame is unnecessary for idea generation alone where the designers are sufficiently experienced with all aspects of a typical design process.

The provision of a different focus from the routine commercial expression of a brief through the medium of the participating extreme user, forces designers back to a first principle position where they must subject each concept generated particularly the nature of user interaction with it. This trigger has provided the richest source of design ideas for all participants irrespective of their professional experience or Challenge format. Where designers however are inexperienced, the guided process described in 2.3 of the longer immersive workshop is crucial to the participants' ability to provide convincing examples of inclusive design that is mainstream in nature.

Acknowledgments. I would like to thank all the designers, users and others who have participated in and supported these Challenges for their dedication and the innovative, inclusive and inspiring examples of good practice for which they have been responsible.

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Meta-design to Face Co-evolution and Communication Gaps Between Users and Designers

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Abstract. The paper presents a meta-design approach to the design and development of interactive systems, which bridges the communication gaps arising among the members of an interdisciplinary design team including different experts: software engineers, human-computer interaction experts, end users as domain experts. Each experts is a stakeholder that proposes design solutions from her/his perspective. The approach, which relies on a novel model of Interaction and Co-Evolution processes, also supports co-evolution of users and systems.

Keywords: Meta-design, Communication gap, Co-evolution, End-user development.

1 Introduction

In the last years we have been working to the design of visual interactive systems supporting collaborative human activities in different domains, such as medicine [6], [7], geology [15], mechanical engineering [9]. All these situations confirm Fischer's claim that "complex design problems require more knowledge than any one single person can possess, and the knowledge relevant to a problem is often distributed and controversial" [13]. Indeed, the design of a visual interactive system supporting the achievement of some activities in a domain of interest involves several stakeholders, each one bringing her/his experience and view of the problems at hand. End users, as the "owners of problems" [12], have their own knowledge and a domain-oriented view of the tasks they have to perform (with the support of a computer) coming from the practice in their working environment. Software engineers have the knowledge about computer science methods and tools; they bring into software design and development their own view of the activity to be supported, focusing on implementation and efficiency aspects. Human-Computer Interaction (HCI) experts give their contribution by guaranteeing system usability and accessibility.

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In the collaboration among such stakeholders communication gaps arise because of their different cultures; users, software engineers and HCI experts adopt different approaches to abstraction and follow different reasoning strategies to modelling, performing and documenting the tasks to be carried out in a given application domain; additionally, they express and describe such tasks in their own language and jargon.

In this paper we describe a meta-design approach to overcome the communication gaps so that visual interactive systems are capable to support people activities by allowing users to act as designers, collaborating with HCI experts and software engineers. The approach also permits to cope with another important phenomenon, that is the co-evolution of users and systems [8]. After analysing communication gaps and the co-evolution process in the next three sections, Section 5 and 6 are about meta-design, first discussing how this concept is presented in literature, then illustrating our specific approach. Section 7 concludes the paper.

2 Competent Practitioners as Users

People facing real world problems act as *competent practitioners* in that "they exhibit a kind of knowing in practice, most of which is tacit" and they "reveal a capacity for reflection on their intuitive knowing in the midst of action and sometimes use this capacity to cope with the unique, uncertain, and conflicted situations of practice" [24]. Competent practitioners use their (tacit) knowledge to interpret documents that support their activity and to understand how to use their tools. In the case of VIS usage, a relevant part of the information conveyed by the system is '*implicit information'* [6], i.e., it is embedded in the actual shape of the displayed elements and in the visual organization of the overall screen image and can only be understood by users who possess domain (tacit) knowledge. For example, sequences of images illustrating sequences of actions to be performed are organized according to the reading habits of the expected user: from left to right for Western readers, from right to left for Eastern ones. Furthermore, some icons, textual words, or images may be meaningful only to experts in some discipline: icons representing cells in a liver simulation may have a specific meaning only for physicians, while a dept core would be meaningful only to geologists.

Moreover, complex activities must be carried out by experts characterized by different cultures, executing different tasks. For example, in the medical domain, neurologists cooperate with neuro-radiologists to interpret a Magnetic Resonance Image (MRI) and define a diagnosis; they are members of two different communities who must analyze and manage the same data set with different tools, on the basis of different knowledge they possess and from different points of view. However, in this activity, as in many others, members of different communities reach a common understanding and co-operate to achieve a common purpose [10].

In a team of competent practitioners collaborating to solve a problem, each practitioner is a stakeholder, owner of a specific knowledge that is crucial to the resolution of the problem, but not sufficient to solve it. This situation is defined as *symmetry of ignorance* [14], [23]; for overcoming it, the knowledge owned by every stakeholder must be shared and integrated with the knowledge of the other stakeholders. This holds for the design of interactive systems as well. The knowledge of software engineers, relative to design methods and technologies, must be integrated with knowledge about human factors, that HCI experts possess, and with knowledge about application domain, that domain experts (end users) possess.

3 Communication Gaps Among Stakeholders

The collaboration among different stakeholders in a design team presents problems, some due to *communication gaps* that exist among the team members, depending on their different cultural backgrounds, experience and view of the problems at hand.

When interacting with a VIS, end users, as competent practitioners, use their knowledge, both explicit and tacit, gained in their traditional and concrete work environments, to understand how to operate in the new virtual environment. In designing a VIS, software engineers bring into design their own tacit and explicit knowledge and their own views of the activity to be implemented, which are different from the knowledge and perspective of end users. Indeed, a gap exists between end users and software engineers: they adopt different approaches to abstraction, since, for instance, they have different notions about the details that can be abridged. Users reason heuristically rather than algorithmically, using examples and analogies rather than deductive abstract tools, documenting activities, prescriptions and results through their own developed notations, articulating their activities according to their traditional tools rather than computerized ones [18]. Moreover, end users and software engineers possess distinct types of knowledge and express such knowledge according to different languages and notations. As a consequence, end users do not understand software engineers jargon and, conversely, software engineers often do not understand user jargon [6]. On the other hand, HCI experts, often advocated to represent user views in the design, own a specific knowledge - on system usability and human factors, which is not the one of the users neither that of software engineers [17]. Communication gaps, thus, exist among HCI experts, end users and software engineers. HCI experts cannot take users' place and, vice versa, users cannot act for HCI experts: only users are able of reading the screen with user tacit knowledge, and understanding what is misleading or difficult to interpret for them, but they are not able to think as HCI experts and propose adequate HCI solutions [21]. Both end users and HCI experts cannot take software engineers place: they cannot evaluate the technical consequences of their proposals nor the influence on the adopted technologies, i.e., they are not able to think as software engineers [18], who know the technology but have difficulties in thinking as end users or HCI experts.

4 Co-evolution of Users and Systems

Many authors have pointed out an important phenomenon that must be considered in Human-Computer Interaction: the user evolution. Nielsen says [19] that "using the system changes the users, and as they change they will use the system in new ways". More recently, Norman says in [21] that "the individual is a moving target". This means that the design of an interactive system may be good today, but no longer appropriate tomorrow. Once people gain proficiency in system usage, they would like to use the system in different ways and need different interfaces than those they required when they were novice users. These new uses of the system make the working environment and organization evolve, and force the designers to adapt the system to meet the needs of the end-user organization and environment. Therefore, it is more appropriate to speak about *co-evolution of users and systems* [1], [4], [8]. In our experiments with end users, we found that several usability problems depended very much on the rigidity of the interactive systems, which are not able to take care of the changes occurring in users' activities and/or in their organizational context. Indeed, two processes must be considered. The first process - the interactive use of the system to perform activities in the application domain - occurs in a short time scale: every activity is the result of a sequence of interaction cycles in which the user applies her/his intuitive knowing and reflects on the obtained results, gaining new experience. The second process is the co-evolution of user and system, which occurs during the use of an interactive system in a longer time period. Co-evolution is also a cyclic process in which two cycles are identified. The first one is the task-artifact cycle, initially discussed in [5]: it refers to the fact that software artifacts are produced to support some user tasks. However, such artifacts suggest new possible tasks so that, to support these new tasks, new artifacts must be created. The second cycle refers to the fact that technology advances give computer scientists ways of improving interactive systems once they are already in use: this leads to new interaction possibilities that might change users working habits. For example, recently improved voice technology allows software engineers to add voice commands to their systems and this might provide an easier and more natural way of interaction. Also the user socio-organizational context is evolving during time, often requiring new ways of performing tasks. Therefore, technology and socio-organizational contexts repeatedly affect each other and this is modelled by a second co-evolution cycle in a model of *Interaction and Co-Evolution* process we have proposed [8]. Software engineers are required to produce the tools to support both interaction and co-evolution processes, i.e., they must not only produce interactive systems supporting user activities, but also the tools that permit to tailor [26] and evolve the system according to user and organization evolution.

5 Meta-design

Software engineers and HCI experts are aware of the gaps existing among them and of the need of communicating and sharing their different points of view during the VIS design process. Lauesen [17] proposes the *virtual window method*, an early graphical realization of the data presentation to bridge the gap between software engineers and HCI experts. Folmer et al. [16] propose *bridging patterns,* which describe a usability design solution and consist of a user interface part and an architecture/implementation part. Borchers [3] recognizes the necessity of capturing the knowledge of competent practitioners, together with HCI and software engineer expertise by forging a *lingua franca* that makes the design experience understandable by end users, HCI experts and software engineers.

However, the problem is how to embed the user implicit information in these languages and how to make the stakeholders express their tacit knowledge. In user-centered approaches, users are analyzed in order to acquire knowledge about work activities, procedures, standards, users' habits and needs [20]; they are also involved in system evaluation. Participatory approaches include representatives of users in the design team [25]. These approaches exploit techniques derived from social science, which support communication and collaboration within the interdisciplinary team, for prototyping [2].

Meta-design goes beyond, but includes the user-centered design approach and participatory design. As defined in [12]: "meta-design characterizes objectives, techniques, and processes for creating new media and environments allowing 'owners of problems' (that is, end users) to act as designers. A fundamental objective of meta-design is to create socio-technical environments that empower users to engage actively in the continuous development of systems rather than being restricted to the use of existing systems". In this perspective, meta-design underlines a novel vision of interactive systems that is at the basis of our approach. All stakeholders of an interactive system are "owners" of a part of the problem and therefore they must all contribute to system design. Moreover, co-evolution forces all stakeholders in a continuous development of the system. This is carried out, on one hand, by end users, who can perform tailoring activities to adapt the software environments they use to their evolved needs and habits. On the other hand, end users should collaborate with all other stakeholders not only in the design but also in the evolution of the interactive system. For these reasons, stakeholders need different software environments, specific to their culture, knowledge and abilities, through which each stakeholder can contribute to shape software artifacts. They can also exchange among them the results of these activities, to converge to a common design or evolve an existing system.

In light of these considerations, we view meta-design as *a design paradigm that includes end users as active members of the design team and provides all the stakeholders in the team with suitable languages and tools to foster their personal and common reasoning about the development of interactive software systems that support end users' work.*

To support a meta-design approach, Fischer et al. have developed the Seeding, Evolutionary growth, and Reseeding (SER) process model, which considers system design as a three-phase activity: 1) seed creation, 2) seed evolutionary growth, 3) reseeding phase [11]. The SER model is exploited in the development and evolution of the so-called DODEs (Domain-Oriented Design Environments), which are "software systems that support design activities within particular domains and that are built specifically to evolve" [11]. Our approach has some similarities with this work, but it emphasizes the need of providing personalized environments to all stakeholders, in terms of language, notation, layout, and interaction possibilities.

6 The Software Shaping Workshop Methodology

In this section we describe the Software Shaping Workshop (SSW) methodology [6], according to which an interactive system is developed as a network of different software environments customized to the different stakeholder communities involved in the use, design and evolution of the interactive system. We show how the SSW methodology helps bridging the communication gaps among the different stakeholders in the design team and supports the co-evolution of users and systems.

6.1 Software Shaping Workshops

In the SSW methodology, software environments are designed in analogy with artisan workshops, i.e., small establishments where artisans, such as blacksmiths and joiners, manipulate raw materials in order to manufacture their artifacts. At each step of their activity, artisans can extract from a repository the tools necessary for the current activity and set back those ones no more needed. In this way, every artisan adapts the environment to her/his needs and has available all and only the tools needed in the specific situation. By analogy, a software environment is designed as a *virtual workshop*, in which users find a set of (virtual) tools whose shape, behaviour and management are familiar to them. Such an environment allows users to carry out their activities and adapt environment and tools without the burden of using a traditional programming language, but using high level visual languages tailored to their needs. Users get the feeling of simply manipulating the objects of interest in a way similar to what they might do in the real world. Obviously, while traditional artisans shape real supplies, users shape software artifacts. For this reason we call these environments *Software Shaping Workshops* (SSWs) [6]. It is worth noting that virtual workshops and the tools they provide are required to evolve more quickly than real ones in the artisan workshops.

The SSW methodology provides each end user community with a workshop, called *application workshop*, used by that community in its daily work. An application workshop is customized to end users' culture, background and skills, and can possibly be tailored by the users themselves, also by creating new artifacts [6]. Application workshops are not directly created (and successively evolved) by software engineers, but their design, development and modification are carried out by an interdisciplinary team that, besides software engineers, includes HCI experts and end user representatives as domain experts. Each member of the team of experts use a type of workshop, called *system workshop,* customized to her/his culture, background and skills, in order to carry out the design, development and evolution of other workshops.

Overall, an interactive system to support the work practice in a given application domain is not a monolithic piece of software, but it is developed as a *network* of *system and application workshops*. The network allows the different stakeholders to communicate and collaborate to the system design, implementation, use and evolution by working with a workshop customized to them, they use their own languages and notations, so that they are not disoriented and may overcome the gaps existing among them. In general, a network is organized in levels. Fig. 1 presents a generic workshop network including three levels:

a) *Meta-design level*. Software engineers use a system workshop, called W-SE, to provide the software tools necessary to the development of the overall interactive system, and to participate in the design, maintenance, and validation of application and system workshops. More specifically, software engineers produce the initial programs, which generate the SSWs to be used and refined at lower levels, and participate in the maintenance of SSWs by modifying them to satisfy specific requests coming from lower levels.
b) *Design level*. HCI experts, and domain experts cooperate in design, maintenance, and validation of application workshops through their own system workshops: domain experts belonging to the user community X

participate in the design and maintenance of the application workshop, W-End-UserX, devoted to their community, using a system workshop, W-ReprX, created by the software engineers and customized to their own needs, culture and skills; they collaborate with HCI experts, who use their own system workshop, W-HCI, to check the functionalities and behavior of the application workshop, W-End-UserX, and adapt it.

c) *Use level.* End users belonging to the community X participate in task achievement using the application workshop, W-End-UserX, devoted to their community.

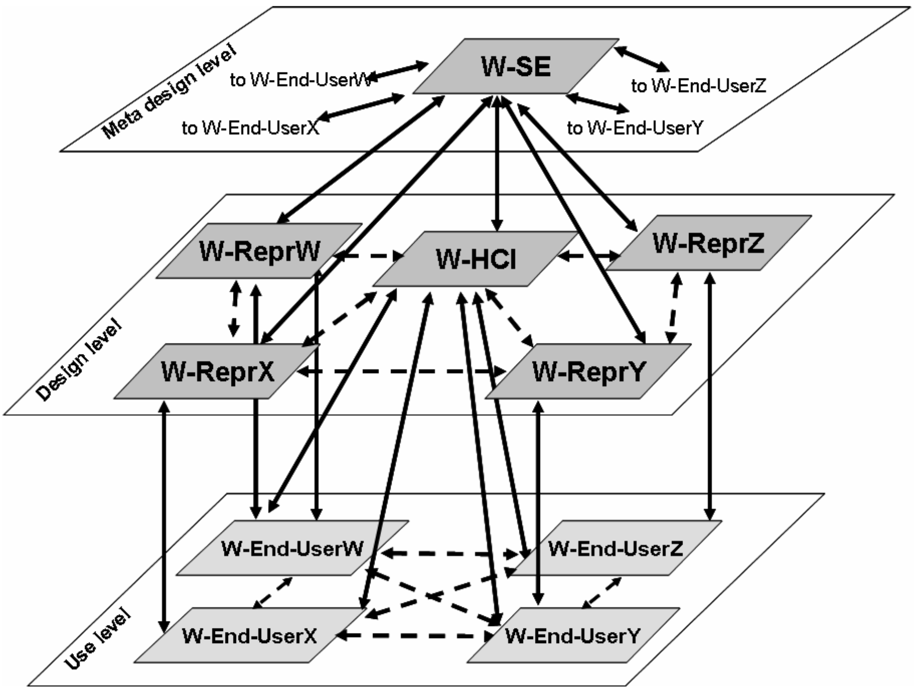

Fig. 1. A network of SSWs. Dashed arrows indicate exchange paths and plain arrows indicate request and generation paths.

On the whole, both meta-design and design levels include all the system workshops that support the design team in performing the activity of participatory design. Such workshops can be considered User Interface Development Environments (UIDEs) [22]. The novel idea is that the UIDEs used by domain experts are very much oriented to the application domain and have specific functionalities, so that they are easy to use by domain experts. On the other side, UIDE used by HCI experts are very much oriented to the HCI domain and have specific HCI functionalities, so that they are easy to use by HCI-experts; UIDE used by software engineers are very much oriented to the software engineering domain and have specific software engineering functionalities, so that they are easy to use by software engineers.

6.2 Communication Among SSW

We show in this section how the network organization supports co-evolution of users and systems and overcomes the communication gaps among the different stakeholders. In a SSW network, communication is guaranteed among workshops at the same level and from a lower level to the upper one, and vice versa, by communication paths. Through these paths, at the use level, end users exchange among them data related with their current task, to achieve a common goal. At the design level, HCI experts and domain experts exchange data and programs specifying workshops. HCI experts and domain experts also communicate with software engineers when it is necessary to forge new tools for their activities. Moreover, requests for workshop modification or extension can be sent to the design level or to the meta-design level from the lower one. Finally, when new tools or workshops are created at high levels, they are made available to the lower ones. Precisely, communication paths can be classified as:

1. *exchange* paths: they are the paths along which the exchanges of data and programs occur. Exchange paths are those existing among the workshops at the same level;
2. *request* paths: they are concerned with the communications going from low levels to higher levels; these communications trigger the co-evolution process, carrying on the feedback from end users that may include requests for workshop modification or extension;
3. *generation* paths: they represent the activity of using system workshops at a high level to generate, modify or extend workshops to be used at the lower level; new or evolved workshops are made available to lower levels along such generation paths.

The design team activity keeps going through the whole lifecycle of an interactive system due to co-evolution. In a first phase, called *design time,* the design team develops application workshops for the user communities addressed by the overall system. Co-evolution determines the adaptation of the workshops to the requests arising from new usage. Hence, at *co-evolution time,* thanks to the communication possibilities the network offers, the design team receives user complaints and suggestions about the workshops they interact with. Request paths are crucial to allow an end user or a designer to notify her/his problems or requests to the higher level. In particular, an end user or a designer finding problems during her/his interaction with a workshop, has the possibility to annotate such problems in the workshop itself. The problems might depend on either lack of functionalities or poor usability. Annotations can be made available to all the experts reachable in the network along the request paths. The experts analyze these annotations, communicate among them using exchange paths (or request paths, if they in turn refer to the higher level), and agree on a possible solution to the notified problems, thus updating the corresponding workshop. Co-evolution is thus the result of a combination of generation, request and exchange activities that are carried out throughout the lifecycle of the SSW network.

Moreover, the design team has the possibility to observe user activities, the new usages of the system, the new procedures induced by the evolving organization. Consequently, the design team updates the system and sometimes also the underlying software technologies. In these phases, HCI experts take the responsibility of usability and accessibility aspects, and software engineers take the responsibility of the efficiency and implementation aspects. Both application and system workshops must be maintained and co-evolved during the system lifecycle.

The fact that each stakeholder works with a customized workshop is the key to overcome communication gaps. Indeed, such workshops allow the stakeholders to interact by using languages, tools and working strategies that are familiar to them.

7 Conclusion

In real situations, interactive systems and their end users undergo a continuous co-evolution. The need of keeping the systems usable and fully fledged requires that the multidisciplinary team of designers remains active for the whole system lifecycle. Our approach conceives an interactive system as a network of software environments (the workshops), each customized to a specific community of stakeholders involved in design and use of the system. This approach permits to bridge the communication gaps existing among the different stakeholders and also to transfer as much as possible the responsibility of system design and evolution to domain experts.

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Enabling International Usability Using Multicultural and Geographically Disperse Teams

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Abstract. This paper explores the challenges of running large scale international usability tests and attempts to provide useful information on how to effectively and efficiently design and administer these types of projects. The information in this paper is based on the experience of the three authors, who have all been involved in a number of large-scale international usability tests as managers of the projects, designers of the tests and as practitioners responsible for the collection, reduction, and analysis of user data. Practical advice is provided on how to best approach the many challenges of running these types of projects.

Keywords: Internationalionlisation, **Internationalization,** Usability Testing, Remote Usability Testing, Cross Cultural Design, Multi-national Teams, International Project Management, International Project Logistics.

1 Introduction: Addressing the Challenge

In today's global marketplace, businesses are looking for ways to efficiently and effectively develop products, systems, and services that are not only desirable to foreign markets, but also acceptable in terms of their usability and applicability for each local market. These same organizations are also looking to lower their costs of development and increase their profit margins to an international market. As corporations strive to offer truly international and easily localisable products and services, the affect on the usability community is clearly visible. The amount of international and multinational usability tests being performed and the increase in number of practitioners worldwide are clear evidence. So how do we, as usability specialist, effectively design and efficiently implement international user testing, such that we offer a quality service at a reasonable cost?

For smaller single location and large international usability companies alike, international user testing can present a number of challenges. The first of these is the logistics of running an international test. Previously straightforward tasks for one country can become an onerous and complicated exercise when having to hire

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facilities and equipment, organize recruitment, hire local moderators and translators, and schedule participants in an unfamiliar country. The organization of many of these activities will fall on the overall project manager, and may prove to be especially difficult when done from a long distance and in a foreign language.

Another issue is the design of the tests themselves. Practitioners will need to determine if the usability testing methods they intend to incorporate into their study will be an effective way of data gathering in all locations. This means that it may not be a matter of simply designing one test and translating the test document for other regions. The entire test methodology may have to be altered to suit the characteristics and norms of the local participants. Then there is the problem of consistency in testing techniques and methodology. How do you ensure that your tests are then consistent and collecting like-for-like data? There is also the cost of having to design and manage the implementation and potentially different data types from multiple methods.

Also to be considered is the provision of moderators and consistency between them for multi-location tests. Do you use the same moderator for all of the countries and provide simultaneous translation for each language session? Using the same moderator for all of the tests will certainly increase the consistency among the tests, data reduction and analysis. It will also increase the time span of the testing and can significantly increase the cost of testing due to the need for translation services and travel.

This paper explores the requirements of running large scale international usability tests and attempts to provide useful information on how to more effectively and efficiently design and administer these types of projects. The information in this paper is based on the experience of the three authors, who have all been involved in a number of large scale international usability tests as project managers, test designers and as practitioners responsible for the collection, reduction, and analysis of user data.. Practical advice is provided on how to best approach the many challenges of running these types of projects.

2 Project Management and Logistics

The first thing to work out when beginning an international project is the project management. Working in multiple locations can prove to be a highly interesting learning experience and as well as something of a logistical nightmare. From the outset of the budgeting of the project to planning and administration of testing, the project manager is required to have detailed knowledge of each testing location and the elements of the local culture that may have an affect on usability testing. Being aware of and planning for the factors detailed below can save a lot of time and effort for the project manager and also help to keep to a budget.

2.1 Creating Project Budgets

When planning and budgeting international tests, it is important to start with time and budget constraints and then select relevant usability methods and a participant sample that fits well within these constraints. The collaboration with local partners can help you plan a relevant budget based on the countries and user groups you want to target.

It is important to remember that the cost of moderators, facilities, equipment rental, and translators (to name a few) may vary greatly depending on the countries in which you are testing. This, along with other unexpected costs, such as requirements of travel stipends in some countries on top of a daily rate and expenses, or the requirement of translation of a moderators notes before data reduction, must all be documented in the budget calculations. If the project covers several countries in different continents, it is good practice to add 10- 25% on the top of the calculated budget to cover any unexpected costs..

2.2 Recruiting Participants

The number of participants and location of the usability tests should reflect the diversity of the target user groups. European and Asian markets have particularly wide-ranging cultures and languages. Ensure your locations reflect the diversity of your user groups.

When doing recruitment across several countries or cultures it is important to remember that a descriptive term, such as 'trend setter' may not always apply to the same demographics in each location. Also, the description of a social strata that holds true in one culture, doesn't necessary hold true in another. For instance 'family income' in the UK means the income of a couple, in India it means the extended families cumulative income, and in Japan it is taboo to ask a person's income at all. Thus it is recommended to research societal standards in different cultures or to hire help of local experts before organizing recruitment of participants.

The same is true with the location of the recruiting. In some countries, you find differences in behavior and customs between people living in the capital city and people living in other cities. For example, in the biggest US cities, people with high incomes tend to live in the suburbs; this is generally not true in France, the UK or Italy. Knowledge of local customs can help avoid recruiting mistakes and bad sampling.

When scheduling tests, be aware of bank and summer holidays (the months of May or August in France can be challenging for recruiting). It may be very difficult to recruit the right people during holiday periods and you may face a higher rate of cancellation of those recruited.

2.3 Renting Testing Facilities, Equipment and Services

The cost and quality of testing facilities and services can vary from country to country. Most commercial hubs have testing facilities with appropriate equipment to conduct and record the usability tests. If your target user groups are not located in a big city or a commercial hub, it is wise to rent a conference room in a comfortable hotel or business centre located centrally. It may be necessary to bring your own equipment. Avoid conducting usability tests in regular hotel rooms as this is normally not acceptable in many countries.

If you do decide to use your own equipment, ensure that it will work well in each geographic location and be prepared for all eventualities. When testing in cold climates (when it is the norm for even indoors to be very cold) be aware that some electronic equipment may not work well or at all. The same would be true for very hot climates where there is no air conditioning available. And always be sure that you have plenty of plug adaptors for each location and spare batteries. Always visit the testing facility a day before the usability tests so you have time to take corrective action in case of problems.

2.4 Translation of Test Documents

For all local language tests it is important to contextually translate all key test instruments. (e.g., Recruitment Screener, Test protocols and moderators guide). Literal translation can completely alter the purpose or meaning of a question. Back translating (translating the document back into its original language) protocols is recommended to ensure your translations are of high quality, but can increase the cost of translation. Pilot testing and having your local moderators check the documentation will highlight any problems or inconsistencies in the translation or problems due to cultural specific differences.

2.5 Legal Requirements for Consent

Legal requirements for testing can be very different from one country to another. This is particularly important when usability tests involve minors, skilled labor, or patients. You should check and review legal regulations and rules with a local recruiting company, then work with the local moderator to develop relevant consent forms. In cultures with high power distance, participants are often taken aback or are uncomfortable signing long legal documents. For example, while testing with illiterate migrant workers in India a number of participants refused to sign consent forms or were very nervous. By Indian law, verbal consent is a legal alternative, so in this case it was not necessary to get a signed consent form.

2.6 Recruiting Moderators and Translators

It is always best to use moderators and translators that have a background or experience in usability testing. When using translators and local moderators it is important to ensure they understand the purpose and of the usability test. The competence and understanding of moderators and translators is vital as language issues might otherwise prevent problems being identified. One technique to minimize confusion is to pilot the test using the moderator or translator as a sample user, so that they better understand the process and aims of the test. It is recommended to make sure that the translator and moderator in question have adequate domain knowledge to comfortably translate complex technical or domain specific jargon.

2.7 Establish Local Partners

Along with the recruitment of moderators and translators locally, selecting and consulting local partners at the beginning of the project can help to avoid planning and project management mistakes. It can be time consuming to work with local partners, but in fact they can save time and money in the end. Local partners can help you understand the local culture and people and to solve planning and development problems you might encounter.

3 International Teams for Moderation of Tests

The whole world is moving away from the 'we design they consume model'. Increasingly clients want input for their designs from local usability professional and they want the input early in the development cycle. Using international teams to conduct multiple location usability tests is necessary to get this information quickly. In many parts of the world the usability profession is nascent. Therefore finding readily available, trained and experienced usability professionals may not always be easy. A combination of a small core team and dispersed local teams can prove beneficial to the smooth running of a project. The core team provides over all direction, methodology and quality control, while local teams execute tests at the ground level and can provide insights into cultural differences that a non-local usability professional cannot.

The key benefits of using local usability teams are:

- Local teams provide valuable local and cultural insights which go un-noticed to outsiders.
- The use of international teams allows for quicker turnaround of projects as testing in multiple locations can happen simultaneously.
- Time zone differences ensure that someone is always working.
- Overall cost of using local partners is lower that using a single global team as travel costs are negated.

Clear communication is the backbone to the success of any project. Lack of a common language and differences in cultural norms are one of the biggest hurdles to overcome in international projects. Even if the whole team speaks the same language it does not ensure smooth sailing. A large number of professionals comprehend written English better than they are able to speak English. Providing all communication in written form or following up verbal conversations with the details repeated in emails can significantly assist in communication. It is recommended to have key requirements of the project documented, as the written word is more easily comprehended and recalled than the spoken word.

At the onset of the relationship it is necessary to communicate the purpose of the test and roles and responsibilities of everyone. This knowledge empowers local teams to make intelligent suggestions and take decisions in your absence. Time zone differences can also be an irritant; as it is difficult to find convenient times for meetings or phone calls. The project team may have to alternate convenient times for conference calls in order to avoid any one location feeling less important than others.

3.1 Ensuring Consistency and Quality Control

How do you ensure consistency in the test methodology and in the data reduction? The whole engagement is always easier if there is a common language between local moderators and the overall project manager, but this may not always be possible. There are various ways to ensure consistency of data and its reduction across locations, given below are some points to keep in mind.

- Sharing templates, exemplars and timelines early on in the engagement ensure expectations are communicated.

- Often a reverse engineering process helps. First create a format for your final report, this helps you understand the different kinds of data that needs to be captured. The protocol and other testing instruments are optimized and aligned to the final report format. These documents when shared with the larger team ensure the correct data is captured.
- Ensure that all documentation is translated.
- Ensure moderators, translators and observers view recordings of sessions to familiarize themselves.
- The core team should review data logs of dry runs and provide feedback to local teams. These ensure inconsistencies are ironed out before you go live.

4 Test Design and Methodology

4.1 Test Documentation and Translation

If at all possible the test documentation should be translated by the translator who will run the test or by the moderator. If the test documentation is translated by a person who will not be involved in the test, then it should be reviewed and edited by the actual moderator. This will ensure that the usability test sessions will run smoothly. The objective of each task should be clearly presented in the documentation in order to give the moderator the ability to ask the same question in a different way if the participant doesn't understand the question or if the question doesn't solicit the information intended. Also note that formal, I demonstrative languages increase test time by about 25% more time than in the UK or US. It is important to take this into account when planning and conducting a test.

4.2 Design and Prototype Translation

Users might not share a common perception of geography as the developers, for example Asian countries and Australia are listed together under APAC. Users usually do not perceive them together. Icons, metaphors, colors can be full of meaning in a country and meaningless in another based on the way people work and live. It is important to take into account these localization issues when translating designs or prototypes. Conducting a pilot test with the moderator or translator should help to identify some of these issues. It is important to note that the purpose of the usability test should be to identify these types of issues that are more abstract in nature. But, localisation details that are more commonly recognized, such as formats of dates, times, and addresses should be addressed in the translation or localisation of any test material.

4.3 Methodology vs. Culture

The way people react to a usability test can be very different based on their age, level of education and culture. When working with children we often customize standard usability test methods. We have to do the same with users from other cultures and be creative and open to find the best way to fit their cultural behaviors.

For example, it is usually very difficult for Indian users to 'talk aloud' during a usability test. Immersing Indian participants via a scenario seems to help take attention away from the 'seriousness' of the task. Thus allowing them to articulate the problems they encounter with the system being tested without the fear of feeling inadequate or offending the designer.

In Asia generally, Users will have difficulty to criticizing a design, even they don't like it. They consider that it is not polite to do so. In Europe, people will have the tendency to over criticize and in Africa people will use only the extreme such as good or bad. It is important to take this cultural difference into account when the test includes satisfaction rates.

4.4 Reduction and Translation of Data

Based on the scale of the project, this phase can be a very lengthy. To make this work easier, it is very important to plan and structure this phase in advance with local moderators. Templates should be developed to describe the type and level of feedback the moderator needs to record. Results linked to cultural specifics should be highlighted.

As an example for all moderators, the pilot test results could be summarized and translated and then be used as a reference document for doing the same with the actual test data.

4.5 Analysis of Data

Be aware that for some data it will not be possible to compare across cultures. For example, comparing user ratings to judge levels of satisfaction can often be misleading. As noted above, users in some cultures are more critical than in others, so absolute ratings (e.g., using Likert scales) may show great variation between cultures due to different cultural norms.

5 Alternative Methods for Small Budgets

Budgetary constraints are a part of usability testing reality. When funds are tight the validation or iteration activities are one of the first activities to be reduced or cut out all together. Such knee-jerk reaction can prove to be expensive in the long run. The importance of iteration and validation from end users cannot be stressed enough, but often clients may not see the necessity of this process as they already have one set of results. One way to circumvent this situation is to use alternative testing methods that are less expensive as a way to validate the results of smaller one-on-one usability testing or increase the geographic range of the tests.

5.1 Moderated Remote Usability Tests

Remote usability testing (RUT) is a reliable and cost effective method to gather user data and iterate early and finished interfaces with a geographically varied user group. As screen and voice sharing technologies are more reliable, remote usability tests are now practical and easy to execute.

The key difference between moderated remote usability tests and Lab based tests are:

- The moderator, respondent and observer are at different locations
- A software tool or application allows the moderator to view the participants screen.
- The moderator and participant communicate usually via a conference call. VOIP often proves to be cumbersome and increases the time lag. Using the phone is also practical if the internet fails, the moderator will still have a phone to guide the participant through reconnection.

5.1.1 Benefits of Running a Moderated RUT are:

- Recruiting benefits
  - Reach geographically dispersed populations
  - Reach hard to recruit populations – participants do not have to leave their home or office
- Maximize returns on a small budget
  - A larger group of participants can be reached with a limited budget.
  - Travel and lab costs are reduced.
- Quick turn around time for results. Less time is spent on planning and scheduling thus overall a larger number of tests can be conducted in less time.
- Performance based tests, test of self evidence; brand perception tests are extremely effective when administered remotely.
- Ethnographic benefits. Participants are tested or interviewed in their actual environment

5.1.2 Key Disadvantages of Running a Moderated RUT are:

- Recruiting and Logistics: RUT's ensure one can reach a wide variety of user group. But as it is remote it also means the control on quality of recruitment is lower.
- Dependence on technology
  - Screen and voice sharing devices can often prove extremely unreliable.
  - Non-technically savvy user groups are awed or uncomfortable by the RUT set up and thus do not perform optimally.
- Dependence on moderator's skills: RUT's are heavily dependant on the moderator's ability to connect with the participant. Often if the moderator fails to build a connection with the participant, the data proves to be light and without any key insights
- Qualitative, contextual, formative tests are tough to execute via an RUT: The geographic barrier makes it tough to capture facial expressions, body language, and environmental cues. The personal contact of in person usability tests is lacking in a remote usability test and participants often do not openly critique or discuss issues.

5.1.3 Points to Remember While Planning a RUT:

- Identify the key purpose of running an RUT and the main questions which need to be answered. The protocol design needs to be optimized to answer the questions.

- Protocols designed for RUT are tighter and more direct than an in-person protocol. Un-structured, bloated protocols are culprits for failed tests. Validate the protocol in advance. Blindfold a colleague and read the protocol aloud. Quiz the colleague to determine if they remember the flow of the questions. This will throw up obvious bottle necks which were not so obvious. The aim is to ensure that the protocol addresses the purpose of the test and at the same time is easy to comprehend.
- Seamless technology that is fool proof is necessary to successfully run remote usability tests. A dedicated and reliable internet connection, a good telephone line to transfer voice, and a reliable and easy to use screen share application is necessary. When taking technology decisions ensure the participants will have the infrastructure to support your technology requirements. Ask yourself: “Do factory workers in Krakow have dedicated internet connection to support a heavy screen sharing application?” If not, then RUT may not be feasible for your intended user group.
- Control and cross check recruitment: To ensure you get the correct sample, develop a detailed and if possible localized screener for your recruitment agency. Ask the agency to send you a spread sheet which contains answers to screener questions for each participant. Cross check the appropriateness of participants at the onset of each test session. Do not feel uncomfortable rejecting participants, but be aware that these participants will still need to receive remuneration.
- Experienced moderators are imperative for the success for a RUT. Incase the tests are in a language that you don’t speak. Find a moderator who speaks the language and train the person. Using a two-way translator is a good strategy but it almost doubles the test time. In case of multi language testing write your protocol in non metaphoric language. As direct language is easier to translate and is not open to interpretation.
- Consider time zones and culture: Most RUT’s are conducted across time zones; plan well in advance so that neither you nor your participants are forced to conduct tests in the middle of the night. People from different cultures react differently when being interviewed remotely. Some become more open others retreat and become more formal. Thus take cultural and social characteristics into consideration while analyzing the data.

5.2 Un-moderated Remote Usability Tests

Un-moderated usability tests are the cheapest way to validate a design and reach out to a wide variety of user population on a very limited budget and resources.

5.2.1 Benefits & Drawbacks

- Cost advantage: Un-moderated usability tests are the cheapest way to validate and reach out to a wide variety of user population.
- Un-moderated remote UT’s work best in scenarios where the designer already knows the attributes of the target user group well and the user group is fairly homogeneous. One can send out the test to as many people one wants, as the cost of mailing is minimal and remuneration is considerably lower.

- Flexibility of time and location: Participants can take the test as and when they require.
- Easy to plan and execute as there a fewer middle men: No moderators, translators or observers.
- It is often impossible to collect qualitative behavioral insights. Surveys, binary choice answers, card sorts, brand perception are most effective.
- The protocol design needs to be tight and focused to ensure participants do not mis-interpret the questions or run though them in a disinterested manner.

The two most popular ways of running a un-moderated RUT are

1. Test instruments with instructions are mailed to the participant. The participant completes the test in his/ or her own time and mails is back.
2. The test can be hosted on a secure website. Participants are invited to take the test. The participant's inputs and actions are captured on the site.

Both these methods have their pros and cons. The latter in recent years have proved to be more reliable than the former. Primarily in the case of tests which provide contextual question and help because participants feel that there is some one at the other end cross checking the data. Both these methods usually have between 10-40% no shows or dead data. Thus it is imperative to send out invites to a large participant group.

It is also important to ensure that the participants are comfortable and with the method used. Ask questions: Does my user group have dedicated internet connection to take this test? Are the comfortable with the media we are using?

5.3 Mixing of Traditional UT and Remote Testing for Validity

In the last few years using a combination of traditional and remote usability tests has become more common. Usually in person tests are conducted at the onset of a project and RUT's are used to quickly iterate a proposed design structure in the latter half of a project. This strategy is recommended as a good alternative, especially as the freedom to change the design reduces dramatically in the latter stages of the development process. But, the reverse, doing an RUT first and following up with an in person test, is often not very beneficial. In the case were both methods need to be used in the same round of testing, test using traditional methods first and then use the remote method to check you insights or hypothesis with a larger group of participants.

6 Conclusion

This paper has provided useful information on how to successfully plan and administer international and multi-location usability tests. The most important guidance is to ensure that each usability test is well planned and designed to accommodate the requirements of testing all of the user groups. As with all usability tests, the through planning and meticulous preparation are the key to the collection of good quality data and the problem free running of tests. Understanding all of the additional factors involved in the running of international tests will help the practitioner to create a sound plan and run successful usability tests.

Shifting Paradigms in Universal Design

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Abstract. The theory and practice of Universal Design have evolved over the last twenty years. Based on a review of relevant publications in design, ergonomics and Human-Computer Interaction, the author summaries the evolution in terms of two shifting paradigms: one is from the separation of the 'Assistive Technology Approach' (top-down) and the 'Idealistic Universal Design Approach' (bottom-up) to the integration of the two approaches; the other is from adopting discipline-specific research approaches to collaboration in multidisciplinary research teams. Because of the close relationship between Universal Design and Human Factors and Ergonomics, the challenges of future development of Universal Design are also discussed with regard to the revolution and shifting paradigms in Human Factors and Ergonomics.

Keywords: shifting paradigms, Universal Design, Human factors and ergonomics.

1 Introduction

Universal Design has a close relationship with Human Factors and Ergonomics (HFE). As a process, they both attempts to consider the abilities and limitations of users when developing a product or building an environment [2]. However, the basic user model used in the two fields differs: in HFE, the typical user model is a bell-shaped curve (Figure 1) [17]; while in Universal Design, the typical model is a User Pyramid (Figure 2) where the lower portion are the able-bodied or fully capable users together with elderly people who have minor disabilities such as reduced strength or impaired hearing or sight. In the middle of the pyramid are people with reduced strength and mobility caused by disease and more severe, age-related impairments. This group contains many older people. At the top of the pyramid are those severely disabled people who need help with many daily activities: people in wheelchairs and people with very limited strength and mobility in their hands and arms [3].

Conventional HFE is often applied to design for the vast majority of a target population (95%, excluding the 5% or the 95% 'tail' in the curve) rather than everyone. Such an approach leaves some reliant on assistive devices to perform at acceptable levels and completely excludes other, for instance those with the greatest physical or cognitive limitations. In contrast, Universal Design places greater attention to designing mass-produced products or environments that can be used effectively without assistance by individuals with functional limitations [2]. In

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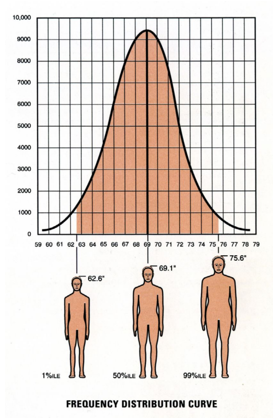

Fig. 1. Typical bell-shaped population model in Human Factors and Ergonomics

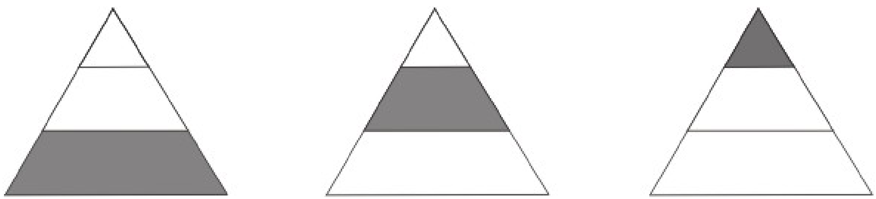

Fig. 2. User pyramid for universal design

reality, Universal Design has been an iterative process to improve accessibility by widening the target user population each time the design of a product or service is re-visited [14,P227]. Over the last twenty years, the theory and practice of Universal Design have evolved. The revolution in Information Technology has spawned a series of transformation revolutions in the nature and practice of Human Factors and Ergonomics [4]. Similarly, it also causes shifting paradigms in Universal Design. The rapidly evolving technologies might even cause a rethinking of the definitions of Disability, Assistive Technology, and Universal Design [18, P32]. Based on a review of relevant publications in design, Human Factors and Ergonomics and Human-Computer Interaction, the author summaries the evolution of Universal Design in terms of two shifting paradigms.

2 Shifting Paradigms 1

There has been a shift from designing special aids and equipments for disabled people (an Assistive Technology Approach) to designing mainstream products for as many people as possible (a Universal Design Approach), and the boundary of the two approaches are increasingly becoming blurred when the rapidly evolving technologies bring new opportunities which challenges the conventional understanding of Assistive Technology and Universal Design.

2.1 An Assistive Technology Approach – 'Top-Down'

There are many definitions for 'Assistive Technology.' Some definitions focus on products that are purpose-built for people with disabilities. Other definitions refer to any technologies, including mainstream technologies that are used by a person with a disability to help offset the disability [18, P33]. So the focus of Assistive Technology is people with (severe) disabilities, those represented by the top of the user pyramid. Hence, an 'Assistive Technology Approach' is also referred to as a 'top-down' approach [7]. Conventionally, "special aids and equipment for disabled people are devised top-down rather than bottom-up" [9]. The problem with this approach is that "the special needs of disabled people are not, however, by any means always best accommodated by targeting them specifically" [10]. Traditionally, Assistive Technology is often associated with 'high price', 'special-needs', and 'gadget-looking' devices.

2.2 An Idealistic Universal Design Approach – 'Bottom-Up'

As a "new paradigm" [9], Universal Design was proposed as an approach to the design of mainstream products and services that are "accessible to and usable by as many people as reasonably possible, without the need for adaptation or specialist design" [5]. The focus of Universal Design is the mass market, those represented by the lower proportion of the user pyramid, so this approach is also known as a 'bottom-up' approach. The essence of this approach is to 'include', i.e. expanding the market to address the needs of less able people or disabled people. The ideal situation for Universal Design would be creating products that could be used by the whole population. However, this is difficult (if not impossible) to achieve. What is more, "many ideas that are supposed to be good for everybody aren't good for anybody" [12]. The author's survey of designers' attitudes towards Universal Design suggests that there is a fear that Universal Design will result in "banal products" or "clumsy" products.

2.3 An Integrated Universal Design Approach – 'Diversity-Focussed'

Assistive Technology and Universal Design have been evolving in parallel and the boundary between the two is becoming blurred. Universal Design in the context of Information Society Technologies is "not to be conceived as an effort to advance a single solution for everybody, but as a user-centred approach to providing products that can automatically address the possible range of human abilities, skills, requirements and preferences." [1, P181].

The (idealistic) Universal Design Approach and the Assistive Technology Approach can be considered as complementary and converging towards the creation of a more accessible information society through the continuous redefinition of problems in accordance with the developments in both fields [1, P182]. So the paradigm is shifting to the integration of the 'bottom-up' approach and the 'top-down' approach – an Integrated Universal Design Approach. Central to this approach is the acknowledgement of diversity, and consequently the design response is to address diversity using a 'portfolio approach'. In the context of Information Society Technologies, the outcome of Universal Design is not intended to be a 'singular' design, but a design space populated with appropriate alternatives together with the rationale underlying each alternative, and critical property of interactive artifacts becomes their capability for intelligent adaptation and personalization [1, P182].

2.4 Summary and Comparison

Fast advancing technologies have brought new opportunities: there are better (cheaper, more effective) assistive technologies and new types of assistive technologies; and there are more accessible mainstream products which are simpler and more adaptable [18]. When an assistive technology becomes so cheap that everybody can afford it, it will become 'universal' and mass-produced; and the mainstream aesthetics of Universal Design will make 'adaptation' as easy and desirable as 'personalization'. This explains why the latest definition of 'Universal Design'– the process of creating products that are usable by as wide a range of people as is commercially possible [18, P33] – tends to put emphasis on 'commercial viability' rather than 'no need for adaptation or specialist design.' 'Adaptation' could be a desirable feature offered by mainstream products.

The shifting paradigm is well illustrated by a Dutch design model (Figure 3) [19]:

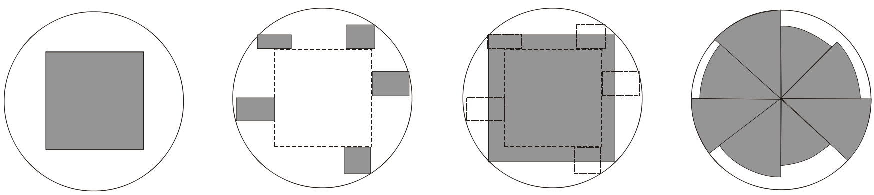

Fig. 3. The Dutch design model: designing for ergonomics diversity

The first image in Figure 3 shows the model of *traditional implicit design*, in which the circle represents the total sum of human needs, and the square represents a design that is implicitly based on a uniform presumption of human abilities. The gap is the space between the circle and the square.

The second image in Figure 3 shows the model of *designing for the disabled*, in which one can see that focussing on the specific needs of categories (squares) beyond the implicit presumed uniform needs, hardly covers the total sum of human needs (circle), and in fact, is stigmatizing and isolating the issue – this is comparable to the traditional 'Assistive Technology Approach.'

The third image in Figure 3 shows the model of an *integral approach*. As we can see, the square has grown, covering parts of the special needs, but not covering the whole circle. There is still a gap, which is logical: An inner square will never cover a circle – this is comparable to the Idealistic Universal Design Approach.

The final image in Figure 3 shows the model of *design based on ergonomics diversity*. It well illustrated how the gap between the environment and its use can be bridged in due course, by dividing the circle of human needs into separated sectors for all aspects of functioning, and then searching for the proper criteria to cover the extremes in each of these aspects – this is comparable to the 'Integrated Universal Design Approach'. The 'integration' is not simply a combination of the 'top-down' approach and the 'bottom-up' approach. It is based on a deep understanding of diversity. In the context of Universal Access in the information society, the source of diversity comes from (i) the characteristics of the target use population (including people with disabilities); (ii) the scope and nature of tasks; and (iii) the different contexts of use and the effects of their proliferation into business and social endeavors [16].

If we see each 'piece of pie' within the circle as a mini 'user pyramid', then it is easy to understand why addressing diversity requires an integration of the 'top-down' and 'bottom-up' approaches. It also explains why this is an optimal approach, it 'include' the most; even if there is an 'exclusion', the exclusion is 'informed' rather than random.

3 Shifting Paradigms 2

Researchers in the Universal Design community come from a variety of backgrounds, for example: engineering, art and design, ergonomics, computer science, psychology…each discipline has its typical approach to research, for example, systematic approaches are typical for researchers with an engineering background; inspirational approaches are typical for researchers with an art and design background; 'user-modeling' approaches are typical for researchers with a psychology or ergonomics background. However, nowadays the trend is towards multidisciplinary collaboration.

3.1 Systematic Approaches

Systematic approaches include design methodologies, processes, and evaluation frameworks or criteria that can be applied systematically in a range of situations to encourage Universal Design.

A typical example is the 'countering design exclusion' approach [11]proposed by the Cambridge Engineering Design Centre. It defines and quantifies design exclusion; outlines a seven-level framework for design and evaluation; and proposes a method of evaluating products' inclusivity based on a set of user capability data. This is a 'problem-solving' approach and the basic assumption is that products exclude users because their attributes do not match user capabilities. Hence it is important to evaluate products and apply user capability data (physical, sensory, cognitive) to estimate the design exclusion and make an informed decision on product improvement.

In the context of Universal Access in the Information Society, a good example of systematic approaches to Universal Design is the Unified User Interface Development Methodology [16] which provides a systematic approach towards coping with diversity in interface design.

3.2 Inspirational Approaches

In contrast to systematic approaches, inspirational approaches typically produce design case studies and examples which are limited in terms of generalizeability to other designs or tasks but nevertheless provide inspirations by challenging conventional design processes and methods.

A good example of inspirational approaches is the DBA Inclusive Design Inclusive Design Challenges organized by the Helen Hamly Research Centre (HHRC) of the Royal College of Art and the Design Business Association in the UK. The emphasis of these challenges is the short-term collaboration (typically 2-3 months) between innovative design consultancies and users with serve disabilities through ‘critical user forums’ [8]. Since 2000, 36 design concepts have been created by over thirty design consultancies. Variations of the Challenges, such as the 24-hour Challenge, the 48-hour Challenge, and Challenge workshops tailored to specific companies, have been created in recent years, forming an effective knowledge transfer model of inclusive design. More details about DBA projects are available from the HHRC’s website: http://www.hhrc.rca.ac.uk/events/DBAChallenge/index.html

Another example of such inspirational approaches is the use of theatre and film in representing user requirements [6]. As part of the research aimed at improving the usability of ICT products and services for older people, a series of narrative-based videos were produced, using professional actors to portray the experiences of many older users of ICT. The video can be downloaded from http://www.computing.dundee.ac.uk/projects/UTOPIA/utopiavideo.asp

3.3 User-Modeling Approaches

Much research has been focused on modeling the user in order to better understand user diversity, for example, the development of the HADRIAN (Human Anthropometric Data Requirements Investigation and Analysis) tool to support inclusive design [13]. The prototype tool contains a database consisting physical and behavioral data on 100 individual covering a broad range of ages and abilities. The latest development of the tool is going to expand the database beyond the physical into cognitive, emotional and sensory data associated with travel. In the context of Universal Access in the Information Society, a model-based approach to Human-Computer Interaction is descried by Stary [15].

3.4 Summary

Although typical approaches to Universal Design adopted by different discipline may vary, an emerging phenomenon is interdisciplinary research through research consortia. For example, the large universal design research project funded by the UK’s Engineering and Physics Sciences Research Council (EPSRC), i~design, has been run by research consortia comprising experts from engineering, art and design backgrounds (i~design1, 2000-2003); engineering, art and design, psychology, computing science (i~design 2, 2004-2007); engineering, art and design, ergonomics, psychiatry (i~design 3, 2007-2009). Researchers within the consortia learn from each other and benefit from multidisciplinary approaches to Universal Design. Recently a five year multidisciplinary research initiative – the New Dynamics of Ageing – has been launched as a unique collaboration between five UK Research Councils: ESRC, EPSRC, BBSRC, MRC and AHRC; this is an even more ambitious interdisciplinary collaboration project.

4 Challenges for Universal Design in the Context of HEF Evolution

Universal design is closely linked to Human Factors and Ergonomics. In the 'Introduction' section, the basic user models adopted by the two subjects were compared. In the 'Shifting Paradigms 1' section, the 'Integrated Universal Design Approach' was compared to the 'Design for Ergonomics Diversity' model – they are identical. In the 'Shifting Paradigms 2' section, it is obvious that Universal Design is influenced by ergonomics. Hence it is worthwhile to discuss the challenge for Universal Design in the context of evolving Human Factors and Ergonomics.

The revolution in Information Technology has spawned a series of transformation revolutions in the nature and practice of Human Factors and Ergonomics (HFE). "Generation 1" HEF evolved with a focus on adapting equipment, workplace and tasks to human capabilities and limitations. Generation 2, focused on cognitive systems integration, arose in response to the need to manage automation and dynamic function allocation. Generation 3 is focused on symbiotic technologies that can amplify human physical and cognitive capabilities. Generation 4 is emerged and is focused on biological enhancement of physical or cognitive capabilities [4]. It is important to note that each successive generation of HEF coexists.

Much research in Universal Design addresses issues relating to HEF Generations 1 and 2. However, what differentiates HFE Generations 3 and 4 from Generations 1 and 2 is a change in the fundamental role of the human as a variable in human systems integration. In generations 3 and 4, human cognitive and physical capabilities may be enhanced well outside the range of normal biological variation thereby altering traditional boundary constraints on the adaptability of human in complex system design [4]. Universal Design aims to 'enable' people, whether it should amplify human physical and cognitive capabilities is under debate. However, "human augmentation" has already been raised as a topic in the newly published report "Over the Horizon: Potential Impact of Emerging Trends in Information and Communication Technology on Disability Policy and Practice" (Available from http://www.ncd.gov/newsroom/publications/2006/publications.htm) where it argues that "combining technologies that mimic human abilities and provide enhanced super-human function in a single implantable prosthesis raises new opportunities and potentials for restoring function that go beyond the ability to restore natural vision."[18]. No doubt Universal Design will encounter challenges brought by the third and fourth Generations of Human Factors and Ergonomics; would this change our future understanding of Universal Design? Would 'enhancing human capability', in parallel with 'improving product accessibility and usability', be an object of Universal design in the future?

5 Conclusions

To conclude, there have been two shifting paradigms in Universal Design: one is from the separation of the ‘Assistive Technology Approach’ and the ‘Idealistic Universal Design Approach’ to the integration of the two approaches; the other is from adopting discipline-specific research approaches to collaboration in multidisciplinary research teams. Although Human Factors and Ergonomics (HFE) and Universal Design adopt different basic user models, they are closely linked subjects and the revolution and shifting paradigm of HFE present challenges for Universal Design, especially in terms of cognitive ad physical enhancement.

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Dealing with the Challenges of Interpreting International User Research

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Abstract. User research always presents challenges of interpretation, but these challenges are much greater when the research is done internationally. This is true regardless of whether the research is carried out in one country other than the researcher's own, or in multiple countries. In this paper, we discuss a number of these challenges, and to offer some practical ways to minimize them.

Keywords: International User Research, Interpretation, User-Centered Design (UCD), Ethnography, User Experience.

1 Introduction

Increasingly, companies are recognizing the need to understand their users in order to design products and services that will really meet their users' needs. This user-centered design (UCD) approach has shown that, by understanding user needs, products and services have increased chances for success.

Designing for international markets makes this approach even more critical, but also much more challenging. Not only is it often difficult for teams to collect information about international users, but also, the interpretation of this information is extremely challenging.

In this paper, we discuss a number of these challenges which we have observed over the course of our own projects for a variety of clients in more than 20 countries around the world, as well as offer some practical suggestions to deal with them. We will also draw on our experiences teaching new researchers how to do international user research, both formally [1] and informally.

The things we discuss are all things that user researchers should be paying attention to both during the planning of the research, during data collection and during data analysis. In contrast, if user researchers are not paying attention to these factors, it is difficult to recognize their influence, and they may compromise the integrity of the entire user research program.

The specific challenges we discuss include assuming that behaviors are caused by cultural factors when they are not (cultural false positives,) over generalizing from a small sample, making false assumptions about the base rate in the society of what the researchers are seeing, missing important significance of data because of a lack of understanding of the culture or country, and retreating into stereotypes.

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2 Common Challenges

In this section we will discuss in more detail some of the common challenges that we have seen teams struggle with when trying to interpret data from international user studies.

2.1 Cultural False Positives

Mrazek and Baldaccini [2] coined the phrase “cultural false positives” to, as they put it, “describe study results that mistakenly ascribe differences in users’ goals and tasks to culture – differences which are actually variations in user type or segmentation.” They point out that overemphasizing cultural uniqueness can make it harder for a team to see design solutions that work for broader markets.

Uncovering something that looks to you a new goal or task does not automatically equate to finding something unique about the particular culture in which you find yourself. You may be discovering something that would be equally applicable in other markets or countries, even in your own. For instance, as Mrazek and Baldaccini [2] point out, the fact that Asian homes tend to be smaller than American homes does not automatically point to the need for a *uniquely* Asian need for a small-sized printer. In fact, considering a small printer exclusively “Asian” need could blind a company to the potential for such a small printer in other countries.

2.2 Over-Generalization

It is equally important to avoid over-generalizing from your experience and your research. Often, due to limited time and budget, we are forced to sample *one* city or region, or only urban people in a country where there is large rural population. When doing research in India, for instance, it is tempting to assume that what we find in Mumbai is equally applicable in Delhi or Chennai, or that what we observe in cities is equally applicable in rural areas, but this is a very dangerous practice. It is important to stick closely to what you have actually observed, rather than making generalizations about “all people in India” or, even worse, “all Asians.” Whenever you find yourself making such statements, you can be certain that you are over-generalizing.

Not all over-generalizing is as blatant as this of course. We can over-generalize to the sample we studied even more easily – and dangerously. For instance, it’s easiest to remember the earliest sessions (“primacy”) and the more recent ones (“recency”) which tends to give these sessions more weight in our minds as we think about our sample. It is important to do thorough data analysis to avoid skewing the results by putting more emphasis on these early and late sessions.

2.3 False Assumptions About Base Rates

A special case of over-generalizing is assuming that the base rate of what you are observing is similar in various geographies. This is rarely true. We saw a particularly striking example of this several years ago when a potential American client contacted us to inquire about doing a study of cell phone and texting or using short messaging service (SMS) messaging in Europe. At that time, SMS had not yet caught on in the States, but it was extremely popular in much of the rest of the world. However, the potential client was adamant that "the average number of SMS messages per day is one or fewer." No matter what we said, they insisted that SMS'ing was as rare a behavior in Europe as it was in the US. Obviously, they incorrectly assumed that the base rate for sending SMS in the US was the same as that in Europe.

Not all false assumptions about base rates are as striking. For instance, to be able to interpret the fact that a university student in the US or in India uses an internet café, it is important to know how common this behavior is among similar students in the US and in India. Knowing this simple fact can help you recognize common and less common behaviors appropriately. Therefore, in the US, most university students have their own computers, so internet café users are rare, and, by definition, probably different on other significant dimensions from their peers in the university. However, in India, most university students use internet cafés, so it is the computer-owning students who are the ones who are different.

2.4 Missing Important Cues

When you are a visitor to another country, it is extremely easy to miss important cues that can help you interpret your data. For instance, people often refer to dates or holidays that are nationally, regionally, or locally important when they are describing their behavior. An American might refer to July 4th, the American independence day, or an Indian might talk about Diwali, an important Indian festival. Knowing the significance of these can help your interpretation.

Additionally, many countries have distinct regional accents, so, for instance, an American will instantly recognize a Southern US accent and differentiate it from a Brooklyn accent. Sometimes accents are clues to larger issues such as schooling, or socioeconomic background, as, for instance, an upper class London accent in the UK is very different, to the local ear, from a dock worker's accent from Liverpool. The same American who can tell the difference from a Texan and a New Yorker may well miss the difference between these accents in the UK and vice versa.

Other things can also pose significant "unseen" challenges. For instance, in a recent study we did in South India, we discussed the impacts of the caste of the facilitator and translator on the participant families we were visiting. Although we were not able to tell the caste of either our local team or our participants, all of the local team members were aware of these issues. This meant that we had to openly address caste (even though it was "invisible" to us) in order to make sure we were at least aware of its impacts on the data.

2.5 Stereotyping

Stereotyping is often the retreat of researchers who enter a company unprepared, who are naïve or have their own unexamined stereotypes about the country they are doing the research in, or are experiencing culture shock. Whatever the source, stereotypes get in the way of accurately understanding the country and stand in the way of gathering useful data. The entire data collection process can be tinged with bias when stereotypes blind the researcher to nuances.

Unconscious stereotypes that are inadvertently reinforced are perhaps the most insidious. Because they are not acknowledged, they result in a false sense of complacency that the researcher understands a locale, when, in fact, the researcher's own stereotypes have simply been reinforced.

On the other hand, when stereotypes are actively acknowledged, they can be examined. The researcher can use them as hypotheses and can explore the nuances that match and that do not match the stereotype. Ultimately, when used like this, stereotypes can actually be useful and, inevitably, the researcher will come away with a much deeper and more complex understanding of the locale and the people therein.

Culture shock is almost inevitable when people paying attention to their surroundings – especially when they are in places that are very different from their own home base. It can be a very good indication of cultural sensitivity of team members, but it also must be managed because it is very easy for people to retreat into stereotyping and negative attributions if it is not. We actively manage culture shock both by normalizing it, and by finding ways to use the observations that underlie the reaction to better understand the local culture. In this way, we can help head off the negative stereotyping that can result from culture shock.

3 How to Avoid These Pitfalls

To deal with these common pitfalls, we will discuss the following ways to avoid them through adequate preparation and planning, combining "insider" (local) and "outsider" (foreign) perspectives, questioning your interpretations and assumptions, not assuming everything you observe is due to cultural factors, and not overloading the experience.

3.1 Planning and Preparation Is Key

The first thing that researchers should do is to prepare in advance by reading as widely as possible about the countries to be studied. It helps to read about the history, culture, and economy. Typically, we follow the news of any area where we will be traveling through online local and national newspapers and through international sources such as the *International Herald Tribune*. Local sources also give important clues about the culture through both the types of items which are newsworthy, and the visual design of the news website itself. We also read travelers' reports (on the web or in books), as well as fiction by local authors and by foreigners, from different historical vantage points if possible.

It is also important to understand relevant statistics and other descriptions of the country as much as possible. For instance, you should find out how many people own computers or cell phones (if that is relevant), how many people have a phone line to their home, how many people own their own home, and what is that home likely to be like for the income band you are studying. Your interpretation of what you see and your assessment of how common that is will depend these factors. In one study we did in South India, the first home we visited was quite spacious by Indian standards, but to the visit team from the US who had not been in India before, it did not seem so. We discussed this with the visitors to help them understand that it was a large home and pointed up the contrasts during subsequent visits when it became increasingly clear to the team that the first home had, indeed, been unusually large. In this way, team members' own insights were sharpened over the course of the study.

Be very careful specifying your sample for recruiting people for your study. You need to do this with your local partners because many things won't directly transfer from one country to another. For instance, when we did a study of a website for technical support in Mexico some years ago, our U.S. screener screened people into the study only if they had a phone line, something that is ubiquitous in the U.S. In Mexico, however, at that time, only wealthy people had phones in their homes. Therefore, insisting on that one criterion would have seriously skewed our sample. Finding out that fact itself was very valuable to the team because it helped them reset their expectations.

3.2 Combine "Insider" and "Outsider" Perceptions

Check all your assumptions and findings with your local colleagues before and during the study. On the other hand, realize that you will probably see things that your local colleagues may not pay attention to and may never have thought about. The combination of perspectives is critical to really make sense of the data.

One way to do this is to make the assumptions behind your product explicit. After all, these are the things you need to learn about. By doing so, you can actively test the assumptions rather than allowing them to influence you unconsciously.

While planning the user research, listen carefully to your partners for their interpretation of events. They can help you avoid making costly errors. For instance, on a recent study, we had originally planned to do shopping visits with families on both days of the weekend until our local partners told us that the stores we were hoping to shop in were actually closed on Sunday in that region, even though they are open in other regions. We quickly had to regroup to restructure the study to allow us to go shopping with our participants at different times in order to get the data we needed.

In addition, creating a focus for your research, or, more likely, a set of focus areas or a "focus structure", will help to make the assumptions explicit and will help guide what you observe. In addition, the focus is shared by all members of the team which not only guides the research, but also helps to ensure that you are not unconsciously influenced by your assumptions.

Your local partners can also help you contextualize your findings during the research itself, because they will know the significance of things that you may not and they also know the local conditions which can help you avoid problems in planning. For instance, when we did home visits in Brazil, our local partners helped us understand the significance of the presence of a phone line – basically, at that time at least, only the richest of families had phone lines in their homes.

When you are debriefing after the user research, be sure to include your local partners. Again, they will help you make local sense of what you have observed. We always discuss our observations and interpretations with our local team as well as with client visitors. They can explain things that may not be immediately clear to us as we are collecting data. For instance, in the shopping study mentioned above, we heard about the "Chit" system for financing a major purchase. Our local partners explained this system to us during the debriefing. We then also checked online resources such as Wikipedia to further understand how this system worked. It was a point that had a significant potential impact on the buying process, but we could not have easily understood its significance without our local partners.

3.3 Keep an Open Mind and Constantly Question Your Interpretations

One of the best ways to keep your mind open is to treat your entire experience while in-country as a source of data, while always to questioning your interpretations and impressions. You will almost certainly notice diverse aspects of life in the country, and these can give you context and help you avoid stereotyping. Each aspect of life gives you information that can help explain how the specific variable you are looking at in your research may be consistent with a larger dynamic at play in the society-at-large. You will also want to look for and test the limits of the generalizations you make about the culture and the individuals ("Users") within it.

It can be difficult to avoid leaping to psychological, "exotic" or subtly judgmental interpretations or stereotyping, which are especially easy to slip into early in your stay when everything is new, and late in your stay, when you are starting to see patterns and may be exhausted by your experiences. Instead, look first for "objective" factors about the local context that make the observed behavior "logical." Ask how the behavior makes sense, given things like the local climate or other geographical factors, history, infrastructure, economic or legal context, demographic profile, and so on. It is extremely important to be aware and ever mindful of your own stereotypes and work to consciously look for other explanations.

3.4 Don't Assume Everything Is Cultural

In many ways, assuming that everything you observe is cultural can make you act as blinders, making it much more difficult to get to the true explanations for what you observe. You can help yourself and your team to avoid cultural false positives by keeping the study focused on tasks, goals and user types and exploring these exhaustively before assuming that your observations are due to potential cultural factors. Educate your team about the traps of making cultural attributions that can keep them from seeing the underlying causes that may be more important to design.

Before you assume that something is cultural, look first for "objective" factors about the local context that make the observed behavior "logical." Ask how the behavior makes sense, given things like the local climate or other geographical factors, history, infrastructure, economic or legal context, demographic profile, etc. Also, do thought experiments where you actively try to imagine other environmental settings or usage factors that might be similar and that might help you to account for your observations with non-cultural explanations. This can help you to dig deeper to understand the wider range of behavior.

In addition, as we mentioned above, it is important for researchers to acknowledge their own stereotypes about the locale or its people. In this way, the stereotypes become hypotheses to be explored rather than unconsciously influences.

3.5 Don't Overload the Experience

As tempting as it is to try to do a number of studies when you are already making the sizable investment in money and time to go to a distant company, this can introduce confounds and problems that can compromise the findings. For one thing, the logistics can become overwhelmingly complex, and it can make your time in-country longer and more challenging, which can make it harder for the whole team.

Also, even though it seems like you *should* be working every moment you are in-country because of the costs of travel, this will also make the research process much more difficult and more fragile. It can be difficult to make sure you are allowing a day off now and then throughout the schedule, especially when trying to cost-justify the significant expense of getting to a distant country. However, without a break now and then, the team is much more likely to experience severe culture shock, or to get sick. Give your team a break to process your findings and to recharge, and you will find that the entire research experience is not only more comfortable, but also more robust.

Do studies iteratively, to allow for testing of hypotheses generated in previous studies. Check all your assumptions and findings with your local colleagues before and during the data collection phases, and consider sharing past research findings with local colleagues to get their sense of the applicability to the current study.

4 Conclusions

Doing international user research is, by definition, challenging and exhilarating at the same time. It is, therefore, very important to be aware of the inherent difficulties that can compromise data integrity, and to make sure that the team – including local partners – is prepared and supported during the process of data collection. By doing this, such research can yield amazing and rich findings that can make a significant contribution to design.

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Privacy Issues for the Disclosure of Emotions to Remote Acquaintances Without Simultaneous Communication

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Abstract. We discuss the privacy issues related to the design of systems that disclose information about emotions to remote acquaintances, without simultaneous communication: users do not chat, see or hear each other. We consider the acquisition of information, storage, processing, multi-modal rendering, and interactions. We illustrate our points with the system we designed for affective bonding and support with family and friends. Our most significant contribution is the provision of a first overview of the whole process for everyday life uses.

Keywords: Communication, Emotions, Family, Friends, HCI, Privacy, Ubiquity, Wearable.

1 Introduction

Disclosure of emotions can strengthen affective bonds between acquaintances such as family members and friends. However it raises privacy issues for senders and recipients due to the acquisition, storage, and rendering of information. These issues must be considered to avoid negative side-effects, satisfy psychological needs, and foster the adoption of systems by the general public [1]. Finding ways to protect privacy while preserving useful affective services is most important because these services do not exist yet; opportunities will be limited when we have to deal with heterogeneous and legacy systems.

We consider here the case of disclosure to remote acquaintances, without simultaneous communication: users do not chat, see or hear each other. This scope is appropriate for continuous information about acquaintances living in different areas, for short (e.g. business trips) or long (e.g. studies abroad) periods. Disclosure face-to-face with, or within the vicinity of, acquaintances shall be treated ulteriorly, as well as simultaneous communication with devices like cellular phones and networked cameras.

We first present background information about emotions and privacy, then discuss the machine and human sides of the disclosure process, taking as example a system we developed for the family and friends. Finally we conclude with a discussion on global issues.

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2 Background Information

We first define the scope we cover in the following sections, and then present a dedicated system, which we later use to illustrate our points.

2.1 Scope Covered

For the sake of clarity, we first define what we mean by *emotions* and *privacy*. Then we highlight the risks associated to the disclosure of emotions in the current context.

Emotions. Although the term *emotion* is frequently used, definitions tend to be circular. Even psychologists still disagree widely on its exact meaning:

> "[W]ere one to ask 'What is basic about emotions?,' one would surely get embroiled in controversy, both in terms of what is meant by 'basic' and what it means to be an 'emotion'.", Panksepp [2, p20].

For the kind of services we aim to create, we can be satisfied with a definition that corresponds to *feelings elicited briefly* (seconds, minutes) *by quick and/or unforeseeable antecedents* (e.g. a car accident as opposed to bad weather).

Privacy. Privacy is the state of being able to be alone, unobserved, free from public attention. More specifically, information privacy can be defined as 'the right to control the disclosure of and access to one's personal information' [3]. It covers the right to know and correct what a third party knows and provides about us, and even to restrict access to such information. This notably applies to raw data, videos and evaluations of emotional states.

Perspectives on Communication and Awareness. Disclosure of emotions can provide much information to recipients. Without additional data, causes cannot be deduced. However, with simultaneous communication or context awareness, inferences of recipients and third parties can become reliable. Table 1 describes the influence of networking, additional communication channels, and types of displays on risks regarding misunderstandings, leaks, and inferences.

Table 1. Impact of several settings on risks related to the disclosure of emotions

	Misunderstandings	Leaks	Inferences
Remote service	-	Risky	Risky
Local service	-	Safe	Safe
Emotional information only	Risky	Safe	Safe
Simultaneous audio/video	Safe	Risky	Risky
During face-to-face contacts	Safe	Safe	Safe
Public display (wearable screen)	-	Risky	Risky
Private display (data-glasses)	-	Safe	Safe

2.2 Design of a System Dedicated to the Family and Friends

After introducing the goal of the system, we indicate its main features then present its visual interface.

Goal and Features. We designed a ubiquitous system to strengthen affective bonds and allow affective support for distant relationships with the family and friends [4]. To complement existing technologies and services, we considered sharing information about emotions. We proposed to acquire data from each user, process it on a server, and transmit personalized updates to acquaintances. In our design, emotion-related data is acquired from physiological sensors embedded in a personal wearable, and copies of e-mails received by the server from registered addresses. After processing the data, the server checks which users should get updates and accordingly creates updates based on the originator's and recipients' preferences. Personalization and privacy information are stored on the server.

Visual Interface. Information can be accessed on a web site (after identification), by e-mail, or on a wearable display that is continuously updated. Emotional states are displayed using a *soap bubble* metaphor (figure 1) in which the background color represents the state of the group, and colored bubbles the state of individuals. The speed of the upward flow reflects that of variations. *Current*, *Day*, and *Week* views are available. This interface works with touch-sensitive displays embedded in watches or sleeves, or semi-transparent glasses combined to mobile devices.

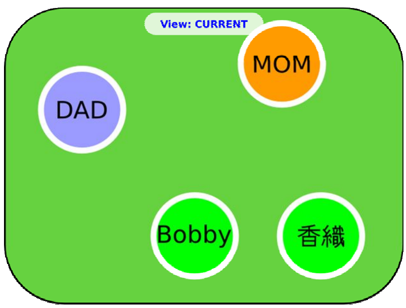

Fig. 1. Example of view for acquaintances' current state with the wearable interface

This metaphor provides a good understanding of the system because it shows data as volatile (bubbles burst and vanish, data is retained for short periods only), because it reflects the passing of time, and because each bubble is independent but from the same source (individuals are from the same family or group of friends). It also allows users to hide meaning by freely associating colors and shapes to intensities and types of emotions.

3 Machine Side

The machine side of the disclosure process mainly deals with first phases: acquisition, transmission, storage, and processing of data.

3.1 Acquisition of Data and Information

Emotions can be evaluated by changes in subjective experience, behavior and physiology [2], and information can be provided to a computer system using introspection, human observers, or machines.

Acquisition by Humans. With introspection, a user indicates her sensations, feelings, and thoughts. This approach is potentially the most accurate because the user has the broadest and deepest access to relevant information. However, it is not perfect due to limited attention and subconscious processes. Observers can also feed systems with useful evaluations. They cannot access internal knowledge of the targeted users but can notice revealing physical behaviors; if trained or familiar, they can provide particularly insightful input. Input by humans is not realistic for continuous real-time services. However it can be used to e.g. inform a group of friends about the state of those met during the day.

Input by humans raises limited privacy issues because only partial, subjective, and eventually high-level information is provided (with possible mistakes or *lies*). One always has the possibility to deny observations or inferences.

Acquisition by Machines. Wearable computers and smart environments are particularly suitable to evaluate users' emotions. A wearable may acquire data about its user[1] with physiological sensors and multimedia analysis. Smart environments have limited access to bodily information (no physiological sensors available) but more resources and space. Thus they can comprise more sensors and process more data. Machines cannot access users' internal knowledge but, with enough time and databases, can be trained or become familiar with specific persons. Raw data can be extracted, timed, cross-checked, and analyzed in depth (later, with improved algorithms) for different purposes such as investigating a user's health, activities or beliefs. The (un-)reliability of current technologies and algorithms has little impact on our discussion because increasing reliability is expected due to innovations.

Systems should therefore be designed to acquire only required data, which means carefully selecting sensors, extracting only required information, and discarding the rest. Typical questions would then be: are physiological sensors required? Do we need precise evaluation of heartbeats or just speed gradients? Should we install standard or infrared cameras? In which rooms? Whenever possible, data should be preprocessed at the electronic/mechanic level before transmission to the computer, and transfers should be limited to minimal qualitative information.

Illustration with our System. Emotional data is currently acquired from physiological sensors and e-mails; it is then processed on a remote server. The system may be improved by adding a *personal* software agent residing in the wearable computer. The agent would select whether to read the sensors or e-mails depending on tasks, then process the data locally and transfer only high-level information. It would let users choose recipients and the accuracy/frequency of transmitted data. By default, raw data would not be sent.

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[1] When acquiring data about *other people*, wearables can be considered as smart environments.

3.2 Transmission, Storage and Processing

Whether with local or remote servers, data should be protected from unauthorized exploitation. Besides, users should keep control over accessible data.

Architecture, Algorithms, and Policies. Architectures and algorithms influence the requirements for processing, data retention, and encryption. Communication should be authenticated and encrypted to ensure that only selected acquaintances and trusted servers access the information. After a transmission, the sender and recipients should apply retention policies. With peer-to-peer (P2P) services, leak-related risks are limited. However retention policies are critical for centralized services: servers are easily identified and attractive targets that potentially store all data about every user. Finally, if learning is used to evaluate emotions, model-based algorithms should be favored over instance-based ones because mathematical models hide original data.

Although P2P architectures appear more respectful of privacy than centralized ones, the selection also depends on other constraints such as energy. For example, with P2P architectures, mobile devices would send duplicated messages (to each recipient). With centralized architectures data can be sent once then processed by servers, saving energy and making the service more viable for continuous use.

Whatever architecture is chosen, a standard retention policy would be to minimize data, store it with the largest granularity required, and remove it as soon as possible. If continuous real-time retrieval is unnecessary, a single–average–value can be retained per appropriate period. For asynchronous services data may need to be stored longer. The retention policy should be clear to users and, ideally, negotiable.

Control by Users. User's control over sent and stored information is critical. Because the modification of data undermines trust in systems [1], it should be avoided. Removal poses similar challenges: what becomes a "feeling of the day" after selective deletions? Tampered information is considered useless, and results in the rejection of systems [1]. Finally, deactivation functions are appreciated proactive solutions to potentially embarrassing or harmful situations [1]; for example when a schedule is known and emotions can be mapped to a specific event.

We propose to let users decide when and to whom information is sent, to allow removals limited to periods, preventing fine tuning, and to indicate the representativeness of accessible data. Users should be incited to justify deletions. This would comfort recipients, and peer pressure may demotivate users from removing data without good reasons. For deactivation, on/off controls should be made available.

Illustration with our System. The server currently feeds on raw physiological data and copies of e-mails. An improvement would be to have a personal agent located in the wearable filter the data, process it, then transmit only intensities and emotional states to selected users, hiding raw data and preventing much additional–unwanted–inferences. The agent would inform with a precision inversely proportional to elapsed time; for a given individual "current", "day", and "month" values only being available. Data older than a month would be deleted. The "current" state can be associated by users to variable durations on a per-recipient basis. An on/off button would request the agent to finish the current transaction then stop its activities.

4 User Side

The user side of the disclosure process mainly concerns its last phases: multi-modal rendering and interactions.

4.1 Multi-modal Rendering

When recipients receive data, they may be notified of the arrival of information before its rendering.

Notification. For numerous services, recipients would benefit from notifications that indicate the arrival of updates or important messages. These notifications need to be efficient enough to raise recipients' awareness about the event. Ideally, notifications themselves would provide information about received content, like what has been done with cellular phones, vibrating or ringing differently depending on whether an e-mail or phone call is received, or on callers' identity.

For systems that disclose emotional states on demand, the notification can simply inform the user that a change occurred, letting her check the information at her convenience, for example later when she is alone. For systems that disclose emotional states on a continuous basis, the notification can inform the user that a change occurred and will soon be rendered (e.g. displayed on her wearable screen), letting her modify her physical and social settings before the event. This latest type of notification implies delays in rendering, either of fixed duration based on user settings, or of variable duration based on context awareness (e.g. presence or absence of bystanders based on radio-frequency identification).

In everyday situations, there is a balance to strike between efficiency and usability. Sound notifications would be disruptive, and eventually revealing to bystanders. Vibrating notifications would be discreet but may go unnoticed during physical activities. Discreet but informative notification is a good objective however its medium and expression should be selected according to the specificities of services and users (notably from expected lifestyles).

Rendering. Information may be provided to recipients via sight, hearing, touch and smell. In all cases, the risks to privacy are related to involuntary disclosure: a bystander seeing information on the display, hearing a message, feeling vibrations, smelling unusual fragrances.

The rendering should provide qualitative rather than quantitative information. To minimize risks, access to devices should be limited: a vibrating device may be around the wrist instead of upon a table, a display can be covered with a polarized film, messages can be listened to with earphones rather than loudspeakers, etc. Beyond the designers' expectations, form-factors and affordances [5] matter.

Finally, information can be coded so as to be incomprehensible to outsiders. The code should not be easily guessed, but may be selected by the user to facilitate his memorization. With simple interfaces, coding schemes are quite limited and should therefore be changed regularly, like passwords should be. With more complex interfaces, this may not be necessary. For example, virtual environments allow so many subtle manipulations (weather conditions, presence of objects, speed of animals) that chances to accidentally understand a message are extremely low.

Illustration with our System. Our system proposes e-mail alerts, visualization in web pages or continuous updates on the screen of a wearable computer. This diversity favors universal access but increases the difficulty to efficiently preserve privacy. The e-mail alerts are expected to reach mobile devices and benefit from their usual notification schemes (e.g. vibrations, dedicated ring tones). During visualization, acquainttances are mirrored with the *soap bubbles* metaphor. In the current version, bubbles contain text indicating the acquaintance's name, and the color reflects the emotions based on a unique color scheme. We propose to let users personalize colors, shapes and sizes to represent identities and emotional states so that users do not worry about what bystanders see. Besides, bubbles should not all be visible simultaneously, to avoid inferences on the number of registered acquaintances. Wearable screens will be covered with polarized films and turned off after a few seconds of inactivity. Finally, the wearable shall be equipped with a vibration-based notification system located on the wrist.

4.2 Interactions

Services may enable recipients to react to visualized information or to emotion-related messages; risks are then related to errors of manipulation and to bystanders noticing and understanding actions carried out.

Actions. Two types of actions lead to breaches of privacy. The first one is sending a message to a wrong recipient, potentially revealing information about the intended recipient. The second comprises actions that are observed and understood by a bystander.

If a message is sent to a person in response to an event (e.g. an "anxiety" alert), the source of the alert should automatically be selected as recipient. After sending a message, the identity of the recipient should be quickly reminded to enable senders to realize they have done an error if it is the case. Then, there should be a way to cancel sent messages as long as they have not been delivered or viewed.

Depending on the equipment, functions might be directly associated to e.g. the buttons of the physical interface. The process should include the information that is necessary to the user but in a way that is not accessible to bystanders. For example, the function of buttons should be associated to tactile labels rather than visual labels.

Feedback. The issue of feedback for interactions is related to the issue of multi-modal rendering described above. For visual feedback, if codes (colors, shapes) are used, bystanders may understand an interaction occurs but neither know what information is sent, nor to whom. Simple languages can be developed but it seems unrealistic for complex messages. It is realistic for simple messages such as "I think about you", "good luck", or "need help?"). One way to hide information to bystanders is to use touch interfaces instead of visual interfaces.

Illustration with our System. With the current design, users can send pre-defined messages, with three buttons ornamented with small drawings that indicate the nature of the message. For example a heart for “I love/support You”, a question mark for “Need help?”, and a OK mark for “I am fine”. The selection of the recipient is done with a click on the touch screen, on the bubble associated to the intended recipient. Instead of the small drawings, we propose to put relief drawings, not visible but felt with fingers tips.

5 Global Issues

In addition to the issues cited previously, we add a few transversal issues: awareness, access, culture, and recommended practices.

Awareness. We considered so far that no additional information is provided besides emotional states. Although simultaneous communication is out of the scope we cover here, the issue of context awareness cannot be neglected. Because information is sent to acquaintances, additional information may be available to understand situations resulting in the elicitation of an emotion. At the minimum, one’s schedule might be known by parents and a few friends.

Ubiquitous systems that have been foreseen may lead to the disclosure of location, co-presence, or type of ongoing activity. Appearing scared when in a vivarium can reveal a phobia of reptiles. Showing happiness or calm (boredom?) when in presence of a certain person can reveal global feelings towards that person. Being systematically walking when sad can reveal a coping practice. In such cases, how do we protect the user’s privacy? Should we? *Can* we? When several services are active simultaneously, we cannot rely on them to deal with such a problem. Neither can we rely on users: they would be likely to forget to deactivate some functions or might decide that the services are too much trouble. As far as input from users is concerned, a personal agent is required to filter the data; and for everyday uses, this agent would need to be much smarter than what artificial intelligence has provided so far.

Access. Privacy is related to accessibility, which can be digital (e.g. stored, transmitted) or physical (e.g. visible on a wrist-located display). Obstacles to access are linked to the environment, to available resources, and to the information itself; they should be exploited as often as possible when useful and practical.

Our proposal to incorporate buttons with tactile instead of visual labels exploited the obstacle of distance. Similarly, providing useless information would add the obstacle of noise. Digital information is much more sensitive in the sense that it is permanent and that memory and processing capabilities are not real problems anymore; only the time to carry out operations remains a tangible obstacle.

Finally, privacy can be threatened if a personal device containing information becomes accessible to an outsider, even if only for a few seconds. This problem can be solved by requesting strong but convenient identification, and by deactivating the device when its owner is not around. Identification can be based on biometrics (e.g. fingerprints), and deactivation can be enforced with the use of an external token [6].

Cultures. When considering the creation of universal services, attention must be paid to cultural factors. People from different countries may share a minimal conception of privacy but not rich ones, leading to clashes when worldwide services emerge [7]. Privacy requirements will–and implementations should–vary:

> "One insight that clearly arises in examining privacy in Japan and elsewhere is the important role trust plays in support of privacy and how the mechanisms of trust can be manifested differently in different cultures.", Mizutani et al. [7]

Bell [8] highlights cultural specificities for actual ubiquitous services, notably in Singapore, at the opposite of the Western-oriented research. Of course the problem is not limited to groups of users but extends to interactions between users of different cultures. Such a situation hints at the interest of contracts sent alongside emotional information, stating how the received information may be used.

Recommended Practices. The ACM's code of ethics [9] provides principles concerning the respect of privacy in section 1.7: *Respect the privacy of others*. These principles were included and adapted in our discussion. Marx also guides system designers with 30 questions that determine the ethics of surveillance [10]. None of these guides however concern emotional data per se.

6 Future Works

In this paper, we discussed privacy issues for the disclosure of emotions in one specific but significant case. Our goal was to clarify basic privacy issues before implementing a related system. Our next steps will accordingly be to create the system, evaluate the pertinence of our proposals, and identify additional issues. We will be interested in checking users' perception of the privacy solutions, and evaluating the influence of these solutions on the acceptance and usability of the system. Finally, we need to investigate in more depth several aspects' of our visual interface: how would colors and shapes be associated to family members and friends? Do patterns emerge, reducing the usefulness of the scheme for privacy? Answers could be exploited in both affective computing and security/privacy communities.

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Strategic User Research at Home and Abroad

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Abstract. Much of the international focus at companies tends to be on localization. Localization is critical to helping a company be a player in international markets, but strategic user research can play a significant role in driving the company's international strategy, identifying and defining key opportunities. The methods used in strategic research also need to go beyond localization in order to realize their full potential. Properly "culturalized" research efforts can help a company reach beyond localization in several ways. This paper will explore how Adobe Systems has engaged in research to extend its offerings in geographies outside of the United States, and in particular it will draw from examples of activities and solutions for the Japanese market.

Keywords: Strategic user research, international research, business opportunities, Japan, culturalization.

1 Introduction

There are many ways to drive a company's business via international opportunities in addition to localization:

1. workflow and feature opportunities
2. fundamentally different product
3. new markets
4. corporate strategy and window-on-the-future

All of these approaches extend the business of a company. Adobe localizes many of its products for Japan and other geographies. In addition, Adobe also conducts research to identify distinct user needs and opportunities.

1.1 Workflow and Feature Opportunities

In our international user research we often uncover unique workflow and feature opportunities within our existing products. For example, Adobe recently created a hanko (approval stamp) feature within Acrobat for the Japanese market. Hanko are stamps that the Japanese apply to documents to indicate approval or acknowledgement of a document's content. Hanko are used analogously to the way signatures or initials are used in the US and Europe. Today, Japanese business

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document approvals are executed on paper in a workflow typically involving a sequence of approvers applying their hanko in an order corresponding to their position in the company hierarchy. This reliance on a physical stamp has been a barrier to the adoption of paperless approval practices in the Japanese market. To overcome this barrier, the Acrobat team wanted to provide features that allowed users to approve electronic documents using a digital hanko, thus making paperless document approval possible.

The user research methodology involved a cross-functional team (consisting of user research, design, Japan product marketing, and US product management, in close coordination with engineering) conducting in-depth interviews with customers in a variety of industries. The sessions also included detailed, task-based feedback on early feature concepts. Key to the success of the project was the involvement of the cross-disciplinary team and their first-hand experience of the team in the interviews and feedback sessions. Constant communication with the engineering team in the US allowed for almost real-time changes to the concept and iterative feedback. The team worked to iterate the designs and revise the underlying architecture while still in Tokyo.

Fig. 1. Hanko workflow: Customer site visits and paper example

1.2 Fundamentally Different Product

In addition to adding features for a specific geo, sometimes the research uncovers fundamentally different workflows and product needs. A key example from Adobe's past is the creation of InDesign J—a version of InDesign fundamentally different from what ships to the rest of the world. Comprehensive research uncovered a distinctly different print publishing workflow in Japan versus the United States. Key to uncovering the user and workflow needs were in-depth conversations and close relationships over time with users in a variety of relevant fields. In addition, first-hand exposure of the US-based team to Japan and the print publishing industry were critical.

Lynn Shade, who led the effort to understand and document the workflows and the creation of a product designed to meet the needs of our customers in Japan, would continually bring photos, videos, photocopies, and real documents the users agreed to share back to San Jose to help the US-based team to understand the need and opportunity. Another component critical to the success of the project was aligning everyone on the project--including marketing, engineering, quality engineering, US team text experts, type team people – via in-person immersion in Japan. The potential customers were exceptionally selfless and were quite humble about how they did things, never arguing about how something should be done. They voiced their needs quite thoroughly, and the main task was to distill the critical components from these numerous needs.

Long-term relationships were absolutely critical to getting it right. No one had tried to write a computer application that does what the team was trying to do – to determine Japanese typographical rules and semi-automate them at the same. To accomplish this ambitious task, the relationships with users (actually, some would never become users, some were typographers, some were using proprietary systems, some had no plans to switch from their paper workflow, some used Illustrator to hand-kern each character) were key to ensuring we made something that fit their needs. Every little detail was checked with them. By mid-way through the project it had gotten so complex that it was necessary to involve two engineers in discussions around the finer points of how the text engine was going to work. Deep and lengthy relationships were key to identifying the high- and low-level needs and creating a product that addressed them. This relationship was not just between the designer/researcher and the customers; the engineers and quality engineering formed an online group called "InDesign-J Friends" to keep checking every detail during the process. Engineers, US marketing, and marketing in Japan became just as invested and involved in user research and maintaining these long-term relationships.

1.3 New Markets

Some of the biggest areas of impact for international research are where we develop strategies for emerging markets or geographies new to Adobe. Such endeavors rely on in-depth observational research--gaining a deep understanding of our users, their current workflows, and goals. But also understanding cultural, technology, and societal trends is critical to developing appropriate strategies for these international markets.

Ethnographic research has played a key role in developing an understanding of our international audiences and situations. We have engaged in extensive ethnographic research in Japan to develop an understanding of many of our user segments. Most of this work relies on a combination of observation and structured interviews. We also monitor trends in Japan—cultural, business, technology, etc and mine these for insights and implications for our business.

One novel approach we have used, the "cartoon card" method, involved a semi-structured conversation focused around a set of cute "cartoon cards" depicting various people, technologies, places, etc. With these we explored the mobile ecosystem, culture, and behaviors. We found the cards to be an excellent ice-breaker and the cuteness created a much more casual environment in which users were more open to sharing their views and thoughts. Through this method we uncovered much interesting information and formed key insights about the current status and future potential of mobile devices. To further explore this topic, we also tapped into local expertise via partnerships with universities and design firms.

Fig. 2. Cartoon Cards and semi-structured interview method

1.4 Corporate Strategy and Window-on-the-Future

One of the most exciting ways to leverage international research is to use leading geographies to help define corporate-wide strategy via insights into the future of an industry. For example, Japan and Korea are a microcosm of pervasive use of technology. We are able to leverage findings from our exploratory work in Asia to not only identify product opportunities within these geographies, but also to envision where things might head back in the United States and/or in the future. Engaging in such research explorations is an opportunity not only to help drive the company's strategy, but also to develop novel and creative methods that tap into the local culture in effective ways. One example of how Adobe has engaged in this type of research include our "magic device" study.

The magic device study was a creative extension of our more traditional methods that served to help us explore future desires. In addition to it being very difficult for people to imagine and articulate future needs, such an exercise is not in context; in real life we encounter a lot of situations that are potential opportunities. Given that it is not appropriate or practical to trail users for days at a time, when we sought to explore future consumer mobile opportunities, we asked users to carry a "magic device" for a week; each time they encountered a problem or desire, they were asked to think about how the "magic device" could address or help them solve the problem and to record their thoughts in a journal (or via email, phone). We also surrounded this exercise with introductory, mid-course, and final casual group sessions to encourage out-of-the-box thinking and sharing of information. We chose events and social settings of a more informal nature to help participants feel comfortable with this activity, and secure in knowing that their original ideas were not only going to be accepted but were also encouraged. The results yielded many fascinating insights that we were then able to translate into storyboard concepts that bring together user needs, Adobe technologies, and business opportunities. The creation of new techniques is critical for this locale and type of activity. We were able to successfully address cultural and communication challenges, and the in-context method allowed greater insight into future needs & opportunities.

Fig. 3. Magic Device and introductory informal group session

2 Conclusion

The above examples help illustrate the numerous ways that international user research can impact both foreign and domestic business opportunities for a company. Creative, geo-appropriate methods are critical, as well as an understanding of the many levels and types of potential impact.

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Designing for Inclusivity

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Abstract. In this paper, the concerns of inclusivity with respect to technology are with the fragmenting effects upon our interaction and social practices of transferring and transforming knowledge when we use technology as part of our communication and decision-making processes. Through identifying and analysing these effects and the issues they raise for design and use of technology, the paper develops some basic principles of human-centred systems deemed essential for designing for inclusivity.

1 Introduction: Inclusivity

In this paper, the concerns of inclusivity with respect to technology are with the fragmenting effects upon our interaction and social practices of transferring and transforming knowledge when we use technology as part of our communication and decision-making processes. Through identifying and analysing these effects and the issues they raise for design and use of technology, the paper develops some basic principles of human-centred systems deemed essential for designing for inclusivity. Inclusion is considered here at a very basic level, as being about our capacity to engage with others in organisations and society as socially skilled persons (social intelligence). Our social interaction in any organisational context enables us to transfer and acquire knowledge and learn implicit organisational codes of conduct, moral practices, and cultures of behaviour. When our practices as 'social beings' in specific organisational contexts is caused to fragment with the integration of technologies, it is because the design of these technologies is not rooted in understanding the complexity of the social and personal dimension in organisational practices (e.g. healthcare systems). The problem of fragmentation arises because the technology is solely concerned with the functional dimension of organisational and domain knowledge, bounded within the functional definition of an organisation, abstracted from social and personal practices and knowledge, and this functionality defines the design requirements, design practice, and applications of interactive technologies. For 'inclusive' design where 'inclusive' refers to human engagement and commitment to socially sustainable knowledge, we cannot be so narrow as to only consider function. The design process needs to consider the social and personal dimensions of knowledge in relation to the objectifiable knowledge, in other words, to how we embed knowledge in our everyday practices. The design requirements then need to identify how the objective information structures that a technology can produce, can best work with or be applied with our everyday communicative

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knowledge practices, and this will shape the objective design. This paper discusses the inclusivity issues arising from the new conditions of interaction that arise with the integration of intelligent interactive artefacts, and proposes a human centred framework for inclusive design.

1.1 Social Intelligence, Human Synchrony and Coordination

The inclusivity concerns lie with the impacts of interactive design on human social intelligence which is considered as essential for sustainable social interaction and culture. In particular the concerns are with the affects on tacit knowing, embodied cognition, learning, and collective action. *Tacit knowing* is the unspoken dimension of human knowledge, formed in practice (through action, adaptation, negotiation, repair of breakdown), and is essential for skilled communication and skilled judgments/decision-making. *Collective action* is our co-performance with each other in the act of communication, achieved through our understanding of the performance of representations of the tacit dimension in our communication - gestures, non-verbal cues, speech, silence, touch, and other structures of information in our environment, evident in how we perform with them (Gill, SP 2006). In our co-performance of social intelligence, we are establishing the context of communication as well as imparting information… and we achieve this by "making mutually manifest the assumptions that underlie the act of communication – with sharing intentionality…"(Cross, 2006). This is achieved by our capacity to coordinate our autonomy in human synchrony, a necessary requirement for sustainable human communication.

Social interaction in everyday life is about making sense and this is shaped by social intelligence. It is the dynamics of the interplay of our personal (self) and experiential (our experiencing), objective (articulation and abstraction) and subsidiary (knowledge that resides in those around us, family, friends, colleagues) dimensions that makes social interaction meaningful and learning possible. The design of interactive intelligent technologies is bounded by rationality, the first order being to observe the present and describe and define the observations (conceptual gap). This raises a first order gap between what will be termed 'actuality' (the experiencing that draws on past, present, and expectations of future) and 'reality' (the observed present) (Uchiyama, K, 2003; Gill, KS, 2006). The second order of rationality is design (technical) limitations that come in designing the technology - create the second order gap that is design gap between human and the machine. The third order rationality of design is technical competence, the application gap - that can lead to the breakdown and disruption of our everyday practices as we interact with the technology, with the consequences that we become deskilled in our social intelligence without our even realizing it. The reason we cannot realize it is because this interaction is with our processes of embedded knowledge which are shaped, shared, and learnt within communities of practice. This is the inclusivity concern to be addressed with respect to social intelligence and social interaction.

Second, the following stages of cognitive walkthrough were adapted to fit in with the above method.

1. The expert (E) considers the initial appearance of the library.
2. E identifies the subject matter definition of the digital library.

1.2 Embeddedness and Embodiment

Embedded knowledge is about fixed and innate structures and we do not have conscious access to these but they are essential in our working, learning, and sharing knowledge within 'communities of practice' (Wenger and Lave, 1991). Organisational knowledge evolves and becomes embedded within organisations through evolving work culture, and within individuals through their social interactions within communities of practice. A reflection on inclusive interaction and embedded knowledge is important because intelligent interactive technologies, be they virtual/artificial agents, etc., necessarily seek to engage us at the embodied and embedded knowledge levels, and this raises concerns about the impact on inclusivity in that is essential for communities of practice.

2 Actuality and Reality Gap

To study the issues of inclusive interaction, we consider how the design of intelligent interactive systems makes salient the need to understand the interplay between technology, application domain (context), organisational domain (embedded knowledge of organisation as process), and cultural domain (moral and social values). Interactive technology needs to be considered as more than just design of an artefact. This interplay provides a holistic framework for the design and application of interactive intelligent systems where the cultural domain drives the application process within an organisation, so that interaction between human and technology could function in a manner that allows for inclusivity. Within the organisation, we look at gaps of responsibility, in knowledge, between actuality and reality, and with the consequences of disengagement of self from other, arising out of the interaction with intelligent interaction artefacts/agents.

3 Privacy and Trust

Interactive intelligent technologies range from digital devices that we wear in our clothing to virtual agents and moving artefacts in our social spaces. Privacy concerns our person in relation to others, involving our social values (from cultural practices in society), organisational values (through communities of practice), for example, the trust between a patient and a doctor. Integrating interactive technologies into the organisational domain has implications for disturbing and altering the value system and how we trust and interact with others. This effect on social values and trust is of concern for.

4 Autonomy and Coordinated Action

In the discussion on social intelligence, coordinated autonomy in human interactive synchrony is identified as a necessary requirement for sustainable interaction, as it carries knowledge transfer and transformation (Gill, SP. 2004). Autonomy in relation to human-machine interaction and design of autonomous or augmenting tools assumes that decision making is a process undertaken by an autonomous agent. However, research on decision making and knowledge formation in collaborative activities shows that there is no such thing as an autonomous agent in human interaction, only coordinated autonomy performed by participants in the way they manage their relations with each other through synchronous adaptation and anticipation, and in the feedback they give each other about the state of their communication. In a study of collaborative activity using large-scale interfaces that did not support coordinated, there were breakdowns in commitment to communicate. Furthermore, the technology imposed a form of cognitive overload (Adams, 2006) onto the participants as they had to try to remember that they cannot perform together, only as separate entities, at the surface of the interface. They would keep forgetting and would automatically engage in attempts at coordinated autonomy. This is not something that we as humans can be trained not to do because it is an essential part of human synchrony, sense-making, and socially sustainable interaction.

5 Human-Centredness- Methodology for Inclusive Design

Our present everyday interactions, in various spheres and working and social life, with intelligent interactive and information technologies are increasing the complexity of our interaction environments in a manner we do not fully understand. This complexity is such that it is causing us to be aware of growing problems in human social practice such as cognitive and social disengagement and loss of privacy. The interaction complexities are disrupting our communities of practice within which we share and engage in the social practices, i.e. that enable inclusivity. Our uses of interactive technologies require us to re-appraise what we mean by human-machine interaction and understand its consequences for inclusive engagement, and use this to re-appraise design and application requirements for interaction environments.

At present, human-machine interaction is conceived as a dualistic relationship and this is extended to networked spaces. The problem is that it is a very limited conception of social interaction which actually consists in multiple structures of horizontal and vertical communications and operates at complex dimensions of human knowing in any communication setting. This limitation creates gaps in the reality and actuality of our experiences in the world. While the actuality is rooted in the past experiences and is shaped by the present reality and future possibilities, the reality is defined by the observable facts and data as of "now", the present. In an attempt to model the user interactive interface, the designer is limited to objectifying the situation as 'observed', thereby excluding the many of the possibilities of the situation as 'being observed'. This leads to a widening of the 'actuality gap' arising from the gaps between the actuality and reality of the both the user and the designer.

For example in addition to the actuality gap, our interaction experiences within our social life, especially the tacit dimension, are 'transparent' to us most of the time, while they may remain hidden to users from other contexts, thereby limiting the inclusive conception of user interaction from a cross-user perspective. Because of the actuality-reality gap (tacit dimension), the rich interaction experiences resulting form social and cultural contexts of users remain excluded from the design of the techno-centric systems and technologies. This exclusion of the ‘tacit’ dimension impoverishes the design and applications of interactive intelligent technology within a wider societal context.

The consideration of interactive technologies within an ethical framework requires us to examine the processes of the design and application of these technologies. At present the design of interactive technologies and the concept of technology as a tool, is limited by a technocentric framework of reality. This limitation is recognised by proponents of the human centred systems framework (Gill, 1996, 2004,2006; Cooley, 1987) which aims to fill the gaps between the reality (observed) and actuality (practice, experiencing) of human interaction within the broader societal context.

At the heart of the human centred framework are the ideas of symbiosis, tacit knowledge, and machines with purpose. Symbiosis enables the continuous interrelationship between the personal, the experiential and the objective dimensions of human knowing and interaction. This extends the scope of seeing information and interactive technologies within an enriching and the holistic framework of technology, organisation, society, and culture, to support inclusive action embedded in the conduct of normal responsible behaviour. The ‘tacit’ is seen here as the inter-relationship between the ‘personal’ (person) (feeling/experiencing) and ‘experiential’ (group) (collective experience/practice) and the objective (society) (Gill, SP, 1995). This articulation of the tacit provides a conceptual handle to articulate interdependent (symbiotic) relationships between the ‘personal’, the ‘experiential’ and the objective. It can be argued that part of the ‘personal’ knowledge can become part of the ‘experiential’ dimension over time during the process of participation in a group, and that part of the ‘experiential’ knowledge can become absorbed into the ‘objective’ dimension over time through the process of collaboration. Following the similar argument, it is proposed that part of the ‘objective’ knowledge can also be transferred to the ‘experiential’ domain, and part of the ‘experiential’ knowledge to the ‘personal’ domain. It is further proposed that this symbiotic idea of transference between ‘personal’ ‘experiential’ and the ‘objective’ forms the core catalyst for designing technological architectures for interaction design. Actuality-reality gap: ‘in comprehending reality, we construct a model which represents facts we observe, and use this model to design technology/techno-economic solutions. However in comprehending actuality, we experience actuality as it is practiced and experienced from within. The model of actuality represents practice (tacit dimension). Designs built on reality can only weakly be applied to actuality and we need to cultivate a design culture that overcomes this gap between what is experienced and the experiencing in order for there to be the merger between morality as practiced, and utilitarianism (rules/principles).

One way to handle this gap is to consider machines with purpose. ‘Purpose’ widens the design and application scope of systems and technologies whilst enhancing and enriching human potential. This is a developmental view that shifts the technical focus of technology from being concerned with human functions or characteristics, rooted in observation (e.g. observations of behaviour in social practices) to include concerns about inclusivity. It can be argued that human centred systems may provide an ethical framework of 'governance' of technological architectures and their operations as they impact societies and cultures. Human-centredness raises three questions:

1. Could we design a technology even if it technically possible? Feasibility question.
2. Should we design a particular technology? Social responsibility question.
3. Is the technology socially sustainable? Inclusivity question.

In order to understand the gaps between actuality and reality, we can take health care as a scenario. In the human-centred perspective, the conceptual gaps between the medical model of health, practice based model of health and community model of health are mirrored by the knowledge gaps between the explicit knowing (e.g. medical), practice based knowing (e.g. health care professionals), personal (e.g. patient and community workers) and subsidiarily (e.g. family and friends) knowing. It is the awareness and understanding of these conceptual gaps, which help us to seek collaboration and interfacing between these models of health care. There are some fundamental research challenges that need to be met to develop a conceptual framework of health care which:

a. finds a symbiotic relationship between the medical, practice based, personal and subsidiary conceptions of health care provision.
b. fills the gap between the technical vision of health system and the social vision of health care systems.
c. develops a holistic approach that can bridge the gaps between the information and data handling requirements of the management and health care needs of both the professionals and users of health.
d. enables the development of interfaces that bridge the gap between the scientific knowledge of the medical practice, the communities of practice knowledge of the health carers and the social knowledge of the personal relations and social networks, in the health care and welfare chain (Gill, K S, 2006).

The health system example above illustrates the interactive and overlapping roles of stakeholders who include medical and health care professionals, voluntary and community organisations, the patients and their families and friends. The complexity of interactions and roles need to be considered as part of design requirements when building interactive technologies in any organisational context and their consideration makes for a complex picture of ethical concerns and overlapping social responsibilities. The challenge is to understand the complexity of inclusivity as socially sustainable interaction, and design based on the principles of human-centred systems that can shape the design of technologies to facilitate this.

The example of healthcare provides some clarity for what the designers for sustainable sociality/inclusivity needs to be aware of. In the first part of the paper we spoke of social intelligence, of embedded knowledge, coordinated autonomy, and communities of practice, all of which enable us to perform as social beings in a socially sustainable way. It was stated that the design of any integrated intelligent technology within the very fabric of human interaction and embedded cognition needs to support social sustainable practices, otherwise it will lead to fragmentation of the communication process that leads to breakdowns, with the consequences that we may become deskilled in our social intelligence without our even realizing it. The reason we cannot realize it is because this interaction is with our processes of embedded knowledge which are shaped, shared, and learnt within communities of practice. A study of the use of large-scale interfaces for collaborative action (Gill, SP. 2004) has shown how they can impede natural social intelligence behaviours, causing participants to have reduced commitment to communicate and discomfort because participants had to hold back on their coordinated autonomy and synchronised behaviours, and would always forget that the technology cannot move with them. The design processes of technologies for inclusive sustainable interaction and communication need to embody the symbiotic idea of transference between 'personal', 'experiential' and the 'objective' knowledge dimensions if they are to avoid such breakdowns in human social intelligence.

The basic principles of human-centred systems are summarised as follows:

1. Symbiotic relations between the tacit, experiential, and objective dimensions of knowledge that underlie our everyday practices of human co-existence and enable us to have social sustainability.
2. Symbiotic relations between human agents and intelligent agents - bearing in mind that autonomy in human behaviour is a collective act of coordinated synchrony, and human-machine symbiotic relations will need to work with this in a manner whereby human behaviour is not compromised.
3. Socio-ethics, which is concerned with the challenges of gaps arising from the application of interactive technologies in the everyday practices of normal responsible behaviour that disrupt this, because the technologies have been designed outside of these practices. Socio-ethics within the human-centred framework acknowledges and supports the overlapping interactions between individuals, communities of practice and society: achieved by designing interactive tools as machines with purpose. It is an insult to people in communities of practice to offer them causal machines without purpose.
4. Risk – If we cannot predict the consequences or even know what action will be of the intelligent agent, we have to keep intervening to delimit the errors. Human agency is critical for the sustainable functionality of intelligent agents.
5. Privacy - This is much more than a matter of data control. Privacy is about the processes of the interrelationship with the communities of practice and society at large.
6. Social sustainability is achieved through tacit knowing and collective action of which coordinated autonomy in human synchrony is essential. Inclusive design has to be socially sustainable in order for inclusivity to be sustainable.
7. Coordinated autonomy – for social cohesion, autonomy is necessarily coordinated, and individuality is part of plurality, in order for collaboration/cooperation to be possible in human interaction. Any intelligent interactive agent has to function within this social system.
8. Minimising entropy - Technocentric systems are brittle and when they breakdown they cause disruption and entropy of the system. But machines with purpose increases both the tacit dimension and the objective dimension, and therefore can be seen to minimise the disruption, and in this sense minimise the entropy of the system where entropy is defined as indicative of the degree of disorder.

9. Responsibility - Communicating via technology, such as in distanced medication by a doctor for her patient, requires an ethical consideration as the more you give to technology, the less you are left with, and ultimately this leads to disengagement of social responsibilities.
10. Calculation and Judgement – Integration of interactive technologies in the complexity of the social domain reduces interaction to data (calculation) and leaves out human social values (judgement). This separation of calculation and judgement disrupts human communication.

These human-centred systems principles are important for the design of inclusive technologies. The key design challenge is that interaction between human agent and intelligent artificial agent needs to function in a manner that allows for inclusivity where inclusivity means socially sustainable interaction that is committed and responsible, i.e. socially intelligent.

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CBEADS©: A Framework to Support Meta-design Paradigm

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Abstract. We have developed a meta-model for Business applications. To generate applications using this meta-model we created a **C**omponent **B**ased **E**Business **A**pplication **D**evelopment and **D**eployment **S**hell; CBEADS©. The meta-model we created was based on three abstraction levels: Shell, Applications and Functions. The Shell provides the functionality common to any Web-based Business Application, and a set of configurable components and tools to create functions that are specific to an application. By using CBEADS© we can rapidly develop Web-based Business Applications by creating instances of the meta-model based on the Meta Design Paradigm. The key aspect that underpinned this research work was the viewpoint that "software is a medium to capture knowledge rather than a product". The developer's knowledge is embedded into the shell and the tools. The End-user's knowledge is used to populate instances of the meta-model from which applications are generated within CBEADS©.

1 Introduction

The AeIMS research group at the University of Western Sydney has been working with Small to Medium Enterprises (SMEs) in the Western Sydney region to investigate how Information and Communication Technologies (ICT) can be used to enhance their business processes to become competitive in a global economy [1, 2]. In this research the challenge was to find a way to develop web-based business applications that can evolve with changing business needs[3]. This is to support the co-evolution of the web application as identified by Costabile et. al. [4]. Also, we had to develop these applications rapidly and in a cost-effective manner [5]. The development approach should also reduce the gap between what the users actually want and what is being implemented in terms of functionality [6].

To address the above-mentioned issues it is very important to empower end users to become involved in the original application design during design time and be able to modify the application as a result of evolving requirements during the use time [7]. If we are to empower end users to actively participate during design time and be able to modify the application during use time rather than developing a specific application, we need to provide a set of tools and a framework that they can use to develop and change the application in response to changing needs. Rather than

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developing "the application" we need to develop a Meta Model of the Application and a set of tools within which the End Users can create the applications that they want.

We define creating an application based on a Meta Model as the Meta-Design Paradigm. One can therefore view the application that was built as an instance of the Meta-Model. The amount of computer domain knowledge required by the people developing the application can be greatly minimised by developing appropriate meta-models to conceptualise the applications users want, and by providing tools to support the creation of the applications as an instance of the meta-model. This can eventually lead to end users being able to develop complete applications.

In this paper we present the meta-model of web application that we have developed for web-based business applications. We have also developed a component-based architecture to implement this meta-model. Based on this architecture we created the **C**omponent **B**ased **E**Business **A**pplication **D**evelopment and Deployment **S**hell, CBEADS©, to support the meta-design paradigm [3, 5, 8].

2 Related Work

The Meta-Design paradigm in the context of End User Development was conceptualised by Fisher G.[7, 9] to address the need to accommodate evolution in Information Systems. They have proposed the following definition [7]: "meta-design characterizes objectives, techniques, and processes for creating new media and environments allowing 'owners of problems' (that is, end-users) to act as designers. A fundamental objective of meta-design is to create socio-technical environments that empower users to engage actively in the continuous development of systems rather than being restricted to the use of existing systems". The *(SER)* process model, the *seeding, evolutionary growth*, and *reseeding,* support meta-design. The SER model encourages designers to conceptualize their activity as meta-design, thereby supporting users as designers rather than restricting them to passive consumers [7, 9].

The Software Shaping Workshop (SSW)[10, 11] methodology is a meta-design approach to develop interactive systems. SSW exploits the metaphor of the artisan workshop, where an artisan finds all and only the tools necessary to carry out her/his activities. The development team including designers and end-user representatives are supported in their reasoning on software design and development by software environments tailored to their needs, notations and experience. They can also exchange among them and test the results of these activities to converge to a common design.

We reviewed the existing component-based development approaches in relation to the support these provide for meta-design paradigm. The component-based approaches such as Catalysts [12] and UML components [13] focus on specifying components required in an application, extending UML to design the components. Web Composition Modeling Language (WCML)[14] is another attempt to specify the individual components based on patterns by extending OOHDM. Li [15] has proposed a content component model within which a content component is regarded as an independent process unit performing necessary content organizing, processing and presenting functions. CoOWA[16] is another component-based approach to develop web applications. CoOWA has two different types of components, called client and server. The server components handle their own functionality and communicate with other components via interfaces. These component-based approaches have been developed with the objective to reduce development time through reuse, and thereby reduce the cost. They are not specifically designed to support the evolutionary growth or changes at runtime.

Won, M. et al.[17] have introduced a customizable approach with two-dimensional and three-dimensional customizable environments based on a component model called Flexibean, which can be used effectively by end users. Integrity checks are built into the customizable environment, and customizable artifacts can be exchanged through a shared repository. This approach can help end-users to use the meta-design based on a meta-model effectively and efficiently.

3 Meta Model for Web-Based Business Applications

As mentioned previously, we view Web-based business applications as an instance of a meta-model. In theory, by creating a meta-model and developing tools to populate the instance values, we can generate business applications. In practice however, creating a meta-model is not easy due to the complexities of business applications.

To manage the complexity we developed the meta-model at three levels of hierarchical abstraction called Shell, Application and Function as shown in figure 1. The Shell provides the common functionality required for any application. The Application provides a set of functions required to perform a business process. Functions provide views or user interfaces required to perform actions in a business process.

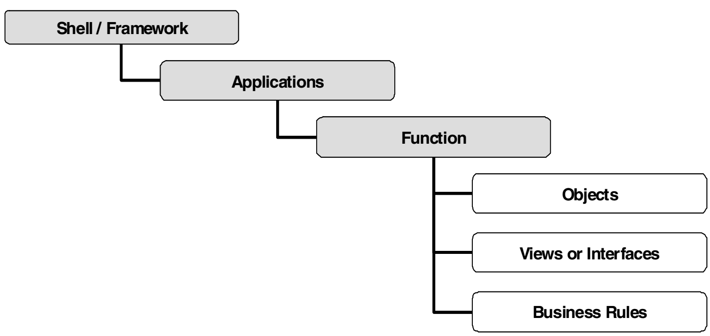


Fig. 1. Hierarchy of Abstraction Levels in Business Application Meta-Model

3.1 Shell Level

We analysed many business applications to identify features that are common to any application. In every application there are users who need to be given the authority to perform various actions. For example in a “Leave Processing Application” we can have a function for an employee to submit a leave form. The manager needs a function to approve this and forward it to a staff member in the Human Resource division. To meet this requirement we require an authentication and access control mechanism. We also require a mechanism to generate "personalised menus" for each user when they log into the system to show what actions they are authorised to perform and a way to execute the corresponding function to perform the action. As access control and personalised menu generation are common to all applications we decided to provide these modules at the Shell level.

We also need databases to store the business objects. We debated whether to keep databases as part of an application or keep them at the Shell level so that data can be shared across many applications. As we saw the importance of being able to share the data across many applications we decided to keep the databases that are used to store Business objects such as 'Employee', 'Products' etc. that are common to many applications at the Shell level and any database that is used to store Business Objects that are specific to an Application at the Application level.

3.2 Application Level

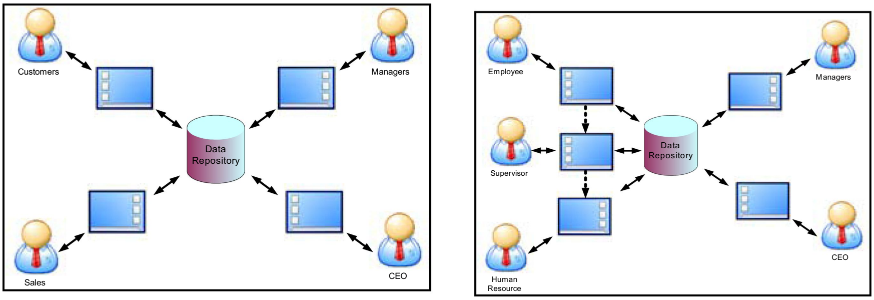
As mentioned earlier, an application consists of many functions. In an application, some of the functions can be performed by a specific user at any time. For example, an employee can apply for leave at any time, but the function for the Manager to approve the leave application can be executed only when there is a pending application. Thus we need a Menu to provide access to functions that can only be executed depending on the state of a process. We call these functions state-dependent functions. As an application can have many state-dependent functions, we have modeled and implemented this at the Application Level. In our implementation we call this state-dependent menu "My Tasks".

If necessary, applications can have their own presentation style rather than the default style provided by the Shell. In addition, an Application may have its own databases.

3.3 Function Level

A simple business application such as maintaining a product catalogue can be modeled as a set of functions that provide different views, such as an interface to view the products, update or add new products. Different users can be given access to different functions, e.g. the product manager of the company can access functions that will allow the product manager to create and update product information. A public user can be assigned the function that will display the product catalogue. These functions are linked to the Business Object "product catalogue" stored in a data repository. Such a model of a business application is shown in figure 2a.

In addition, more complex applications will require sequencing of different views. For this we need business rules to govern what happens after an action is performed. In a leave processing application, when an employee submits a leave form, a link to the function to approve the application should become visible to the Manager. Thus we need a way to define a flow. A model of such an application is shown in figure 2b.



(a) **(b)**

Fig. 2. (a) Application model without sequence-ing of Interfaces. **(b)** Application model with sequencing of Interfaces.

There could also be rules to specify who can access what instances of a Business object. For example, if the Organisation has a Sales Division, Production Division, and Accounts Division then it may be necessary to specify that the leave application from an employee in a particular division needs to be approved by the Manger of that division.

Another category of business rules that needs to be specified is how new information can be derived based on existing information. For example, an organisation might give discounts based on quantity purchased; such as 5%, 10% and 15% discounts for 10, 100 and 1000 items respectively. When deriving the total cost we need to base this on the base price, quantity purchased and applicable discount.

The elements of the three levels of abstractions of the meta-model are shown in Table 1 below.

Table 1. Three Levels of Abstractions of the Meta Model of Web Application

Abstraction	Description
Shell (Framework)	Has Applications Has Databases Has an Authentication Mechanism Has an Access Control Mechanism Has Session Management Mechanism Has a Menu to provide access to 'functions for authorised users Has User and Access Control Management Application Has a Function to create New Functions and Applications Has a Directory Structure for application related physical Artifacts Has a Default Presentation Style
Application	Has Functions May have many Presentation Styles Has a Menu to provide access to state depended functions May have Databases
Function	Has Objects Has interfaces (Views) to perform actions Has Business Rules

4 CBEADS© Architecture

The high-level architecture of CBEADS© is shown in figure 3. The Shell itself is made of components, which can be grouped into two major sub-systems. The first sub-system is CORE CBEADS that provides the overall framework within which different business applications can be developed and deployed. All the aspects of the meta-model corresponding to the Shell level are implemented in the CORE CBEADS sub-system. It consists of a security module, system components, a system database and a workflow component. The second sub-system consists of various applications deployed within the shell. The detailed application architecture was created based on the MVC architecture pattern introduced in 1979 by Reenskaug.

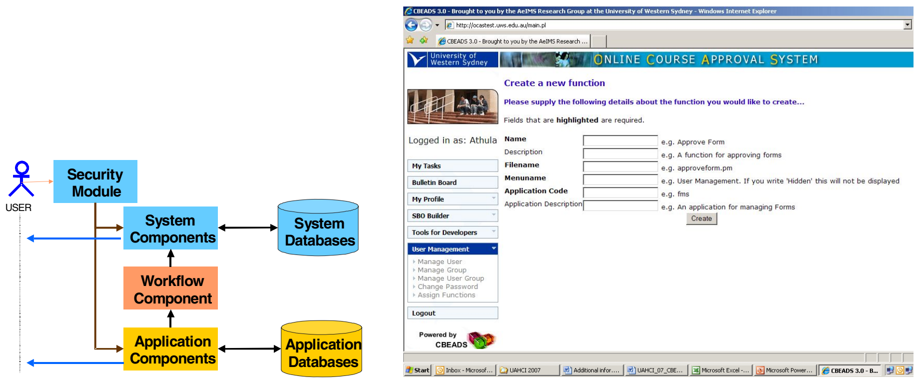


Fig. 3. Overall CBEADS Architecture and User Interface

All user interactions coming from Web browsers on users' computers are passed through a security module that performs authentication and checks what applications and functions the user is permitted to access. Firstly, a user needs to login to the system. After verifying the user, the user is given a personalised home page. This page displays the applications and the functions that the user is permitted to access. The user can activate these functions by clicking on the links. As an added security measure, before the requested function is activated the security module again checks whether the user is permitted to use the requested function.

Within the system components there is the User and Access Control Management Application. This application has functions to create user groups, allocate different functions within other applications to user groups, and create users and allocate them to user groups. This user and access control Management Application can be considered as a configurable component to suit the needs of the Business applications.

There is a special function among CBEADS© system components that can be used to create new functions, enabling CBEADS© to grow. Created functions can be grouped to form new applications. This function on the CBEADS© user interface is shown in figure 3.

Using the function to create new functions in CORE CBEADS, we have developed set of tools to facilitate the development of applications. These tools range from simple code editors and tools to create databases, to SMART tools for generating Smart Business Objects (SBO) [18], Workflow Engines (WFE) and State Dependent

Access control (VTMAC). Using an English-like language, users can specify the object model using the Smart Business Object generation tool, which then creates the business objects required for the application. We have embedded some of the computer domain-specific knowledge into these SMART tools.

5 Developing an Application Using CBEADS©

In this section we show how a leave processing application would be modeled based on the meta-model and implemented within CBEADS©. The Use Case Diagram for the leave processing application is shown in figure 4. Based on the use case diagram we can identify four functions required for the Leave Processing System which are given in Table 2.

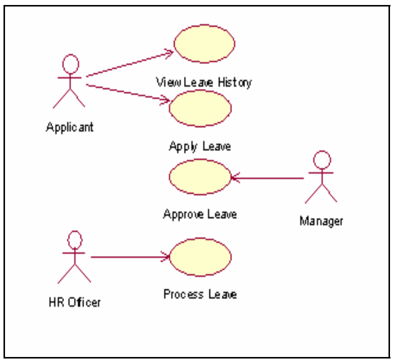


Fig. 4. Use Case Diagram for Leave Processing System .Example

Table 2. Functions in Leave Application System

Function	Type of Function	Actor
Apply Leave	Static	Employee
View Leave History	Static	Employee
Approve Leave	State depended	Division Manager
Process Leave	State depended	HR Manager

Using the SBO builder tool in CBEADS© we then specify the data objects required for the Leave Application using the SBOML language [18] as shown in figure 5. The SBO builder then generates the Business Objects for the application.

In leavesystem, leave has date, applicant, from (date), to (date), type (which could be sick or annual or no pay), status (which could be approve or reject), many approval (has date, approved by, comment)

Fig. 5. SBOML Specification of the Leave Object

Next, we develop the interfaces required for the four functions using the UI Generator shown in figure 6.

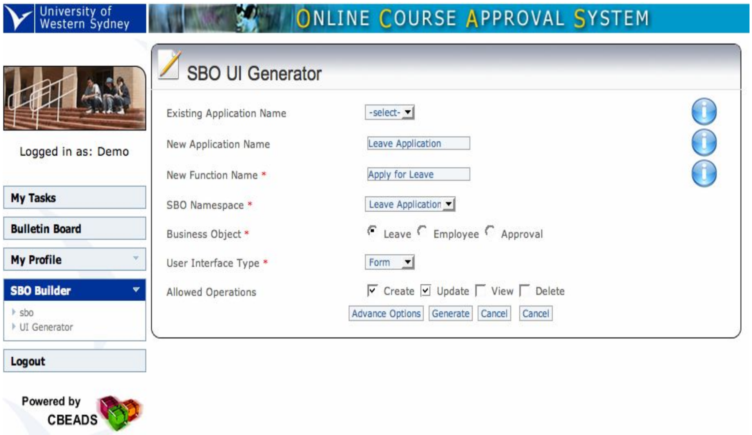


Fig. 6. Generating UIs for leave processing application using SBO UI Generator

Next we need to sequence the views. We specify the sequence of views or the workflow in a spreadsheet, upload to CBEADS© as a tab delimited text file and generate the required workflow definition file using a parser available within CBEADS©. For this application we modeled the workflow as shown in Table 3.

Table 3. State Table for Leave processing workflow

Current State	Actor	Function	Buttons	Do Action	Next State
1	Employee	Apply_Leave	Submit	Email Division_Manager	2
2	Division_Manager	Approve_Leave	Approve	Email HR_Manager, Employee	3
			Reject	Email Employee	4
3	HR_Manager	Process_Leave	Processed	Email Employee, Division_Manager	4
4	HR_Manager	View_Applications	-		4

Once we have defined the workflow, we can specify the instance level access rules by defining Departments and their Managers. Finally, reports such as the Leave History, which is based on existing data, can be generated using the UI Generator. Using the tools provided within CBEADS©, this whole application can be generated within an hour without writing any code or SQL queries.

Over time, roles can change in such an application, e.g. a new manager being employed. Through the "Access Control and User Management Application" in the Shell the new person can be assigned as a Manager. Changes to the Business Object may also occur, e.g. there may be a need to add a new leave type called "Paternity Leave". This can easily be done through SBO Builder. You can easily add an attribute to a Business Object; deleting attributes however is a non-trivial task. Another type of change could occur at the business process level, e.g. a new policy specifying that all leave greater than five days requires the CEO's approval. In the Excel spreadsheet that we use to define the process flow, a new state needs to be added to include the CEO's approval and a new workflow definition file needs to be generated using the tools provided.

Thus Business Applications developed using CBEADS© can evolve with changing Business needs.

6 Conclusion and Future Work

In this paper we have presented a framework to support the meta-design paradigm within which users can develop and deploy evolutionary web-based applications. We adapted the philosophy that "software is a medium to capture knowledge than a product". To implement this philosophy we developed a meta-model to represent Business Applications to capture the knowledge of computer domain experts. This knowledge was then embedded into a component-based shell, as well as tools that can be used to generate web-based business applications. Users can create a Business Application by instantiating an instance in the meta-model. The knowledge captured from the users during this process is used to configure the relevant components in the shell or to generate new components using the tools. To a limited extent we have experimented with the meta-design paradigm using CBEADS© framework with SMEs and obtained successful initial results. Based on the results of these experiments we have plans to refine and extend the tools.

Acknowledgements. Since 1998 when CBEASD© was first created it has evolved considerably. From time to time many research students in the AeIMS research group have made valuable contributions to the evolution of CBEADS©. The authors would like to acknowledge the support of these researchers, particularly; Ioakim (Makis) Marmaridis who designed the session management module, security subsystem and implemented the workflow engine, Anupama Ginige who developed the workflow modeling method for end users and Xufeng (Danny) Liang who developed the Smart Business Objects.

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Formats for User Data in Inclusive Design

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Abstract. Although information about users is vitally important in inclusive design, its use is often limited. The literature suggests that this is, at least in part, due to the ways in which the information is provided, which do not always match designers' needs. We therefore conducted a study to discover the information formats that designers do and do not like and use. In this paper, we draw implications for the presentation of design information, suggesting that it should be quick and easy to find and use, visual and stimulating, flexible and open-ended, and relate clearly and concretely to design issues. We also propose two categorisations of information formats and types and discuss the suitability of some specific examples of types of user information.

1 Introduction

Information about users is vitally important in the user-centered design of accessible and assistive technology. The users of such technology, who may include practitioners as well as people with impairments, often have a wide variety of capabilities, requirements and preferences that may differ from those in the population as a whole and from those that designers are familiar with [11]. Designers therefore need to be provided with a variety of information about their target users.

Some such information is already available [e.g. 11,19]. However, its use is often limited. For example, Strickler says that "questions regarding how an end user might interpret, interact with, and act on designed communication objects generally have been presumed to be addressed adequately by the designer's intuition" [20].

The literature suggests that this is, at least in part, due to the ways and formats in which the information is provided. It can be difficult to locate [15] and, once found, can be difficult to interpret and use [1]. Lofthouse suggests that information needs to be more suited to designers' needs and should match their ways of working [12].

We therefore report on the results of a study of design practice, drawing on designers' practical design experience and on observations of an annual design competition. We examine whether and how the format and type of information, particularly user information, affects its take-up and use. We draw implications for the presentation of information and propose two categorisations of information formats and types. Some examples of information formats for inclusive design are given and their suitability for designers' use is discussed.

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2 Methodology of the Study

We carried out a one year study of design practice in product and communications design in order to inform guidance for the development and use of information and methods in design. The study examined a variety of facets of design practice (e.g. design methods and team organisation) and this paper presents findings that relate directly to information use. Further findings about other aspects of the design process, such as design methods and user involvement, are presented elsewhere [6,7].

Our study adopted a convergent methodology, employing a number of research methods that are capable of independent results. Each method has its own advantages and disadvantages with respect to objectivity, accuracy and its ability to reveal non-obvious features of designers' work practices. Using a convergent approach allows findings to be cross-checked; avoids favouring any one interpretation; helps to balance the advantages and disadvantages of the particular methods, and obtains a spectrum of views at different levels of objectivity. The particular methods used are shown in Figure 1. Note that, although survey data was used to build up the picture of design practice as a whole, it focused on industry response to inclusive design [7] and so is not closely related to the topic of the current paper.

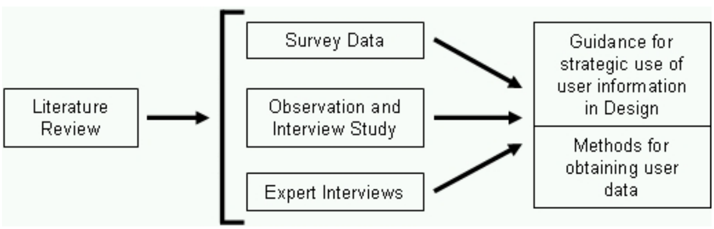

Fig. 1. Overview of methodology

Literature Review

As a first step, we carried out a review of the literature on designers' work practices, from fields such as HCI, engineering design, product design, social science, methodology and psychology.

Observation and Interview Study

An observation and interview study was conducted of the 2005/2006 Design Business Association (DBA) Inclusive Design Challenge [5]. This is an annual competition, organised by the DBA in association with the Royal College of Art, challenging teams to work with disabled users over a period of about six months, to create examples of inclusive design. Of the six teams taking part, three lay in product design and three in communication design. Information was collected from all six companies but we focused especially on three of them, tracking their processes in more detail.

We observed the teams' process in formal meetings and interactions with users, collecting audio and visual data and making structured observations. These were augmented with semi-structured interviews, developed based on findings from the literature review and earlier projects. These interviews investigated what happened outside meetings and also examined the companies' general design process.

Expert Interviews

To augment this information, interviews were carried out with two expert designers and design facilitators. Expert 1 is a design researcher, specialising in inclusive design, and with many years of experience in facilitating user involvement amongst designers. Expert 2 is a practicing designer with a particular interest in inclusive design. He is a Creative Director with an international product design company.

Analysis

The analysis of these findings was based around a three-tier coding scheme. Items of data were coded according to the particular points of interest that they related to. The first two levels of coding were identified through the literature review and these informed the subsequent studies. As the studies progressed, both levels of codes were refined and further sub-codes were identified and drawn out.

3 Findings

3.1 Information Sources Used

Although designers obtain information from a mix of different sources, our study indicates that the first point of reference is often the client, in particular through the design brief. The literature, our interviews on the DBA Challenge and expert interviews all indicate that designers place a high reliance on this for information, particularly for information about users (e.g. [10,18]). We noted in our interviews with Challenge companies that this may also be accompanied by a reluctance on the part of designers to carry out additional information searches for themselves. Indeed, within design teams, the primary information search is often carried out by account handlers or new business managers rather than designers.

Apart from obtaining information from the client, designers' information search can be fairly opportunistic [17] and use a variety of sources, as shown in Table 1.

3.2 Information Formats Used

The format of a piece of information is closely connected to its source. For example, information coming directly from people is often verbal and books use paper and text. We thus found that designers consult a range of formats, including their own experiences and imaginations, paper and digital documents, product examples, verbal information, and observations and videos of users.

Much of the designers' information comes from the client. It is therefore useful to examine the formats in which this is provided in more detail. We found that these vary widely, from a simple brief, just saying what was researched and what the client wants done as a consequence, to video footage and quotes from users. Crilly et al [4] explain that the "formal reports that research specialists produce often include…

images supported by titles, text and tables that provide additional details". However, one of the experts we interviewed said that these reports are usually quite "word-heavy", for example, charts, tick lists and typed-up descriptions of user sessions, presented in Powerpoint and possibly summarised as a set of keywords.

Table 1. Commonly used information sources

Source	Details
Client	Communicates information particularly through the design brief.
The Internet	Information is obtained through both specific sites (e.g. news sites and design blogs) and the use of search engines.
Specialist research departments and agencies	E.g. market research companies and reports.
Domain experts	E.g. contacts at the RNIB for information on visual impairment or a manufacturing company for data on particular manufacturing techniques.
Users	There may be some direct contact with users. Different research methods are used, but are not discussed in detail here.
Other people	E.g. members of the design team, friends and family.
Trade literature	E.g. design magazines.
Books and journals	Including books of guidance, materials and measurements, as well as academic publications.
Professional conferences and workshops	These may be more commonly used as sources of knowledge and expertise than for specific pieces of information.
Other projects	Includes information gathered for other projects and the study of the history of related products.
Self	The use of intuition, past experience and the designer's own use of the product.

3.3 Difficulties with Information

Clients are often primary sources of information and frequently provide user information, especially in the form of market research data. However, some of the DBA Challenge companies said that they often don't provide enough, especially on how users work. Conversely, our study highlighted the fact that designers can often find themselves faced with too *much* information which they then need to filter. In particular, designers spend little time reading and do it selectively [12]. Expert 1 explained that the cost and time needed to search for information can be prohibitive.

There are also certain characteristics that make a piece of information less likely to be used or well-received. Some characteristics identified primarily by the expert interviews and the literature are shown in Table 2.

Table 2. Disliked characteristics of information

Characteristic	Example
Irrelevant	"designers generally don't gain much relevant insight… from just looking at cold lists of facts and figures as to how many units of this have sold relative to that" (Expert 2)
Dull	"Questionnaires can be a bit sort-of flat and a bit dull" (Expert 2)
Difficult to find	It can be difficult to locate relevant guidelines [9]
Inaccessible	Academic papers are often not used because "It's all seen as totally indigestible" (Expert 1)
Too authoritarian	Designers react badly to being told they must do things in a certain way: "There is that… resistance to strict guideline cultures." (Expert 1)
Too academic / abstract	Guidelines are often very abstract and general-purpose and it can be hard to translate them into practice [9]
Doesn't fit with the standard process	"Brainstorming is actually a very low tech process… So suddenly to have to get out the computer and to have to bring everything up – it's too much of an [effort]" (Expert 1)
Out-of-date	"the other big factor is that they see academic information as being several years out of date" (Expert 1)

3.4 Information that Designers Like

Conversely, the experts and literature also identified several characteristics of information that designers did like, shown in Table 3.

For user data, the literature suggests that raw data is used more productively than more abstracted data, with designers tending to reject abstracted models of user behaviour in favour of richer user stories [13]. As designers also like concise formats, "manageable nuggets" of video footage are suggested as a compromise [14].

The design teams on the DBA Challenge suggested that a mixture of different types of information is needed: there's no one single most useful kind. One team said "a good mix of statistical hard facts and figures is great but you need a more human qualitative feedback as well".

4 Discussion

4.1 Implications for Presentation of User Information

In summary, designers use information from a range of different sources, with the client usually being their first point of reference. In fact, designers often obtain information via clients and account managers rather than searching for it themselves.

It is therefore important to consider the information needs of clients and account managers as well as those of designers. Information needs to be straightforward for clients and account handlers to find and obtain (and identify its applicability to a project), as well as easy for designers to use and apply.

Designers themselves access data in multiple formats, but they tend to prefer those with the characteristics highlighted in Table 3: information that is concise, visual and tangible; generates experience and insights; can be explored in flexible and open-ended ways; and is quick and easy to use. Conversely, they tend to dislike information

Table 3. Preferred characteristics of information

Characteristic	Supporting quote
Concise	"Designers tend to prefer the research findings to be presented concisely." [1] "Typically I would say… images and keywords and succinct things" (Expert 2)
Visual	"visual stuff rather than word-based stuff" (Expert 2)
Tangible	"also having samples or prototypes or real, tangible elements" (Expert 2)
Experiential	"[designers] love the things that help them to have a short experience… Simulatory, like the [simulation spectacles], getting in a wheelchair or having an experience of that disability… very experiential." (Expert 1)
Stimulating, generating insights	"actually watching through tapes of someone being interviewed or… responding to stimulus material… tends to generate genuine insights rather than just people's existing perceptions or preconceptions." (Expert 2)
Open-ended	"something that they feel is open ended, where they have actually made the discovery themselves… something will then act as a trigger for an idea that they feel that they own." (Expert 1)
Flexible	"The designers wanted a flexible and intuitive resource that allowed access to information in different ways" [16]
Exploratory	"they like websites… because they felt that they could take what they wanted from it and… they're used to navigating" (Expert 1)
Up-to-date	"whatever is on the web is [seen as] timely… it's seen as 'of the moment', 'the latest' " (Expert 1)
Quick and easy to use	Designers would use a new information format "if it gave them a quicker and easier way of accessing the… information" than existing methods (Expert 1)

that is perceived to be irrelevant or dull; is difficult to find, inaccessible, authoritarian, too abstract or out-of-date; or does not fit with their standard design processes (Table 2). These characteristics were identified by the experts we interviewed and by the literature, and can also be observed in the kinds of information sources that were commonly consulted: in addition to paper and digital documents, designers often referred to their own experiences and imaginations, product examples, verbal information, and observations of users.

These characteristics have direct implications for the presentation of user information. To help such information to be more widely used and applied, we should consider providing it in formats that have the characteristics listed in Table 3 and that avoid those in Table 2. In summary, it should be quick and easy to find and use, visual and stimulating, flexible and open-ended, and relate clearly and concretely to design issues.

This reflects what we previously discovered about the nature of the design process and the kinds of design methods commonly used by designers [12]. The design process was found to be variable, often informal and flexible, with diverse activities and stages of design mixed together. We also found that there was a tendency, especially in early stages, to use informal, exploratory, light-weight methods and that visualisation methods were also popular. These characteristics match those suggested for information formats: flexible, open-ended, visual, quick and easy to use.

As a consequence and as the examples in Table 2 show, unsuitable formats include lists of facts and figures (such as questionnaire results), academic papers and abstract guidelines. Also inappropriate is information that does not fit with the relevant parts of the standard design process, such as computerised information that aims to help the predominantly low-tech brainstorming process. Suitable formats, on the other hand, include the examples mentioned in Table 3: concise descriptions of findings, backed up with images; videos of users; simulation kits that help designers to empathise with disability first-hand; and hyperlinked electronic systems (such as the Internet).

4.2 Categorisation of Information Presentation

In order to assess the current situation and suggest improvements to information formats, it is helpful to create a categorisation of the kinds of design and user information that are currently available. To do this, we first compiled a list of different kinds of information. We drew from the list in Table 1 and augmented it with other information mentioned by designers and with other kinds of user information that we were aware of.

Table 4. Categorisations of design information

Categorising by format		Categorising by information type	
Paper	Data tables	Background	Culture
	Books		Personal experience
	Academic publications		Prior knowledge
	Design press	Stories	User stories – personas, biography, fiction
	General press		Anecdotes
	Reports and leaflets		User observations
Mixed media	Film, video and TV		Design case studies
	Internet	Data	Data tables
	Software and interactive media		Academic output
	Lectures and talks		Design data
	Courses and interactive sessions		Ad-hoc information
	Physical kits		User testing
People	Talking directly to someone, specifically to obtain the relevant information	Guidance	Patterns
			Design Guidance
	Observation		Lectures/courses
	General absorption from the culture		Advice (e.g. from experts)
	Personal experience	Simulators	Physical, software, engineering

This list was then categorised in various ways. Two categorisations were found to be particularly helpful: categorisation by format and by type, as shown in Table 4. These factors are independent so that each information format can be used to convey information of various types and each information type can be presented using more than one format. For example, talking to people (e.g. experts, users or other designers) can provide background information, stories, specific data and design guidance.

These categorisations outline the main areas of information presentation, but we recognise that they may not be complete. Further formats can be added within this framework.

4.3 Discussion of Some Specific Types of User Information

There is not enough room in this paper to go into all of these information formats and types in detail. Instead we examine some particular examples of ways of conveying user information that are of particular relevance to inclusive design. We briefly examine their characteristics in the light of the suggestions in Section 4.1 above and suggest how they might be improved, giving examples from our own work. Some discussion on these formats in the light of preliminary findings on information use was previously published in [8].

Capability Data

A particularly important type of user information for inclusive design is detailed data on users' capabilities and how they vary across the population. Such information provides a detailed understanding of disability and how it impacts product use. It also supports designers in making detailed decisions, enabling them to consider, for example, how many people would be excluded by certain design features.

However, this information is often presented using methods such as tables of figures and graphs (e.g. [19]). While these formats are concise, a characteristic that designers like, they do not fit designers' preferences for being visual and flexible and they do not tend to simulate creative insights. Similarly, the data is concrete but it can be difficult to translate it into design terms. It can therefore sometimes seem rather dry and abstract and may not encourage empathy with users.

We are exploring alternative, promising methods of presentation, which apply the data more concretely to design by using examples to illustrate the effects of capability restrictions on daily life and on product use. Photographs and diagrams can be used to do this in a visual and engaging manner, and flexible, exploratory formats such as card packs or websites can be adopted to enable more open-ended use of the data.

Personas

Personas are fictional users, often based on real people, who represent the end users during the design process [3]. They can be presented in many different ways, from textual descriptions through photographic montages to video snippets, and help to focus the designers' attention on the needs of the end users. If sufficiently detailed, they can help to create empathy with the end users and provide in-depth insight into their needs and lives.

Personas can be used informally and flexibly and they allow and encourage the exploration of user needs, all characteristics that designers like. Different methods of presentation mean that they can be adapted to different situations of use, with visual methods showing particular promise for engaging designers. They can also be used cheaply and quickly. However, really reliable and representative personas can take a long time to create, especially if they are tailored for a particular project. In addition, personas are not well suited to presenting detailed technical information, e.g., about disability, and their focus on representative individuals can make it hard for them to communicate the range of abilities in a population.

We are developing personas that present some of the main issues in inclusive design and that can be used directly by the designers without them having to engage in an extensive research period. Sets of personas, built and described as social groups, help to communicate a range of abilities and discourage designers from thinking just of individuals in isolation. Video clips of real users help to emphasize the reality of the situations behind the fictional accounts.

Simulators

Another way of communicating about capability loss is by simulating its functional effects in the designer. For example, spectacles can simulate various kinds of vision loss and arm and hands restraints can restrict movement, simulating some of the effects of arthritis.

These simulators can help a designer to sympathise with disabled users and to gain an internalised understanding of capability loss. They fit with designers' preferred characteristics by being tangible, stimulating and engage the designer in experiencing the user's situation first-hand. However, it can also be difficult to translate the information from simulators into design terms. There are also limits on what can be simulated, e.g. suitable and realistic methods of simulating cognitive impairments have yet to be found. Simulators can also only communicate certain aspects of what it is like to have a disability, failing, for example, to account for context, support and coping strategies.

We are therefore developing graded simulators that allow the examination of individual capabilities separately [2], thus allowing more flexible use. This also enables designers to identify the particular capability losses that cause difficulty, thus helping them to translate their experiences into concrete design actions. For example, if vision loss causes particular difficulty in distinguishing colours on the screen of a mobile phone, the designer will know to work on that particular aspect.

5 Conclusions and Future Work

This study of design practice discovered various commonalities in designers' preferences for design information. The evidence from the literature, observations of a design competition, and interviews with designers and experts converge to indicate that designers prefer information that is quick and easy to find and use, visual and stimulating, flexible and open-ended, and relates clearly and concretely to design issues.

Some specific examples of types of user information have been described. Their suitability in terms of the above characteristics has been discussed and suggestions given for how they can be improved, based on our current work. We plan to continue to develop these types of user information and other methods for supporting designers in carrying out inclusive design, based on our findings about the design process.

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Designers' Perceptions of Methods of Involving and Understanding Users

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Abstract. Numerous methods have been developed to help designers to understand and consider the needs and desires of end-users, but many have had limited uptake in design practice. In order to understand why this is and to enable the development of more effective methods and tools, it is important to uncover how designers themselves think about and react to these methods. We are therefore currently conducting a card-sorting study with designers. We aim to uncover their perceptions of underlying similarities and relationships between design methods, and relate them to the frequency and enjoyment of use. This paper presents results from an initial sample of six designers. A cluster analysis identified a very strong clustering in these results, indicating that common underlying views about methods do exist. Six key clusters are identified, including two focused on user involvement and one on understanding users without direct user contact. The effect of different method characteristics on the frequency and enjoyment of method use are also considered. Initial results indicate that certain clusters of methods are used more often, as are methods that are informal and cheap.

1 Introduction

In design, it is important to keep in mind the needs and desires of the end-user if products are to be produced that these users will find useful and usable in practice [9]. This becomes essential in universal design because of the special needs of many of the end-users and the extra challenges they face in using products. However, this can be very hard to do. Designers are often young and able-bodied and can find it difficult to understand and remember the characteristics of people in very different life situations with different needs, abilities and desires [6].

Many methods have therefore been developed for both involving users directly and helping designers to understand and empathise with users' situations. However, many of these methods have had a mixed and limited uptake in design practice (c.f. [5]). We previously carried out a literature review [7], finding various reasons for this, such as a lack of resources and uncertainty about the methods' usefulness and their effect on design. In particular, one of the key explanations is that there is often a poor fit between the (perceived) nature of the techniques and the ways in which designers think and work [4].

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It is therefore important to uncover more about what designers think about and how they react to a variety of methods, particularly those for understanding and involving users. Understanding more about how designers perceive and respond to methods can help us to identify those techniques that fit well with the ways in which designers think and work. This will help us to produce, adapt and present methods in more suitable ways. As a result, methods of user involvement will be more likely to be used in practice.

We are therefore conducting a study of designers' response to a variety of design methods, using card-sorting techniques in an interview setting. We involve a range of methods from across the spectrum of design methods and techniques because this enables an understanding of how methods of involving and empathising with users fit into the wider picture of design practice.

This paper presents some results from an initial sample of designers, as part of this on-going study. After discussing related work, we describe how the study was conducted, before presenting and discussing the results.

2 Related Work

Many researchers and designers have created frameworks for thinking about and categorising design methods. These frameworks are often based on the authors' experience and knowledge of the methods and the design process (e.g. [1,10]), or on studies of commonly-used methods and their characteristics (e.g. [3]).

These categorisations provide helpful ways of viewing design methods, but it is important to supplement them with an understanding of how and what designers themselves think about the methods, so as to ensure a good fit with their ways of thinking and working.

There has been some research looking at designers' response to methods. For example, Stanton and Young asked participants to rate ergonomics methods on various dimensions chosen by the researchers [13]. These studies, however, did not examine designers' own perceptions of what is important in categorising methods or their views of the underlying relationships between methods. The study described in this paper therefore adds to our understanding of designers' ways of thinking and working, and thus enables the production of methods and sets of methods that fit better with design practice.

3 Method

3.1 A Representative Set of Design Methods

A large number of design methods, tools and techniques were identified through a literature review of publications from fields such as product design and development, HCI, engineering design and ergonomics. We searched for descriptions of methods for use at any part of the design process, including but not limited to methods that consider users explicitly. Several collections of methods were particularly useful (e.g. [1,11,12]), but many others were also helpful, yet cannot be listed here for reasons of space.

We identified over 330 methods and techniques for use in design. As this was too large a set to present to designers, a smaller subset was chosen. To ensure that this subset covered a representative range, we categorised the methods according to type (e.g. Analysis, Decision making, Ethnographic). We then selected representative methods of each of the main types, with an emphasis on methods for involving and understanding users, since this was the focus of the study. The categorisation was used solely to ensure a representative selection, not to create an underlying structure to the set. Alternative criteria for categorisation were considered; the type of method was chosen as being best for ensuring a wide and representative range of methods.

The selection of methods was cross-checked and refined by other experts in the field, resulting in a final selection of 57 design methods and techniques, which can be seen in the table of results in Table 1 in Section 4.

Each method was then described on a card, along with alternative names for the same or very similar techniques, as shown in Figure 1.

Fig. 1. Examples from the set of design methods cards used in the study

3.2 Interview Procedure

Participants were interviewed individually. After an explanation of the purpose of the study, they were given the set of design methods cards described above. Blank cards (on the right in Figure 1) were provided so that participants could add additional methods, if they felt any were missing. They could also add new labels to cards. Participants were then asked to group the cards using two card-sorting exercises as described below.

Unconstrained Card Sort. Firstly, the participants were asked to sort the cards into groups that made sense to them. They could use any criteria they liked to do so and could use any number of groups, sub-dividing them if desired. Once they had done this, they were asked to label the groups and sub-groups, as shown in the example in Figure 2.

Fig. 2. A completed unconstrained card sort from the study

Guided Card Sort. Participants were then asked to place the cards on the grid shown in Figure 3, thus sorting them on two criteria: how often they used the methods and how much they felt they would enjoy using them. Methods were rated simulataneously on the two criteria, rather than on each separately, to reduce the length of the interview.

Fig. 3. The grid used for the guided card sort

4 Results and Analysis

4.1 Unconstrained Card Sort

An example of the groupings produced by the participants is shown in Figure 2. By examining the group labels given by the participants, we can gain an idea of the underlying criteria they used to group the methods. It seems that four of the participants grouped methods primarily according to their type or function (e.g. “Roleplay”, “Market” and “For Structuring Design Ideas”). The remaining two grouped them principally by the stage of the design process when they were most commonly used (e.g. "Context and Situation", "Conceptual Design" and "Developing the Idea"). However, a mix of sub-criteria were often used by the same participant and there were some types of groups that were common across the whole sample.

Table 1. Clusters of methods identified by the cluster analysis

Cluster A: User involvement 1: More active involvement Usability evaluation Validating in use Diary methods Participant observation Focus groups User forums Co-design Involving boundary users Involving mainstream users Involving extreme users Informal interview Informal people watching	Cluster B: User involvement 2: Getting information from users Cultural inventory Customer return cards In-depth interview Questionnaires Shadowing Thinkalouds Wizard of Oz experiment Contextual interview Online discussion groups
Cluster C: Knowledge of the market Brand audit Demographics Market segmentation Media-awareness Opportunity map Sales figures Competitive analysis Forecasting	Cluster D: Understanding users without user contact Role play Try it yourself Videos of user needs Informal personas Research-based personas Scenarios Involving existing contacts Personal experience Expert opinion
Cluster E: Visualisation and prototyping Idea scoring methods Image boards Sketching Storyboards CAD modelling Rapid prototyping Paper/foam prototyping Maps of (interpersonal) relations Simulators	Cluster F: Idea generation and analysis Anthropometric data Guidelines Heuristic evaluation Task analysis Brainstorming Creativity workshops Mind mapping Exclusion analysis SWOT analysis Quality Function Deployment (QFD)

Cluster Analysis. Cluster Analysis is an exploratory statistical technique that is traditionally used to group and classify objects in a dataset. It was applied to the results of the card-sort to uncover the participants' common perceptions of underlying similarities and relationships between the methods. For this initial dataset, we examined only the highest-level groupings given by participants. So, if a participant placed method M1 and M2 within two different sub-groups of, say, “Brainstorming”, they were considered to be in the same group in that participant’s results. When further data is available from more participants, we hope to run analyses on the sub-groups as well.

Cluster analysis was run using two types of linkage methods (complete linkage and Ward’s method) to establish the stability of the clustering over different linkage rules. The two methods identified very similar clusters, indicating a stable clustering with six clear clusters, as shown in Table 1. Clusters A and B were closely related, as were clusters E and F. These clusters were then named by the researchers, based on an examination of the methods within each cluster.

Table 2. Most common locations of methods in the grid sort. Abbreviated method names are used and letters indicate the clusters that methods belong to.

<table>
<tr><th></th><th>Never heard of it</th><th>Heard of it but never used</th><th>Use Occasionally</th><th>Use Frequently</th></tr>
<tr><td>Like</td><td>Maps of relations (E)
Research-based personas (D)
Wizard of Oz experiment (B)</td><td>Focus groups (A)
Boundary users (A)
Extreme users (A)
Participant obs (A)
Sales figures (C)
Usability eval (A)
Videos of users (D)</td><td>Contextual interview (B)
Creativity workshop (F)
Demographics (C)
Diary methods (A)
Image boards (E)
In-depth interview (B)
Informal interview (A)
Informal people watching (A)
Mainstream users (A)
Opportunity map (C)
Shadowing (B)
Validating in use (A)</td><td>Brainstorming (F)
CAD modelling (E)
Co-design (A)
Competitive analysis (C)
Expert opinion (D)
Existing contacts (D)
Media-awareness (C)
Mind mapping (F)
Paper/foam prototypes (E)
Personal experience (D)
Rapid prototyping (E)
Scenarios (D)
Sketching (D)
Storyboards (E)
Task analysis (F)
Try it yourself (D)</td></tr>
<tr><td>Neutral</td><td>Cultural inventory (B)
QFD (F)</td><td>Role play (D)</td><td>Idea scoring (E)
Market segments (C)
User forums (A)</td><td>Guidelines (F)
Heuristic eval (F)</td></tr>
<tr><td>Dislike</td><td></td><td></td><td></td><td></td></tr>
<tr><td>No agreement</td><td colspan="4">Anthropometric data (F)
Customer return cards (B)
Informal personas (D)
Simulators (E)
SWOT analysis (F)
Thinkalouds (B)
Brand audit (C)
Exclusion analysis (F)
Forecasting (C)
Online discussion groups (B)
Questionnaires (B)</td></tr>
</table>

4.2 Guided Card Sort

The method cards were placed by participants on the grid shown in Figure 3 and the most common category for each method is shown in Table 2. The majority of methods were placed in the first row, indicating that these methods were "liked". Few methods were placed in the row labelled "Dislike"; in fact, only 16 of the 57 methods were placed in this row by even one participant.

Methods from Cluster A were mostly placed in the columns "Never used" and "Use occasionally". Some of Cluster B's methods were also placed in these columns, but Cluster B also contained some methods that participants had not heard of and some that they did not agree about. Only one method from Clusters A and B was most commonly placed in "Use Frequently". Indeed, the methods in this column were almost all from Clusters D, E and F.

Most methods were placed in the row "Like". Of those rated "Neutral" (or "Dislike"), methods from Clusters C and F predominate (this is more pronounced when examining the most common placement along the "Like" axis only). This observation is tentative and awaits data from the fuller study for confirmation. In particular, there is some indication that it only applies to some of the sub-clusters of Cluster F, but fuller analysis on the sub-groupings is needed to clarify this.

In order to estimate the effect of methods' formality and cost (in terms of both money and time) on their use and on designers' preferences, we roughly rated each method according to these two criteria. This initial rating was done quickly, based solely on the authors' opinions and therefore only gives a rough indication. We plan to conduct more reliable analysis on the full dataset using ratings obtained from a selection of independent experts.

Based on these initial ratings, it seems that:

- The methods used frequently are mostly informal and cheap.
- Methods that are disliked are more often formal, and ones that are liked are more often informal, but this is unclear.
- Expense has little effect on whether designers like methods; in fact, most of the expensive methods were liked.

5 Discussion

5.1 Types of Groupings

There were two main underlying criteria used to group the methods: the methods' type or function, and the stage of the design process where they were most commonly used. These reflect common ways of thinking about methods in the design community, and they were used as the key grouping criteria by two distinct sets of participants.

In this initial study, there are insufficient people in each set to examine differences in their responses in detail. Nonetheless, the existence of two separate sets indicates that there are key differences in the ways in which different designers think about methods. In addition, some common ways of thinking are identifiable, with some groupings being common across the whole range.

We conclude that it is unlikely that a single way of structuring method sets or a single type of method that will appeal to all designers, although there are some commonalities that will be helpful. Flexible ways of navigating method sets and selecting methods may be needed.

5.2 Identified Clusters

Six clusters were identified, as shown in Table 1. The methods of user involvement are grouped together in Clusters A and B, and there is also a distinct cluster (D) dealing with understanding the user without direct user involvement. This indicates that designers often think of user methods separately, rather than as parts of other elements of design, such as idea generation or understanding the market. Perhaps there is a need to help designers to see user methods more as a natural part of the key components of design. We want designers to naturally reach for users and user information when they want inspiration, understanding of the market or analysis of their concepts.

Within user methods, there is a clear distinction between those that directly involve users (A and B) and those that enable understanding of the user without direct involvement (D). There is also a less clear differentiation between those that simply get some information or response from the user (B) and those that involve the user more actively in the process (A). These categorisations begin to help us understand how we might structure sets of user methods. Further insight will be gained from our extended study and cluster analysis on the more detailed groupings used by participants.

5.3 Preferences and Frequency of Use

There was a generally positive attitude towards design methods, with few methods being listed under "Dislike". This indicates a degree of openness to a wide range of design methods and techniques. However, caution should be exercised because it may also reflect a bias in participants' responses, perhaps from a desire to please the interviewer. Despite this bias, we can still obtain some useful information about participants' preferences for methods, by examining the methods' relative positions. In particular, there is an indication that participants may like methods from Clusters C and F *less* than methods from other clusters. However, more data from the fuller study is needed to confirm and clarify this.

As well as designers' preferences, we examined frequency of use. The most commonly used methods tended to come from clusters D (Understanding users without user contact), E (Visualisation and prototyping) and F (Idea generation and analysis). In particular, methods for understanding users without user contact were used more often than methods of direct user involvement.

The continuation of this study will help to uncover why these clusters are more popular, but possible reasons include that designers may see these methods as more essential to the design process, or that they are more traditional, deeper-rooted, less formal or cost less to implement. It does not seem like there is a correlation between the extent to which methods are liked and whether or not they are used; for example, it seems that user methods are often liked but not often used.

Some insight can be gained from previous studies of commonly-used methods. In particular, Bylund et al [3] highlight the need for methods to fit with a company's "modus operandi" and Brusberg and McDonagh-Philp suggest that commonly used methods tend to be those that can be adapted and "used in an intuitive and iterative manner" [2]. Our previous studies of designers' practice also identify a tendency to use informal, quick and cheap methods, particularly in early stages of the design process [8].

Our initial ratings of methods according to formality and cost back this up, indicating that more commonly used methods tend to be informal and cheap and that designers tend to prefer less formal methods.

6 Conclusions and Future Work

The initial results of our study show a strong and stable clustering in designers' grouping of methods, indicating that common perceptions of underlying similarities and relationships between methods do exist. This therefore lays the ground for a fuller study and more in-depth analysis.

The initial analysis identified six clear clusters: "Active user involvement", "Getting information from users", "Knowledge of the market", "Understanding users without user contact", "Visualisation and prototyping"; and "Idea generation and analysis". This provides insight into how to structure method sets and develop methods so that they fit with designers' existing thought and work patterns. However, further detail is needed, which we hope to gain from future work.

Commonly used methods tended to come from the latter three clusters, and initial ratings of methods according to formality and cost indicate that more commonly used methods tend to be informal and cheap and that designers tend to prefer less formal methods. Again, further work is needed to obtain more reliable results.

We therefore plan to extend the study to include 15 to 20 designers, from a better balance of design disciplines, including communications design. With more participants, we will be able to investigate whether there are differences between responses from different design disciplines. It will also be possible to identify sets of participants who use different key criteria in their sorts and examine the differences in their resultant groupings. We also plan to conduct more in-depth analysis, examining participants' lower-level groupings of methods, in order to identify more detailed clusters of methods.

We hope that the resultant greater understanding of designers' perceptions of underlying similarities and relationships between design methods will enable the development of more effective methods and tools for considering users in design.

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Redesigning Earplugs: Issues Relating to Desirability and Universal Access

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Abstract. Young people growing up with increasing social noises face the risk of hearing damage because of their long term exposure to loud music. Few hearing protection products on the market were designed for this young market. The challenge was to design earplugs that appeal to 18-30 year olds with a focus on desirability. Using personas and scenarios as tools, design students at Brunel University developed a range of creative concepts for aesthetically pleasing earplugs. The project illustrates that by focusing on desirability and key issues of universal access (i.e. diversity of users, tasks and contexts), a medical type of product could become as popular as fashion accessories, thus appealing to the mass market.

1 Introduction

Noise levels in social places in the UK have tripled since the early 1980s. This means that people are prone to the exposure of loud noise in our daily lives more than any generation before us. Exposure to loud noise such as in nightclubs or gigs where loud music is played can cause permanent hearing damage. Over the course of 2002, 15.7 million people visited the UK's 1750 nightclubs to enjoy themselves dancing to their favorite music [3].

Unfortunately, many of the clubbers (who are typically from the 18-30 year olds age group) do not realize that the very thing they love could be causing them harm [2]. Research conducted by RNID, the leading charity for deaf and hard of hearing people, showed that of the 66% of 18-30 year olds who regularly go to clubs and gigs, 73% have experienced ringing in their ears or dullness of hearing – a warning sign of permanent hearing damage. Moreover, the majority of the same group did not know that hearing damage is irreparable or how to look after their hearing [2].

Aiming to raise awareness amongst music fans of the dangers of over exposure to loud music and advise them on how to listen to loud music safely, the RNID launched a campaign 'Don't Lose the Music' (http://www.dontlosethemusic.com/) in May 2003. As part of the campaign, the attitudes of the 18-30 years old towards protecting their hearing were investigated. It was found that only 3% of people wear earplugs in

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a regular/occasional basis. Despite the fact that a range of hearing protection products is available on the market, few were designed for the young (18-30 year olds) at music events.

Based on the experience of an earlier project: Hearwear – the future of hearing (http://www.designboom.com/contemporary/hearwear.html), the RNID believes that a radical change in the design of hearing protection products has to occur, that is, focusing on 'desirability' rather than 'disability'; focusing on 'design innovation' rather than 'medical protection'. With this belief, the RNID created a design brief: redesigning earplugs to suit the 18-30 year olds market. This paper describes how a group of design students at Brunel University answered this challenging design brief, and how the project addresses issues relating to desirability and universal access.

2 Background

A preamble of this design project is Hearwear – a joint effort of the RNID (the UK's leading charity representing 9 million deaf and hard of hearing people), Blueprint magazine (an international commentator on contemporary design), Wolff Olins (a brand consultancy) and the V&A (a museum of art and design). In 2004 the RNID, in partnership with Blueprint and Wolff Olins, commissioned fifteen of the UK's top contemporary designers to design desirable and innovative hearing products, with the aim of making hearwear as acceptable as eyewear. Many interesting design concepts were generated, ranging from jewelry-style hearing unit that can be customized according to the user's outfit or mood to futuristic sound control devices that 'select' pleasant sound and 'mute' unpleasant noise. These concepts were displayed in the V&A from July 2005 to March 2006 and generated a large amount of media and public interest. More information about the Hearwear project can be found from websites (e.g. http://www.vam.ac.uk/hearwear/) The earplug project can be seen as a natural extension of the Hearwear project.

2.1 Related Studies

The RNID had commissioned/conducted several related studies for the earplug project.

The first study was a national survey conducted in October 2002. The aim was to collect information from young people about their social activities, and in particular whether they had ever experienced hearing difficulties, their levels of concern about potential damage to hearing as a result of social activities, and their understanding of hearing damage. 1,400 16 to 30 year olds across the UK were asked to answer questions about their hearing and their social activities. In terms of earplug use and attitudes to it, it was found that:

only 3% of people wear earplugs on a regular/occasional basis
18% of people have never worn earplugs but would consider doing so
34% of people think earplugs look silly and would not consider wearing them
28% of people like loud music so would not wear earplugs
24% of people rarely go clubbing so do not think wearing earplugs is important

It was also found that people who go clubbing more frequently were more likely to show resistance to wearing earplugs.

The second study was a survey of nightclubs across the UK. To get an idea of what noise levels the UK's clubbers are exposed to on an average night out, RNID commissioned a survey of 15 nightclubs around the country. Between December 2003 and March 2004 noise levels were tested in three nightclubs in each of the following cities: Belfast, Cardiff, Edinburgh, London and Manchester. It was found that noise levels were highest on the dance floor – on average between 90-110dB(A). Even in the 'chillout' area, the average noise level ranged from 81-96dB(A), on average 12 decibels higher (or 16 times the sound energy) than the 80dB(A) average recommended by RNID.

The third study was conducted by RNID in April 2006. Six focus groups containing 6 to 10 people aged 16 to 30 were run in London, Glasgow, Birmingham, Manchester and Southampton. It was found that 'lack of knowledge', 'concerns about look', and 'practicalities' were main reasons for not wearing earplugs, for example:

Lack of knowledge:
"…I'm not really aware on what are the best types of earplug to use…"
"People think that if you wear earplugs you can't hear anything at all…"

Concerns about look:
"…I don't wanna walk around with things sticking out my ears…"
"…that looks like an older person's hearing aid or something…It looks like NHS prescription. Horrendous."

Practicalities:
"…it (the earplug) is quite small…I look at it and think 'That's gonna get lost'…"
"…I've just put off getting them (earplugs) for ages cause I keep forgetting…."

2.2 Design Brief

RNID's analysis of earplugs on the market reveals that current earplugs are not designed with aesthetics for fashion in mind, in fact there is no ear protection product on the market that has been directly designed and marketed at the 18-30 year old music loving demographic.

Backed up by the research findings and the market analysis, the RNID created the following design brief:

"The main aim of this project is to turn a medical product into a desirable one.

Your brief is to design a manufacturable concept for an earplug of the future, a product that young people will actually want in their lives.

Your product needs to target 18-30 year olds. Your product needs to protect hearing but not look like a protective 'safety' product.

Packaging and marketing issues should also be considered and they should interlink with the actual concept to produce a whole product."

3 Method

The brief was given to the first-year design students at Brunel University, as a design project within the 'Design Process' module. It last for five weeks:

- 1st Week: briefing and introduction to relevant research methods: 'personas' and 'scenarios; Hierarchical Task Analysis (HTA), Link and Layout Analysis (LLA)
- 2nd week: Guest lecture (from the RNID Product Development) on hearing loss, hearing protection, basic technical data and the role of product design; group tutorials (personas, scenarios, HTA, LLA)
- 3rd week: Lecture on Detail Design; group tutorial (design concepts)
- 4th week: Further development of the concepts, 2D and 3D sketching
- 5th week: Presentation (Two A3 display boards) and submission of development work.

It was expected that students spend on average six hours per week on the project.

3.1 Research Methods

For this project, students were introduced to two popular design tools, i.e. 'personas' and 'scenarios' and a couple of relevant methods in ergonomics: Hierarchical Task Analysis (HTA), Link and Layout Analysis [6].

Personas are hypothetical archetypes, representing real people throughout the design process. They are defined with significant rigor and precision, backed up by actual user research data [1]. Since the earplug project was focused on the 18-30 year olds market (a diverse market), it would be beneficial for the students to further break down the market through developing 'personas', so that their design concepts can be more focused on a certain type of users within the targeting audience. 'Scenarios' can be used to describe natural, constructed or imagined contexts for user-product interactions [7]. Defining a typical use 'scenario' for the persona will help the students to understand the context of use (the physical, social and cultural environment) and identify a range of issues relating to earplugs (for example, carrying, unpacking, wearing, dealing with 'dropping' or 'missing' situations, purchasing etc) .

Task analysis is a process by which detailed information is gathered from users about what they are required to do, in terms of action and/or cognitive processes, to achieve a task object. More simply, it is used to gain an understanding of what people do in the tasks and jobs they carry out [4]. Using Hierarchical Task Analysis (a technique of task analysis), an instance of the scenario will be further broken down into a hierarchy of goals, operations and plans – this will help the students to identify 'pinch' points – the most challenging part within the hierarchy, and help them to understand the interlinks between the goals and operations. Link and layout analysis are introduced as visual tools to help analyse the eye and hand movement associated with using earplugs.

Many students developed 'personas' based on themselves or their close friends. To emphasize the importance of 'designing for others' rather than 'designing for yourself', a dozen 'personas' were selected, and the students were asked to choose one of the personas from the list and modify their scenarios based on the chosen persona. Each persona has a title, a text description and a visual expression, and an example is given below:

Title: "Singleton"

Text description: **"**Sophie Palmer, 26. She's a bit like Bridget Jones. She's got a decent job and lots of girl friends. She drinks a lot, for confidence, and goes clubbing to find the perfect man – Jamie Oliver if he's available. Fashion's a big thing. Lots of shoes and completely different looks for work, clubbing and casual."

Visual expression (Fig.1):

Fig. 1. Persona: "Singleton"

4 Results

The students developed a wide range of solutions: in addition to exploring new forms of earplugs, many of them explored state of the art technologies. Three people from the RNID were invited to give independent judgment. The judges from the RNID particularly liked concepts which are simple, manufacturable and marketable. Concepts that make effective use of existing technologies and simple mechanical controls are preferred to those with more complex technologies.

Table 1. Top ten concepts selected by the judges from the RNID

Design concepts	Key features
Trojan Horse 	The idea was to fuse ear protection with entertainment; this was achieved by adding earphones inside the earplugs. To reflect the music playback feature of the earplugs, a row of LEDs was added which reacts to sound in a similar way to how a sound bar graphic reacts to music. The user can select input for the LEDs: the surrounding sound or the music he or she is currently playing through the earphones.

Table 1. (*continued*)

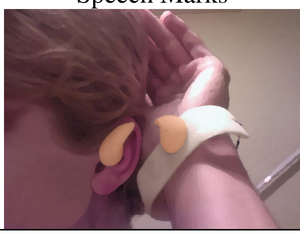
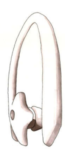
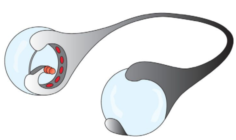
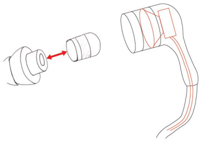
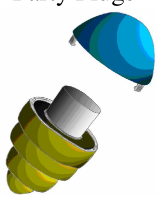
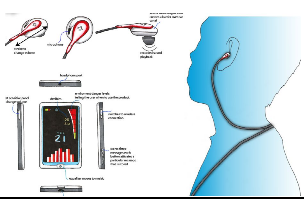
Shutter 	The sound waves are directed through the filter or tunnels by mechanical shutters like in a camera shutter. The level of filtration is adjusted using a Bluetooth connection with a remote bracelet worn on the user's wrist. This is attached to an earphone shape plug that sits inside the ear. The plug is then attached to a wrap around style clip that goes round the back of the ear and connects together at the bottom to keep the earplug secure in the ear.
Speech Marks 	The design is to facilitate the transition between loud music listening, and out of the way conversations. This is achieved via the use a magnetic inner material inside both the ear bud and the bracelet, in which direct contact between the two would be sufficient enough to safely remove the ear bud off the ear and onto the wrist quickly and effectively.
HEAR + 	By wearing the wristband, microphone and headset you are connected to your friends, the bar and the band. Touch your hear + against the receiver pads on the bar and the barman will be able to hear your every word. Being on the same group network you can talk to your friends in crystal clear sound. If music in the venue is too loud simply turn down the volume on your wristband. Touch your band to others to add new friends to your group.
Glow Plug 	Glow Plug could be bought when required and then easily be disposed, like glow sticks. They fit snugly over the ear, incorporating the filter which is placed in the inner ear. When "cracked" it begins to glow, generating atmosphere and excitement for the user and those around them.
Sonic Eardrums 	Bold and brash hearing protection device. The design has two Perspex domes covering the ears which are lit up with a series of LED's inside the head band. There is a simple ear seal to block out the ambient noise; these are fixed into the headband so it isn't fiddly putting them in. The head band wraps around the head creating the main feature of the design, and also keeps the earplugs in the ear.

Table 1. (*continued*)

SOUND bud 	Earphone and hearing protection: two in one solution. Simply clip on the end cap to the bud and put them in your ear. A variety of end caps are available to match your mood. The speaker bud channels the music directly into your ear, blocking out background noise and enhancing the music.
Rock-Ears 	Rock-Ears are ordinary sealed ear plugs, but have a face on the end of the plug. The face of the ear plug is a lot of surface area to look at. That is why the product colours would come in black, orange, red, purple, and many others. The reason is to be proud to wear earplugs by making a fashion statement and support a band. The face offers surface area to brand band names/logos or anything written.
Party Plugs 	The Party Plugs have a built in microphone sensor, continuously monitoring sound/noise levels and sending signals to mobile phones via Bluetooth. The user act on the information by using the volume keys on the phone to increase attenuation. They can also change the covers on the Party Plugs to match the colour of their clothes: keeping up with the latest fashion and look cool!
Valve 	A device that cancels the damaging loud noise from the outside and replaces it with a lower volume of sound. There is also a feature that helps the user communicate in the form of text instead of sound, which is very hard in noisy environment. This can allow the user to display messages such as his name to a new friend, the drink they like to the bar man.

5 An Example

In this section we look at a detailed design example: "Speech Marks" (Table 1, item 3) designed for the persona "Sophie Palmer" (Fig.1)

The student first analysed the persona:

"Lots of girlfriends" – always on the phone to her mates if not MSN, gossiping and chatting about everything!
"Drinks for confidence" – occasionally will drink too much and lose track of things.
"Clubs to find the perfect man" – needs to chat as well as dance, not to mention look good!

"Fashion's big for Sophie" – has good fashion style, and tends to wear top brand names.

Then he applied the Hierarchical Task Analysis (HTA) tool to analyse a typical clubbing experience of the persona, identified the scope and nature of tasks. His creative use of HTA also helped him to identify potential selling points of the earplugs, advertisement points, and chances for recycling the products.

The Link and Layout Analysis (LLA) was used to identify a series of design issues arising from specific scenarios based on the characteristic of the persona:

- "At a nightclub Sophie may need room up to a forearms length in order to insert an earplug. This could be an issue at a nightclub as sometimes the surrounding area and personal space can be limited. Such a problem could make it difficult to use current market earplugs as well as bothering nearby clubbers" – Question: can the product be designed with a minimal of physical movement in order to operate?
- "For most women like Sophie a certain problem arises in using earplugs at particular times. For instance: how would Sophie access her earplugs and use them accordingly if she was holding her handbag and her drink? Could she put them in safely and securely without having to find a table to put things down on? Or perhaps go to the toilet, but then what if she wanted to take them out to chat?" – Question: can the product be designed to be used with minimal effort, or retrieved and equipped with one hand or less?
- "One of many similar situations is stopping to talk or to go to the bar. These earplugs must be easily removable for Sophie in order to tell the bar staff or her friends what she wants to say. After that she can then reuse them and begin dancing once again." – Question: can the product be designed for the period of communication in between – or – while being in use?
- "If Sophie was to use earplugs when clubbing they would need to operate safely and securely while under going various speeds and styles of movement. Due to the size of earplugs, it must be ensured that they would not fall out and end up lost if Sophie was to 'head dance' to her favorite tune, or impress a bloke she likes with her dancing skills" – Question: can the product be designed to withstand varied motion and turbulence?
- "One other thing is that Sophie likes to drink for confidence. If she was to get too drunk would she be able to insert, remove and store her earplugs in an intoxicated state"? – Question: can the product be designed to tolerate unconscious use?

The solution was 'Speech Marks' which has the following key features:

- Safety with style – the product offers a wide variety of colours and accessories just like any other type of clothing – why should safety be limited?
- Wild and vibrant looks – perfectly suit clubbers who enjoy expressing themselves
- Precaution with function – ensures that a user is protecting herself from hearing damage with little change to her normal routine – whether it be ordering drinks, gossiping with mates or flirting with others.
- A premoulded silicon exterior – provides a comfortable fit for the users while its magnetic interior allows it to operate in its unique manner.
- Speech mark shapes – going to clubs is more than about listening to music – chatting is paramount.

- An easy to use interface – simply touch the magnetic bracelet to the ear, and the earwear is safely stored on the bracelet until required later.

A scenario featuring Sophie's use of the 'Speech Marks' is illustrated in Figure 2. The story goes that "Sophie tried out the new earwear. She was able to quickly and confidently remove them using the bracelet on her arm while she was approached by a man and talked to him easily. She did not need to worry about losing track of her earplugs as they were safe on her wrist. When she had finished talking she took the earplugs from her bracelet, quickly snapping them into place. While dancing the rest of the night with her new friend, she could be assured that her ears were safe. "

Fig. 2. Scenario: Sophie Palmer using 'Speech Marks'

6 Discussion and Conclusions

As the design brief emphasized, the redesign of earplugs should focus on desirability. The students' work has largely been focused on visual elements – a key factor to make earplugs appealing to the young 18-30 year olds market. Traditionally earplugs are designed to be discrete, neutral looking. The new approach is to make the earplugs eye-catching and customizable. Using a variety of shapes, colours, materials, advertisements, decorations, earplugs become collectable items. Some form exploration is revolutionary, for example, 'Shutter' (Fig 3, also see Table 1, item 2) has totally changed the image of hearing protection devices which tend to look like barriers/filters between the user and his sound environment; its form gives a fantastic visual representation showing that communication is 'open' – the sound is being 'sucked in' rather than 'blocked out'.

According to the RNID's organizers of Hearwear project, 'form' creation for earplugs was a real challenge for the professional design companies involved in that

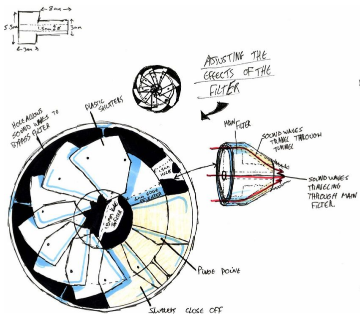


Fig. 3. 'Shutter' – 'sucking in' rather than 'blocking out'

project. The RNID is very satisfied with the wide range of visual ideas Brunel design students came out with in this project.

The RNID project has addressed all the key issues of 'Universal Access', i.e. coping with diversity in (i) the characteristics of the target user population; (ii) the scope and nature of tasks; and (iii) the different contexts of use and the effects of their proliferation into business and social endeavours [5].

Using personas as a tool, the students were able to focus on the specific characteristics of their target user population. HTA and LLA helped the students to understand the scope and nature of tasks and their interlinks; and scenarios were effective in visualizing different contexts of use. These are well illustrated by the example given in Section 5.

In summary, the personas helped the designers to focus on the user characteristics, the HTA and LLA helped identify the tasks involved, and scenarios contributed to the analysis of the context of use. The project illustrates that by focusing on desirability and key issues of universal access (i.e. diversity of users, tasks and contexts), a medical type of product could become as popular as fashion accessories, thus appealing to the mass market.

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Universal Design and Mobile Devices

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Abstract. The use of mobile technologies for self services, and the inclusion of elderly and cognitively disabled users in the self-service society can be improved by the application of appropriate accessibility guidelines for mobile devices. We show how to operationalize the principles of universal design, and how to realize these principles on mobile devices. Ten categories of accessibility guidelines are presented, and accessible user interfaces for an electronic service on a mobile phone are demonstrated.

Keywords: Cognitive disabilities, Design guidelines, Elderly, Mobile phones, Self-service society, Universal design, User interface.

1 Trends and Developments

1.1 Development of the Self-service Society

The emerging self-service society undoubtedly has a great impact on all citizens. A few years ago customers preferred to speak to the help-desk directly. Today we expect to find the information we need and be able to purchase goods or access services *on-line*. The introduction of the self-service society affects nearly every area of our lives. Daily we get cash dispensed by automatic teller machines, we buy train tickets at self-service kiosks, we keep our own banking accounts over the internet, we file our final tax statement electronically, and we report the electricity-meter reading over the phone, to name just some examples.

Self-service thinking is transforming the way many businesses and public organizations operate. Both the service provider and the customer benefit from this. For the user the opportunity to control the timing and method of transactions is appealing. The driving force for the service provider is the opportunity to reduce administrative overhead and still give a better service. The emergence of secure electronic payment systems has accommodated the development of self-served electronic commerce and customer relationship management. Over the last decade this transformation has been vastly augmented by the internet.

Besides the technological advances made during the last decades, an equally important driving force behind the development is the commercialisation of *services*. Within many areas, the welfare state is clearly moving towards a regulatory state in which market mechanisms are widely accepted. The government's role is to ensure a legislative and regulatory environment where self-served solutions and electronic

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commerce can flourish. Consequently, cost-effectiveness must be gained and maintained. Since electronic solutions and self-services offer significant potential benefits for businesses and public organizations, these are and will be important drivers of this development (Figure 1).

The self-service "movement" is reinforced by societal reforms and national development programmes. One example is the goal of "round-the-clock service" as displayed by many Nordic public administrations. Over the internet the citizen may for example apply for a building licence in the middle of the night if he/she so desires. Another typical programme in the Nordic countries is aid to disabled and elderly citizens to enable them to lead as autonomous lives as possible. Therefore, both these groups are becoming increasingly important users of digitised self-services accessed from the home or from public places, such as day-care centres. Finally, maintaining the population of rural areas is an important governmental policy goal in the Nordic countries. To ensure sustainable settlement, services need to be available and accessible. Self-services provided electronically on a diversity of technological platforms seem to be a sought-after solution.

1.2 The Mobile Phone Industry

The combination of mobility and the internet is creating a new and powerful industry that will deliver attractive, content-rich services to users on the move. All over the world companies are preparing for the mobile internet. Mobile data networks with increasing bandwidth, together with advanced phones and handheld computers, are bringing a new generation of services into use. As the mobile industry keeps rolling out new services, the concept of self-service is entering yet a new stage. It will move from finding information on the web towards the concept of mobile portals and web-based services (Figure 1). In other words, the industrial development is moving towards a new class of services situated at the cross-section between telecom and ICT.

In many European countries, the penetration of mobile devices is rapidly approaching the penetration level of TV. Recent market research suggests that in Western Europe, the mobile phone penetration – which excludes phones that have not

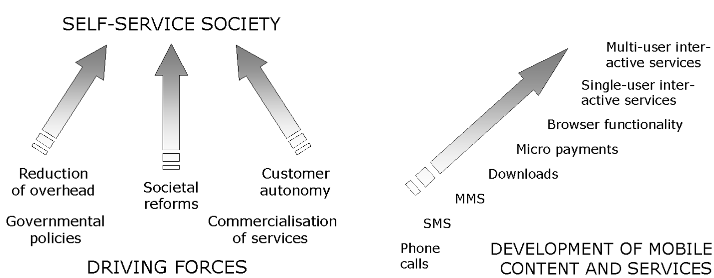

Fig. 1. Examples of the driving forces behind the development of the self-service society (left). Milestones in the development of services on the mobile phone (right).

been used for about three months – would rise to 98% in 2006 and hit 100% by 2007 [1]. The number of mobile phone connections is increasing in a similar manner all over the world [2].

In other words, the mobile phone is rapidly becoming common property. This development introduces new challenges to the usability and accessibility of the mobile content and mobile services. These challenges are reinforced by the self-service "movement" as described in the previous section, and they become even more demanding when new user groups enter the scene.

1.3 Elderly and Disabled People as Important User Populations

Our research focuses on the usability and accessibility of services on mobile phones. Accessibility problems are of particular concern to older people and people with disabilities. In parallel with the technological development, many developed countries undergo remarkable changes in their demography. The percentage of elderly citizens in the population is increasing rapidly. In Norway, for instance, it is estimated that in 2050, 15-28% of the population will be over 67 years old (13% in 2006) [3]. Another estimate says that in developed countries 20% of today's population is 60 years or older, and by 2050 that proportion is projected to be 32% [4]. Population aging is becoming a pervasive reality in developed countries. This must be taken into account when designing future technologies and services. As an OECD-report concludes, age exerts a strong influence on computer use, showing a significant decline after age 45. The findings show a negative association between age and cognitive skills [5].

Cognitively disabled people have difficulties interpreting what is seen or heard and/or difficulties making mental connections between different pieces of information, or have trouble with abstract reasoning. The type and degree of cognitive impairment can vary widely. Well-known cognitive impairments are dyslexia, dyscalculia, learning and language disabilities, and dementia. [6].

Cognitive skills or abilities, or the lack of these, thus define an important area of concern. Here the statistics clearly show the extent of the challenge. In Norway it is estimated that approximately 15% of the population aged 16-66 years suffer from a more or less permanent physical or psychological health problem that may cause difficulties in daily life [7]. International estimates show that 15-20% of the population have a language-based learning disability [8]. As shown above, the spectrum of cognitive disabilities is broad, and the affected population is large.

We acknowledge the great efforts that have been made for disabled users, e.g. those with visual or hearing impairments. However, it is obvious that the user requirements of *cognitively* disabled users have been poorly acknowledged in the context of self-service solutions or digital media generally. Therefore, practical guidelines for the interaction design of mobile devices for elderly and cognitively disabled users are called for. We limit our research to elderly persons and users with moderate cognitive disabilities who are potential users of self-services as outlined in Section 1.1. This limitation is made because it is reasonable to assume that not all information and services can be made accessible to a user population with severe cognitive disabilities, such as dementia or severe intelligence deficit, no matter what design principles are applied.

2 Towards Universally Designed HCI on Mobile Phones

2.1 State of the Art

The development of the mobile phone is more or less unproblematic for many, *but not for all*. Even “average” users are becoming increasingly confused by mobile services as these become more and more complicated to understand and configure. For cognitively disabled or elderly users, the situation is potentially much worse.

In order to compensate for the challenges, simple physical designs as well as design guidelines for content and interactivity are being developed in usability laboratories all over the world. Examples of physical mobile phone designs that aim at increased usability for the elderly are illustrated in Figure 2. The “elderly-design” is mainly achieved by stripping features from the established mobile phone concept and providing large buttons.

Fig. 2. Mobile phones for elderly and people with vision impairments, by Emporia [9], Kyocera [10] and Owasys [11]

A large number of different design guidelines are available for content carried by modern information and communication technologies. For the mobile phone, examples are the basic guidelines recommended by the W3C [12], or the guidelines suggested by Nikkanen [13] or Hays [14].

Many issues that are important to accessibility can be achieved by following accessibility *guidelines*. By using accessibility *tools* it is also possible to detect missing table headers, missing Alt-texts and so on. Moreover, it is becoming more and more common to provide options that make web-content accessible for users suffering from sensory disabilities. Large fonts and high contrast increase accessibility for users with vision impairments. Voice on the web makes content (more) accessible for people with dyslexia or other learning disabilities and people with impaired vision (e.g. elderly). In fact, many of the existing accessibility guidelines and accessibility tools based on established guidelines focus primarily on vision impairments. Other types of common disabilities, such as the cognitive ones, have not received an equal amount of attention. Even though this category of disability may appear conceptually and analytically difficult to handle, our work with mobile accessibility and usability has focused precisely on these users.

2.2 Mobile Usability Based on Principles for Universal Design

In order to approach accessible HCI-designs for mobile devices we have analysed the principles of universal design [15]. The principles are: 1. Equitable use. 2. Flexibility in use. 3. Simple and intuitive use. 4. Perceptible information. 5. Tolerance for error. 6. Low physical effort. 7. Size and space for approach and use.

Based on these principles and the underlying guidelines we have developed design guidelines for the management of service content on mobile devices. Our design guidelines are organized into ten categories of advice/guidelines, each contributing to the accessibility of the service through the user interface (UI). Below we present an overview of these.

1. Navigation and work flow

As we see it, navigation makes the service and its work flow work. The main navigation should be placed identically on all pages or cards of the UI, and critical functions should never disappear. The service should clearly express where the user is in the dialogue, and which tasks are active. The system should make it possible to go back to earlier phases of the dialogue, and it should be possible to end or terminate the dialogue at all times. In order to allow multiple navigation modalities the system should allow navigation by the device's physical keys and by screen buttons.

The small size of the screen implies splitting the task between a number of pages or 'cards'. However, one page or card should only contain related elements, and actions which are implemented as a series of pages or cards should be organized as a path of pages or cards, not a network. Scrolling should be reduced to a minimum. During complex tasks the system should inform the user about his/her progression. If the user can initiate several simultaneous tasks, the method of initiation should differ from ordinary navigation and input. In electronic forms it should be possible to proceed between (uniquely named) fields by using the Tab-key.

2. Errors

Error messages disturb any user, and even after decades of usability studies they are still often presented as cryptic alarms. However, error messages that are connected to the use of the service should be explanatory, easily read and presented in the user's mother tongue or the language he/she prefers. If the information is intended for the technical support personnel, this should be explicitly stated. It is also important that the error message is shown immediately after the occurrence of the error. In case of repeated errors, the system should offer additional information or propose an alternative way to proceed.

Not troubling the user needlessly implies that if any input is out of range or illegally formatted, the system should accept the valid input, and only invalid input and /or uncompleted input fields should be shown to the user. In case of web-applications the service should return automatically if the target page does not exist. Finally, it should be possible to present all error messages in an alternative modality, such as voice (cf. also points 7 and 9).

3. Search and queries

One of the most basic and frequently used functionalities is search. That is why it should be placed visibly. In order to manage the information (over)load, the presentation of the search results should be well-structured and easy to read. In connection with search it is often possible to choose advanced alternatives. In our case, the service should offer the use of simple search as default and advanced search options as optional. To support users who suffer from impairments connected to reading or writing, the search function should automatically correct misspelling based on lists of usual typing errors or alternative spellings (hyphens, capital letters, singular/plural forms etc.). The user should also be able to build personal lists of words.

4. Input/output-techniques

Multi-modality applies to input and output, too. It should be possible to give input and to confirm or end input both by using the physical keys of the device and by screen buttons (if appropriate). Multiple choices should be presented in a simple and consistent manner: alternatives in a menu or a list should be displayed together, and if necessary due to the number of alternatives, as layers or a hierarchical structure. The system should support self-population of input fields when the information is practically available. Word lists or dictionaries should be enabled in connection with input fields. The focal area or the working area should be accentuated.

5. Time

Sometimes the user needs time to accomplish a task. The more complicated the task flow becomes, the more flexibility should be offered with respect to elapsed time. The service should allow the user to work in his/her own pace, and it should show progression. Instead of time-out, the service should automatically save status and data input. Finally, when valid data input has occurred, or when the task is accomplished, the service should respond with appropriate feed-back.

6. Text and language

For this point we simply present a set of common rules. Information to the user should be available in her/his mother tongue or the language he/she prefers. Foreign or professional words, or extraordinarily long words or abbreviations should be avoided whenever it is possible to use ordinary words and everyday language. Sentences should be short and grammatically correct, and long texts should be divided into sections or summarized as a list.

The most important content should be presented first in all textual text units. All titles and labels should describe the content that follows, and all textual content should be relevant in the current use context. Text lines should not continue horizontally beyond the edge of the screen or the window. The text should not move unless the user explicitly allows this. Links should differ from ordinary text. Links in a text should not consist of one very short word or a string of many words. The name of a link and the title of the target page should correspond. Finally, links should indicate if they have been followed.

7. Voice and sound

In case of cognitive challenges, multi-modality *may* support the user. The user should be able to choose text and other information elements to be read aloud, and it should be possible for the user to choose precisely what should be read aloud (in a logical and meaningful order). The implementation of the UI should make it possible to read any user input aloud, and it should be possible to start and stop the reading at any time. An even more advanced feature, based on voice, is the management of the use session by speech input, with respect to both input and navigation.

8. Graphics

The use of graphic elements may support or confuse the user. For cognitively disabled users the requirements in this category are strict. We argue that graphic elements should only be used to support focus, orientation or work flow. Moving elements should only be used when this feature adds information or supports the user. In that case, blinking and movement should be slow and non-persistent.

As far as colour is concerned, it is obvious that the contrast should be high and consistent, and opposite colours should not be used, in particular not combinations of red and green. Screen fonts should be used, and it should be possible to enlarge the text. Further we argue that it should be possible for the user to choose between different colour schemes, and that information should – naturally – be accessible even if multi-colour scheme is not available. It should at least be possible for the user to choose a simple high-contrast presentation. (Colour schemes in connection with *links* should follow established conventions.)

Icons or symbols should be consistent, and follow established conventions or standards. Otherwise the symbol or icon should clearly illustrate the functionality. Pictures, animations, illustrations or icons should not be used as links except those that are standardized symbols. If icons are used as links, an Alt-text should be provided.

9. Figures and numbers

Figures and numbers easily represent a barrier for many users and in particular for those suffering from dyslexia or dyscalculia. Therefore the service should minimize the need for, and support alternatives to PIN-codes and other figure-based codes deployed as user identification. The service should also support alternative presentation forms for quantity and volume, such as diagrams or verbal descriptions of quantity.

10. Help and information

Help and information functionalities are of crucial importance for all users. These should be placed and visualized identically all over the UI by using accepted principles or symbols. For instance, a question mark or an 'i' for information probably communicates better than a picture of a life buoy. Moreover, help or information functionality should be connected to all input fields, and when it is used it should be shown so that the use context remains unchanged. Finally, it should be possible to turn off any automatic help or information functionality.

4 Case: The Mobile Tax Demonstrator

Below we will illustrate how the guidelines affect the HCI-design of our case application: the mobile phone demonstrator for the Norwegian Tax Authorities [16]. The '*mobile tax demonstrator*' shall provide functionality for updating information required for tax calculations and consequently for ordering a new tax deduction card. This is a suitable service for demonstrating the principles, as it is meant to be used by all citizens, including the elderly and disabled. The screen shots show the demonstrator's user interface with dummy data. In order to demonstrate the realization of the guidelines, we have selected seven areas of detail, which we visualize below.

The demonstrator has been developed with the use of ServiceFrame. ServiceFrame is an application execution and creation framework based on Java. It provides functionality for communication with users connected through different types of terminals such as mobile phones, PCs or PDAs. ServiceFrame has been developed by Tellu AS [17] together with Ericsson NorARC as part of the ARTS research project [18]. It was created to support rapid development of internet and telecom services.

In our view, one of the most important areas of universal design in the context of services is that of managing the work flow. In Figure 3 the use of 'cards' is illustrated. The phases of the current task are organized as task cards, and the user maintains an understanding of position and progression. The number of the active card is clearly marked. Within one task the information may often be more comprehensive than the size of the screen. We take it for granted that two-dimensional scrolling should be avoided. We allow vertical scrolling, but we make an effort to manifest the position by a clearly visible scroll bar. The scroll bar also illustrates the relative vertical position on the card. In Figure 3 the scroll bar is illustrated.

The input-output techniques deserve a good deal of attention. In connection with input or output users often arrive in error situations. In order to avoid some of these we have implemented a colour scheme that indicates invalid or incomplete input. The colour scheme changes when the task is completed. Before completion a field or a card is identified in a colour that differs from the ordinary colour scheme of the design. This mechanism also ensures the quality of input data (Figure 4).

Fig. 3. Task cards and marking of the active card, i.e. the active task, in the task flow (left). Scroll bar showing the relative position (right).

Fig. 4. Changes in the colour scheme indicate invalid input; input field containing '12' and card number '4' have changed colour (left). Working area is accentuated by a frame (right).

In a flow of tasks and in a sequence of dialogue activities the user needs a focal point. This may be connected to input or output, or to any information that the user manipulates. In our demonstrator, this challenge is solved by implementing a focal frame. This frame follows the active area of input or output as illustrated in Figure 4.

Another design feature connected to the visualization of the content is the size of the font. Obviously, both visual and cognitive impairments dictate the need to let the user choose both the density of information on the screen and the resolution of the presentation. In Figure 5 the possibility to adjust the size of the text is visualized in two different situations: a) the user chooses to enlarge all textual information, or b) the user only wishes to see one field of textual information in large font.

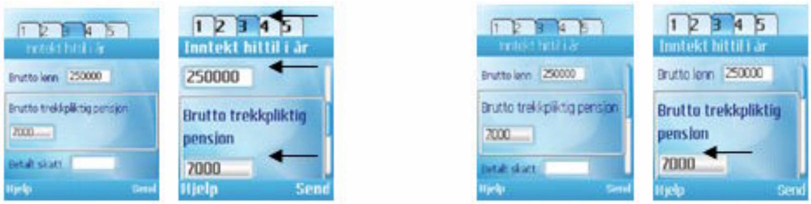

Fig. 5. Changes in font size all over the user interface (left), or only in selected fields (right)

Fig. 6. Help texts can be read aloud (left). Menu and help functionality can be connected both to a physical key on the device, and to an easily operable screen button, as here (right).

Services on a mobile phone may often appear quite complex. Walking through a dialogue which is composed of several phases requiring navigation, selection, input, output, confirmation and so on, may easily lead the user into a trap. Hence, the help functionality can hardly be good enough. In order to prevent errors and to help the user out of trouble we have implemented two help functionalities in the tax demonstrator. One is voice-based help. Any help text that appears on the screen can also be read aloud, e.g. the help texts in Figure 6. Moreover, the help button on the screen is connected to the functionality of a physical key on the mobile phone (Figure 6). This feature also covers the requirement that the user should be able to navigate in alternative manners, i.e. function keys or screen buttons.

As a conclusion to this chapter, we wish to emphasise that generally not all services necessarily benefit from all guidelines as presented in Section 2.2. Also, conventions evolve together with technological changes. So, practically all guidelines are inherently unstable. Moreover, it is not possible to demonstrate all applicable guidelines in the context of one service. The screen-shots above should, nevertheless, illustrate our approach to universal design on mobile devices.

5 Concluding Remarks

Universal design evolved two decades ago. New accessibility challenges have arisen in parallel with the advances in information and communication technologies (ICT). Today ICT is addressed by design teams all over the world. In this paper we have approached accessibility for one specific technology. The next steps include profound usability testing of the demonstrator, and the development of industrial guidelines for a variety of mobile devices with different functionality, capacity, operating system, screen technology and so on. In other words, the work has just begun.

Acknowledgments. This research has been conducted within the project 'Universal Design in Norwegian OSIRIS', financed by the IT Funk-programme of the Research Council of Norway. The research teams of Karde AS (www.karde.no), Tellu AS (www.tellu.no) and the Norwegian Computing Center – NR (www.nr.no) have contributed to the research. Special thanks go to Kristin Fuglerud and Knut Eilif Husa.

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A Method of Design Improvement with the Structured Product Concept

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Abstract. The product development in service science will become important for manufacturing industry. Therefore, the introduction of the "service science" concept is necessary in product development. This paper proposes a design improvement method based on HCD (Human Centered Design) concept, which can be introduced to middle/small enterprises, with the structured product concept. A case study of the operation panel design of home security system is discussed in this paper. This method is effective not only in making new products but also in improving developed products. Making a structured product concept is also effective to get consensus among the developers.

Keywords: Human Centered Design, Usability, Product concept.

1 Introduction

It is necessary to offer attractive products to get customer satisfaction. HCD (Human Center Design) is one of the techniques to gain user's satisfaction, and happiness on developing the products. In view of service engineering, it is important to adjust design and specification to yield the satisfaction. Therefore, HCD method can be used also for service science.

Since HCD has been recognized as a powerful tool for service science, large enterprises have been introducing HCD method and facilities. But, it is hard to introduce present HCD methods to middle/small enterprises because introducing HCD method is rather expensive. Thus, we have studied a design method to introduce HCD into middle/small enterprises.

In this paper, we suggest a method of design improvement with the structured product concept. This method makes it possible to introduce HCD into middle/small enterprises. The usability of products that were developed without the product concept also can be improved in terms of the product's usability by this method.

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2 A Method of HDT (Human Design Technology)

HDT is a logical product development and Human-centered Design method easily accessible to anyone. Defined as "Method to integrate Ergonomics, Industrial design, Marketing research, Cognitive science, Usability engineering, and Statistics (Multivariate analysis), to review process of product development to rely on intuition in the past by aspect of quantification as much as possible, and to support product making with charm of man priority that examines". HDT is developed in the following process.

Step(1) Gather user requirements
Extracting problems and needs related to a product. This usually involves group interviews, observation and task analysis.

Step(2) Grasp current circumstances
Investigating how users perceive a target product in the market.

Step(3) Formulate structured concepts
Constructing structured concepts based on user requirements and other types of information. Since the main specifications must be determined at this stage, structured concept should be structured for logical continuity among their various items, thereby avoiding any omissions. The weighting of the different concept items is particularly important as a measure to ensure logical continuity among them. This is also significant for revealing the items that are important. Once the items are weighted, those that should take precedence may be determined automatically when certain design items must be traded off against one another.

Step(4) Design (synthesis)
Visualizing a product based on the structured concepts. HDT requires that the design be based on the seventy predetermined design items. The seventy design items of

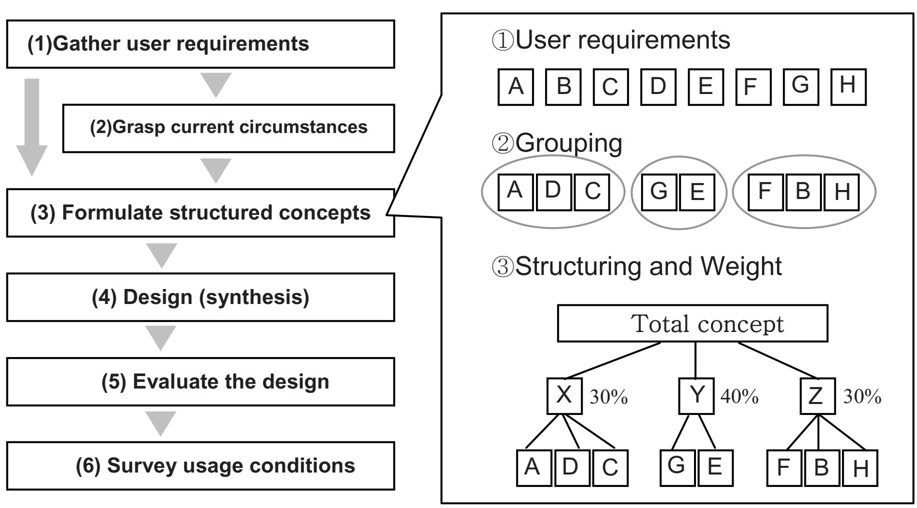

Fig. 1. Design process by HDT

HDT are classified into the eight large groups: 1) User interface design (twenty-nine design items), 2) UD (nine design items), 3) Kansei (sensitivity) design (nine design items), 4) Product liability design (six design items), 5) Ecological design (five design items), 6) Robust design (five design items), 7) Maintenance design (two design items), and 8) other (human-machine interface design) (five design items).

Step(5) Evaluate the design
Evaluating the plan (design) as visualized.

Step(6) Survey usage conditions
Investigating purchaser attitudes towards the resulting product to identify needs for future product development.

3 The Case Study of the Panel Design Improvement

3.1 Outline of the Home Security System

The home security system illustrated in Fig 2. was developed by a middle/small enterprise in Hyogo prefecture, Japan. The concept was "an easy operation with a large operation panel". It is able to operate with the touch panel of 17 inches. It is set up in the entrance. "Floor plan of the room" besides the operation button and "Image of the web camera" and "Web page" are displayed on the screen. The state of lock can be confirmed with the floor plan of the room. When windows of the house open without permission, an emergency signal is send to the owner's cellular phone and images of the situation are recorded in the home security system's server. Moreover, it has the web browse function and the remote consumer electronic function besides the security function. In addition, it is possible to upgrade the software of contents in this product.

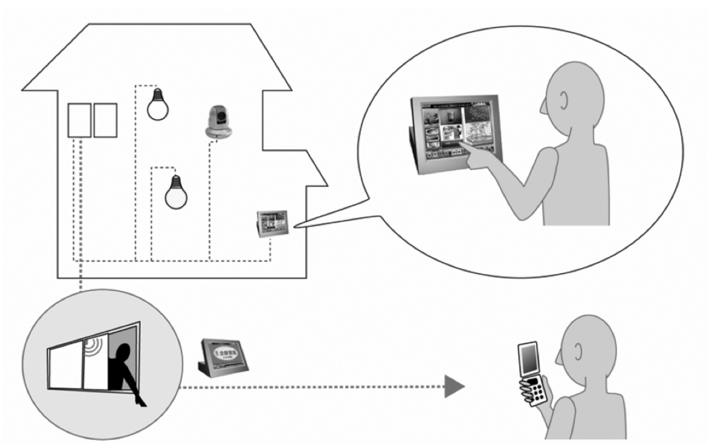

Fig. 2. A home security system

3.2 Improvement Based on HDT

Step1. Constructing structured product concept

The designing process with the general product concept sometimes has the problem which item should be chosen if the items have the trade off relation. We can't determine the items if they don't have the priority. In addition, the detailed development policy is not shared among the developers with the general product concept.

A method of the structured concept was effective to solve these problems because it gives priority to some items for improvement. First, the characteristic items were examined from the product. These items were grouped by relation to make hierarchy. After that, weight is put to each item so that the total weight of the items becomes 100. The priority of each item was described as the weight in this process.

In this case, the target product has been made without the structured concept. We have aimed at the proposal of the technique for improving a present product. There was only a rough product concept when it was made. Therefore, the design items were resolved by observation on the feature of the product and then the structured concept was reconstructed.

6 items were extracted from the characteristic of the operation panel of the home security system (Fig 3.). These items were grouped in 3 items and distributed the weight to each item.

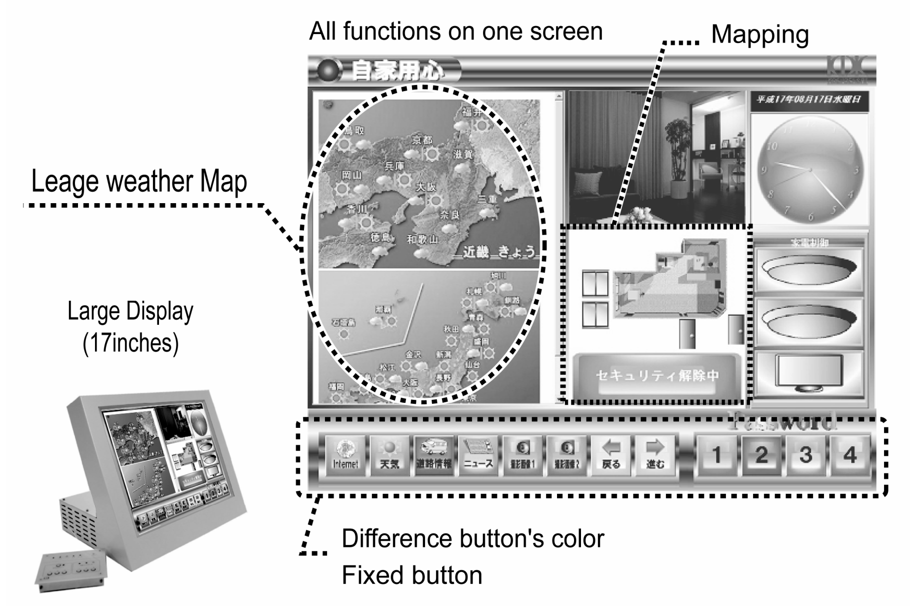

Fig. 3. Past panel design

Step2. Evaluation of the product's usability and verification by task analysis

To evaluate the operation panel's usability, task analysis was made to extract problems on the panel. On the task analysis, scene displayed in some situation was assumed. Problems of this scene were extracted from five view point of Human

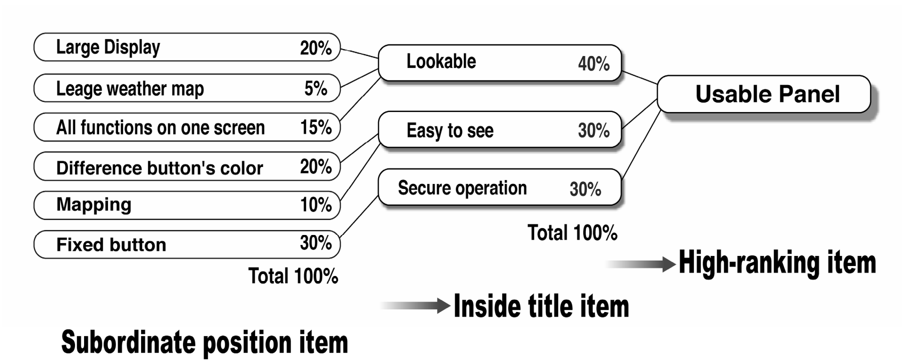

Fig. 4. Structured Product Concept (Past Design)

Machine Interface (Physical aspect, Information aspect, Temporal aspect, Environmental aspect, and Organizational aspect). The method of the extraction from three sides "Access to information", "Understanding and judgment", and "Operation" is acceptable according to the product.

79 problems about the product usability were found on the past design by task analysis.

Step3. Validation by User test

User test was conducted to verify the problems extracted by the task analysis. A protocol analysis, questionnaires and interview were made on 5 people.

The feature of this improvement process was to assume the product concept from the feature of the target product that has already been developed, and to verify the consistency of the design and concept. The feature of the present product became clear with this method, and the correction and the improvement points were found.

Step4. Constructing the structured product concept of design improvement

The problems extracted from the task analysis and the user tests were made into groups. The priority level was put on the problems, and the improvement plan of the item with a high priority level was made. After the made settlement plan was compared with the present product concept, the structured concept was corrected as an improvement concept (Fig 5.).

Step5. Design and make prototype

The design improvement idea (Fig 6.) was made based on the improvement product design concept. To conduct user test for evaluation of the design improvement idea, the prototype was made.

Step6. Evaluating Design idea

Evaluated the design improvement idea by user test. A protocol analysis, questionnaires were made on 5 people who were different from Step3 with a same protocol analysis task as Step 3.

Results of the evaluation, it found that past design's problems were solved by the design improvement idea.

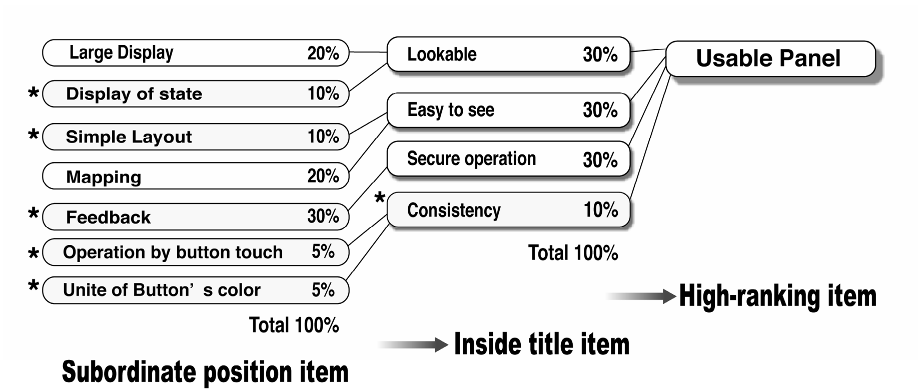

Fig. 5. Structured product concept of design improvement (* Item that is changed or added)

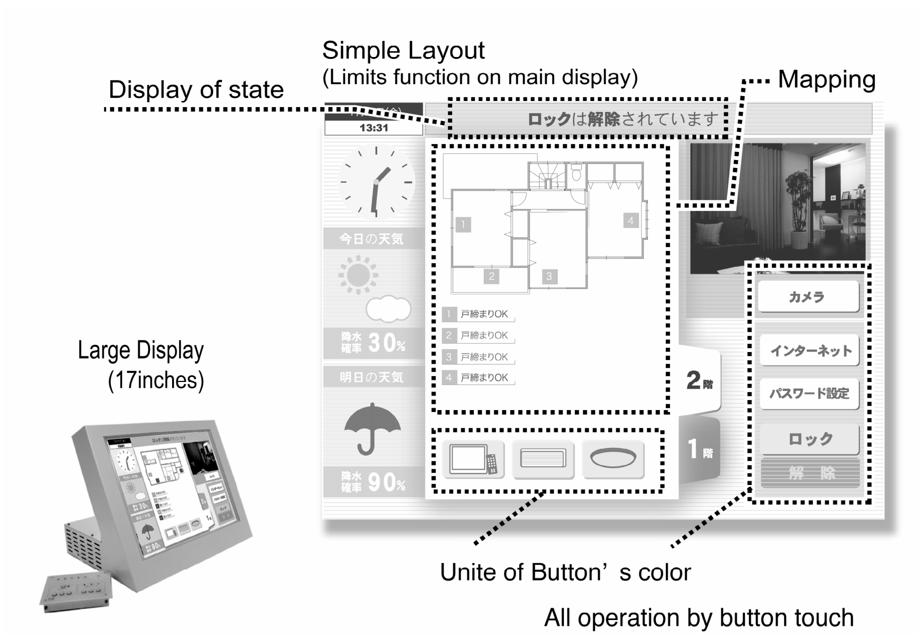

Fig. 6. The design improvement idea

4 Conclusions

To verify the effectiveness of the design improvement method with the structured product concept, we improved the operation panel of the home security system by this method. As a result, problems that have been extracted to evaluation of the past product could be almost solved. This method is effective for products that have been already developed in addition to make new products. Moreover, to make structured product concept is found to be effective for getting consensus among the developers in addition to the extraction of problems in the product.

In addition, the structured concept can give priority to items by putting different weights to them. This method can be applied to service science in addition to product development.

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Scenario-Based Design as an Approach to Enhance User Involvement and Innovation

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Abstract. Scenario-Based Design has been implemented widely to the concept and product development processes. Especially in the development of Information and Communication Technologies the Scenario-Based Design approach has been utilized widely though with different variations and modifications. In this paper I focus on experiences how Scenario-Based Design approach has enhanced better user experience of design and increased user involvement and user-driven innovation in product development processes.

Keywords: Scenario-Based Design, Information and Communication Technologies, Human-Centred Design, User Involvement, Innovation.

1 Introduction

As a design instrument scenarios are stories about people and their activities in a particular situations and environments (contexts). The value of scenarios is that they make ideas more concrete and describe complicated and rich situations and behaviours in meaningful and accessible terms. Scenarios can be textual, illustrated (for example picture books or comic strips), acted (for example dramatised usage situation) or filmed (for example videos) descriptions of usage situations. The users in these descriptions are usually fictional representatives of users (personas) but might also be the real ones.[1, 8, 17]

Scenario building is a way to describe current situation of humans in particular context or generate design ideas for new products and to identify potential user groups and contexts of use for the product. The design team with or without users can generate one or more ideas (or system concepts) for the new system. The most feasible concepts can then be selected for further elaboration toward user and application requirements specification. [1, 8, 9, 10, 17]

Scenarios have been used actively in system design in past decades. [1, 3, 4, 5, 8, 9, 11, 21] Recently Alexander and Maiden (2004) has edited a comprehensive book for using scenarios as an effective technique for discovering, communicating and organizing user and technical requirements at any stage in the system life-cycle. [1]. Besides using scenarios as a design tool for product development, scenario-based methods have also been used to enhance user involvement to design e.g. system, appliances or work. [2,13,19]. In addition the user involvement in product

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development life cycle enables users both to give their feedback to the pre-designed solutions as well as innovating totally new designs for their purposes. [12, 20]

2 Scenario-Based Design Projects

2.1 mmHACS

The user and concept of elderly focused mobile services were completed as a part of the 3-year mmHACS (multimedia Home Aid Communication System) project which started in the summer of 1998 at the University of Oulu. Nokia Mobile Phones was a cooperative partner in the project. The idea of the project was to create and demonstrate new products, services and a complete system based on modern technology for the homes and service providers of elderly and disabled people. The main emphasis of the project was on developing a multimedia communication terminal called Home Assistant. This terminal allowed elderly and disabled people to keep in touch with relatives, friends and service providers. [14]

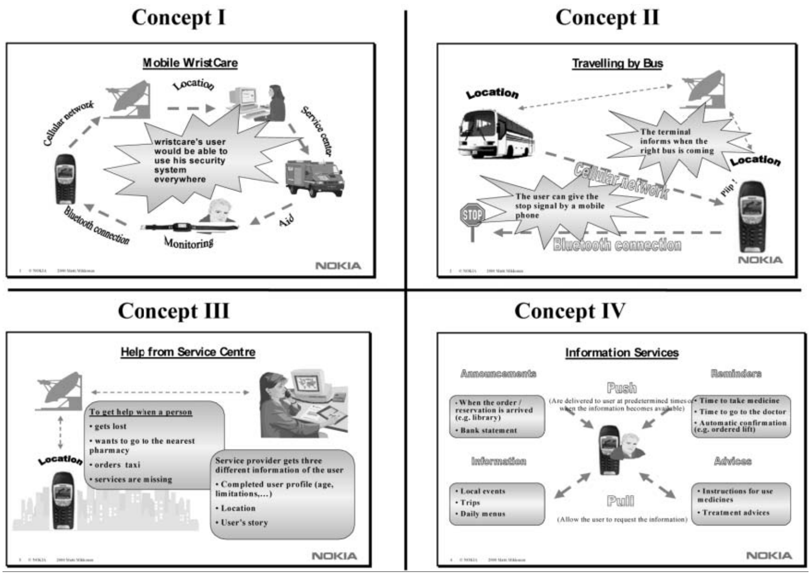

Fig. 1. Elderly-Driven design concepts of the mmHACS –project

The particular study of mmHACS surveyed product development and design in the field of mobile terminals and considered the suitability of mobile services, in particular, in facilitating the life of elderly and disabled people. The study concentrated on finding out the key service needs of elderly people. The service needs from the end users' as well as the experts' perspective were gathered by means of various group methods such as ideation sessions. Four mobile communication service concepts were created using these groups' opinions (Fig. 1). After diverse communication, these concepts were tested by the elderly. Forty-four elderly people (average age: 74 years, range: 51–87 years, male = 27, female =17) evaluated the concepts. [14]

The concept study was used to ascertain what the elderly themselves thought of mobile services, and how important they felt the service concepts developed on the basis of the user study and the experts' statements were to them now and in the future. The example stories were implemented into the concepts for the concept study with the elderly. Based on the study, the main conclusion was that the elderly valued the freedom of travel brought by mobile terminals. They were ready to accept new forms of help made possible by mobile technology and were ready to begin to use the services as long as they truly facilitate independent living indoors and outdoors. Elderly people were also willing to pay for the use of the service concepts presented. [14]

2.2 KEN

One of the tasks of the KEN project (Key Usability and Ethical Issues in the NAVI programme 2000- 2002) was to examine the potential usage cultures of navigation services and devices. Fourteen different groups were selected for the study as potential users of personal navigation. The intention was to maximise the diversity of the customer groups. Groups at different stages of life were selected to include the various needs of persons from children to the oldest of the old. Also some specials group, like hunters, were included in the study to determine the focused needs of personal navigation for these groups. It was intended that elderly persons suffering from memory disorders would make up one potential user group. However, it proved to be very difficult to assemble such a group for the scenario evaluations. For this reason we ended up gathering the opinions of this group by interviewing the relatives and care-giving personnel and in the group discussions we finally had thirteen different groups. [18]

The products and services for personal navigation were presented to the user groups in pictured scenarios (Figure 2). Every group evaluated 3-5 scenarios, which presented different perspectives of the products and services for personal navigation. The use of scenarios was intended to help people to understand the idea of personal navigation and then to elicit the ideas, attitudes, opinions and needs of different user groups with regard to navigation services and products. [18]

The purpose of these evaluations was to chart how much the user groups currently know about navigation services and devices and what kind of experiences they have had of navigation in general. The second goal was to study how credible and useful potential customers considered the scenarios. Third purpose was to identify needs of the user groups for navigation services and let the participators innovate new navigation services. The evaluations were carried out as group discussions. Beside the group discussions there have been interviews with experts of elderly care and rescue services to complement the information of some special groups. The scenario evaluations and interviews focused on consumer focused personal navigation. [18]

The user groups that we interviewed assumed that the first users for PNS (Personal Navigation Systems) would be found among different professionals and among the people that need extra guidance (including professionals caring for these people). Special interest groups like yachters and hunters already use GPS and VHF navigation devices. These kinds of groups will probably be among the early adopters

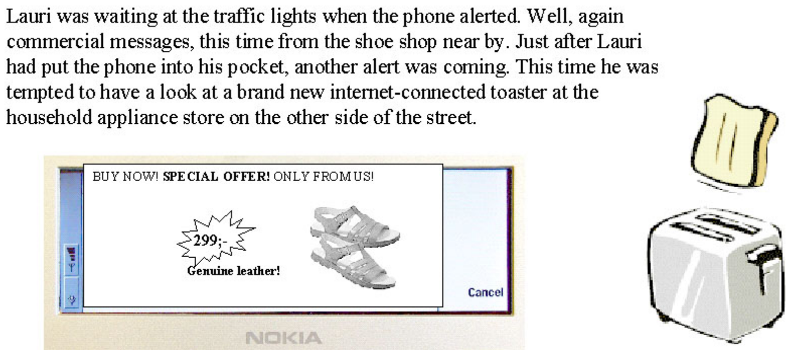

Fig. 2. Example page of the Junk Mail scenario

of the new services and products if they detect those as practical solutions for their use. In the interviews, young people were also generally mentioned as the first users of PNS even though some of the youngsters themselves did not see themselves as going on forefront in using PNS. Route guidance in unfamiliar places was generally seen extremely practical. Wilderness, hobbies related to nature, and cities were mentioned in all the user groups as places where the PNS could be usable. Commercial services and ads based on location were seen amazingly acceptable in the groups. People who did not want ads today did not want them either in future with another media. Most of the people considered location based ads useful since one could precisely define what kind of bargains one wants to receive and one could make exact search entries for needed items. Indoor navigation was seen rather useless for an ordinary user. In special situations and for special groups it was however mentioned as a practical application. Alongside with privacy the issues of safety and control were discussed widely in the interviews. Criticism towards new technology was brought up in many groups. Predestined and over-controlled environment was seen dubious. Participants in the user groups mainly wanted solutions to ease their life in some functions but they did not want their life to become totally controlled by the demand of super-efficiency. Fear of radical changes in human interaction, usability of systems and narrow use of new services and products were commented generally in the groups. [18]

Later on in Ken project the concept study of personal navigation in work contexts was carried out between May and August 2002 with Benefon ltd. The objective of the study was to find out how different kinds of occupational groups could take advantage of the information technology and communication system that is based on personal navigation. In addition, the objective was to verify the upcoming product concept of Benefon and make sure that it would be appropriate for the planned purpose of use. During the work on the Benefon case, multidisciplinary group of researchers from Benefon and VTT Information Technology carried out two rounds of interviews. The researchers from Benefon interviewed representatives of different occupational groups in the US, the UK Sweden and Norway, whilst the researchers from VTT interviewed a number of representatives in Finland. There were 23 interviews in all (14 interviews were conducted abroad and 9 in Finland). Two of the Finnish interviews were pilot interviews. Each interview was divided into three sections:

Design of the Mobile Device, Usage Scenarios and The Feature Assembly method. There were two kinds of interviewees in the Benefon case: decision-makers at the selected target group companies and potential end users. The Design section was a structured interview, the Feature Assembly method was a game including interview and the Usage Scenario section was conducted as a thematic interview by using six different usage scenarios as a guide to visualising the context of use, functionality of the device and user's interaction with the system (Figure 3). [6]

In general the interviewees liked the scenarios presented to them. Using annotated cartoon panels was quite a useful and informative way to present the stories to the interviewees because we had to deal with difficult technical terms and functions during the interviews. In particular, the flow chart proved to be a very useful part in the scenarios because it helped to went through the one whole working day with problem scenarios and suggested solutions. According to the results of our study in the Benefon case, it seems that the end users and decision-makers of different occupational groups were quite interested in positioning devices as well as exploiting geographic information in their workplaces or working environment. However, the interviewees thought that the device should be quite simple, easy to use and easy to tailor to the needs of the company/organisation in question. Some of the users pointed out that it is important to them to know when they are being located and how accurate the positioning is. The set-up and controlling of the device should be able to be done remotely so that the end user does not have to do everything by her/himself. Many decision makers who were interviewed considered that the possibility to use new positioning technology could make the allocation of resources easier and more effective, which would also reduce costs. Of course, the price of the device should be reasonable so that the investment is profitable. [6]

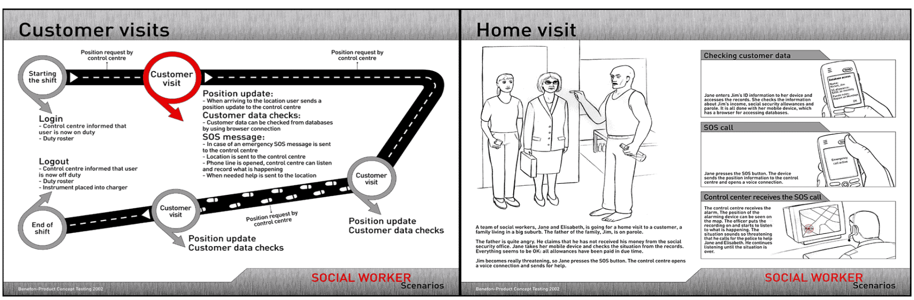

Fig. 3. Flow cart of the scenario and one page of the social worker scenario

2.3 Käykse

The goal of Käykse project has been to recognise the problems in designing and evaluating intelligent environments, and evolve the research frame. The intention was to increase the dialogue between technology developers, system designers and users. The project aimed to develop design methods that help in adjusting user needs and technical possibilities to each other. We have sought to understand user experience of tomorrow's services and products as early as possible, and to create an innovative, inspiring, pleasurable and entertaining user experience and concept definition session to all stakeholders.[19]

We developed interactive scenario -method to increase the participation of the potential users in the early stages of the concept design process. We sought flexible methods, so that they can be utilized in various projects dealing with ubiquitous computing. We started with role-playing methods and found it very useful and rather light to take in to use. However, we wanted to evolve methods which involve physical participation. Improvised acting and scenario playing contain many of the elements we sought, so we decided to base our methods on them. [7, 19]

In testing the method we concentrated on case smart home, because at that moment there was a project going on that needed new ideas for designing a smart home concept. We found it is essential to know the theme of the development. The aim of the testing was to develop the methods further, find new ideas, discover the methodological problems and try to solve the found problems. According to observation, findings and feedback the upcoming sessions were prepared and the method was developed further. [19]

We staged three improvisation sessions, each with different participating groups. The first session consisted of experienced improvisation actors and our research team. Our aim was to test the method and improve it based on our results. Potential users attended the second session in the audience, influencing the acting, and in the last session the improvisation actors were left out and the users were encouraged to act out scenes with the research team. In order to gain results of first-time experiences, we had different actors and users present in each session. [19]

2.4 Nomadic Media and Mimosa

In Nomadic Media project [16] we aimed to develop innovative solutions that will allow consumers to use the devices that best suit them in respective time and place. The solutions should adapt more readily to people’s personal preferences and needs, be enjoyable to use, and provide low-entry thresholds for all sections of society. In MIMOSA project [15] the main focus was the development of novel low-power microsystems to create the MIMOSA technology platform. MIMOSA achieves this by developing a personal mobile-device centric open technology platform to ambient intelligence. Microsystem technology is the key enabling technology for realising the MIMOSA platform due to its low-cost, low power consumption, and small size. The design approach of both projects was strongly human-centred.

In both projects scenarios were used as descriptions of usage situations in selected application areas, and they also described the common vision of the project: (1) What could different technologies provide to the end user and (2) how will the technology look and feel in different everyday situations. Scenarios were also used as a design instrument in the human-centred design (HCD) process of Nomadic Media and MIMOSA technology and applications. The initial scenarios were produced with the contribution of all partners, both technology and application developers. Second, the scenario ideas were analysed and refined and new scenarios created. These scenarios were later analysed to identify usage and application requirements, which lead to some refinements in the scenarios.The scenarios were updated throughout the projects, based on technology development and continuous user feedback. [10]

The main method of the early context requirement phase was scenario evaluations with application developers and end users. The scenario material including texts and visualizations (Fig. 4) was delivered to the focus group participants beforehand. One group included normally from 2 to 8 participants and two to three evaluators. The acceptance of the concepts described in the scenarios was evaluated and the users could present new ideas for improving the concepts or even invent new ones. The multiple-choice questionnaire was used to collect accurate and non-interpretative data in order to compare the evaluations carried out in different sessions. [10]

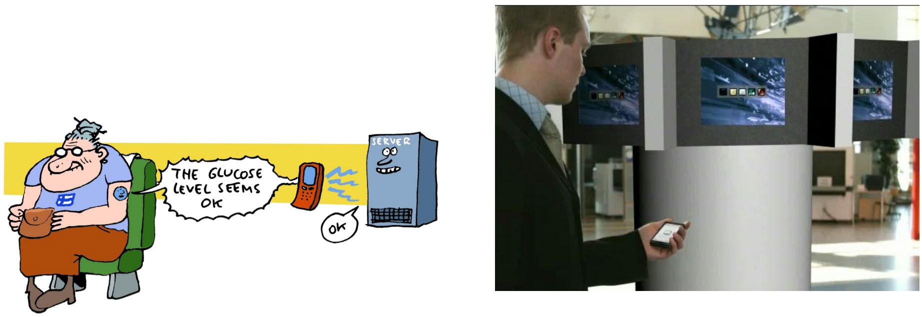

Fig. 4. Example scenario visualisations of Mimosa (left) and Nomadic Media (right)

3 User Involvement and Innovations

In mmHACS scenarios presented well defined service and technology concepts and potential users evaluated these scenarios. Scenarios were realistic and users could empathise well to the situations and characters presented in the scenarios. The user study of mmHACS was used as a tool to identify the needs of the users. It would have been good if more concrete and functional prototypes could have been used in the concept study to communicate and demonstrate the service concepts as the concepts had to be evaluated on the basis of the picture created by the researchers. Nevertheless, with the help of the example stories the elderly probably received the picture of the service concepts that was in the minds of the researchers. However, the elderly were often left with the understanding that the service is applicable only in the situation described in the story. To correct this misunderstanding, it was explained that the services were applicable in many situations. We believe the concept study gave most of the participants the intended picture of the service concepts. [14]

In Ken projects professional service part main result was that the three-stage method of the product concept interview seemed to be working well also in international studies (anyway in US, the UK Finland, Sweden and Norway). Evaluators (potential users and decision-makers) gave positive feedback of the interview and especially the Feature Assembly was commented by some users outside of Finland very competent way to collect user requirements for the concept. Researchers of the study were also happy with the developed methodology. The three-stage method made the concept study more understandable for the users and the interaction between researchers and interviewees was well organised but also flexible when needed. Visualisation of the design, scenarios and the features helped communication between different nationalities in interview situation. Also the Feature Assembly played as a game made prioritising the features easier and more like a fun thing to be done. [6]

In mmHACS, KEN, Mimosa and Nomadic Media user involvement was mainly enabled by using scenarios as a design tool. Based on these experiences scenarios enhance the user involvement into the concept evaluation sessions. If the design concepts are well defined then the scenarios help potential users to evaluate concepts and subsequently evaluation results help developers and designers make their decisions for the further development of technologies, concepts and designs.

In projects like KEN, Käykse, Mimosa and Nomadic Media scenarios enable people to think devices, services and functions that were not experienced yet in real life. However, the stories presented in the scenarios were such that they could happen in real life to real persons. This is why people could identify themselves or probably other people in their community with the persons presented in the scenarios.

Our aim in scenario evaluations is not to present only so called neutral stories because our assumption is that critical scenarios could bring up some (e.g. ethical) questions related to personal navigation, which otherwise could be left out of the discussion. In scenario evaluation sessions the critical aspects presented in the scenarios actually makes it easier to bring up suspicions, e.g., questions about the rights of the authorities to locate persons. However, the critical scenarios were not only commented as undesirable concepts but in many cases the users are also innovating improvements to the scenarios. Illustrating the scenarios with pictures is a good method to clarify the concepts presented in the scenarios and to lighten up the stories to be easier to go through. Terminology of new technologies and services were in many evaluation sessions commented odd. Scenarios of course clarify the meaning of the concepts but still one has to be careful when launching new services and device – is it better to use existing and familiar terms or to create a brand new terminology?

The Interactive scenario method developed in Käykse project works at its best in the ideation phase when designing large complex entities, e.g. ubiquitous computing environments. The technical features cannot be gone through in detail using this technique. Improvisation is good in testing ideas, specifying existing scenarios and designing concepts. The method works also when illustrating ideas, concepts or usage situations for e.g. end users. Services, especially everyday life systems related to spaces, operating sequences and stages that differ from each other, can be designed by means of improvisation. In addition, improvising occupational services can be useful with professional users.

4 Conclusions

Scenario-Based Design fits well to all kind of projects. Scenarios have been used in Human Centred Design of computing applications and they seem to be especially useful and popular when designing smart environments and inventing new possibilities to utilise new technologies in our living environments. Complicated technological systems can be laid aside when using scenarios to describe the future possibilities from the user's perspective. Product development process is a cycle where scenarios in general can be utilised in many ways. The strong user involvement already in the early concept definition phase shifts the user-centred design and innovation processes over the manufacturer-centric and technology-driven development and innovation that have been the ruling agenda for ages [20]. One of the outcomes of this process would be the opportunity to integrate the designer and the user again and give back to the user control over his computerised environment. If these kinds of user-innovation enabling (e.g. easily customised and personalised computing applications) tools and environments will come more common in the future I guess that then we are approaching the era of calmer computing.

Acknowledgments. The projects presented in this paper have employed numerous persons and the work has been mainly team work. So though I am the sole author and the only one who takes responsibility of this text I owe a big thanks to all the colleagues whom with I have been working in these projects. Furthermore I would like to present my gratefulness of the valuable participation to all the persons who have been involved in our projects as potential users of planned solutions. We have tried our best to make research situations comfortable and even fun experiences for you (and for us too).

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Customer-Centered Product and Brand Experience Design in China – What HP Is Learning

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Abstract. With the fast economic development in emerging markets, Hewlett-Packard (HP) has to focus on satisfying the needs of customer in these markets. However, due to cross-cultural differences, HP can not automatically assume that products designed in the USA can satisfy customers in those markets. For this reason, HP wants to set up UCD teams to help design products for those markets. Setting up a UCD team in China is the first step of this plan. In this article, through a case study, we want to share what we have gained in past work, what lessons we have learned in practice, and what our next steps will be.

1 Introduction

The Hewlett-Packard (HP) Company categorizes its world-wide markets in a variety of ways, one of which is whether the market in a particular region or country is viewed as mature or emerging. Country or regional markets like those of the United States or Western European countries are considered to be mature, meaning that other than taking market share from a competitor, the opportunities for market growth are more limited. On the other hand, markets in countries like Brazil, Russia, India, and China are considered to be emerging, meaning that there has been more limited adoption of technology or the opportunities for adoption are still quite large so the potential for growth in those markets is much greater. The U.S. share of total HP revenues is already less than 50%, and the non-US and emerging markets portion of revenues can only be expected to grow and contribute an increasingly important share of total company revenues. For those reasons, it is just "good business" for HP to be very interested in focusing on satisfying the needs of customers in these emerging markets.

At HP, the community of customer-centered design practitioners has adopted a classic model of the Customer-Centered Design process as represented in this graphic:

The community uses this process model to tell the story of what customer-centered design practitioners do, what value we add, and how we do that work and make those contributions. This model is used among our community so that we can better understand and share each other's work and the learnings and best practices that can be derived from that work. We feel this process model can be applied at various levels of experience design, including design of the individual offering, design of the

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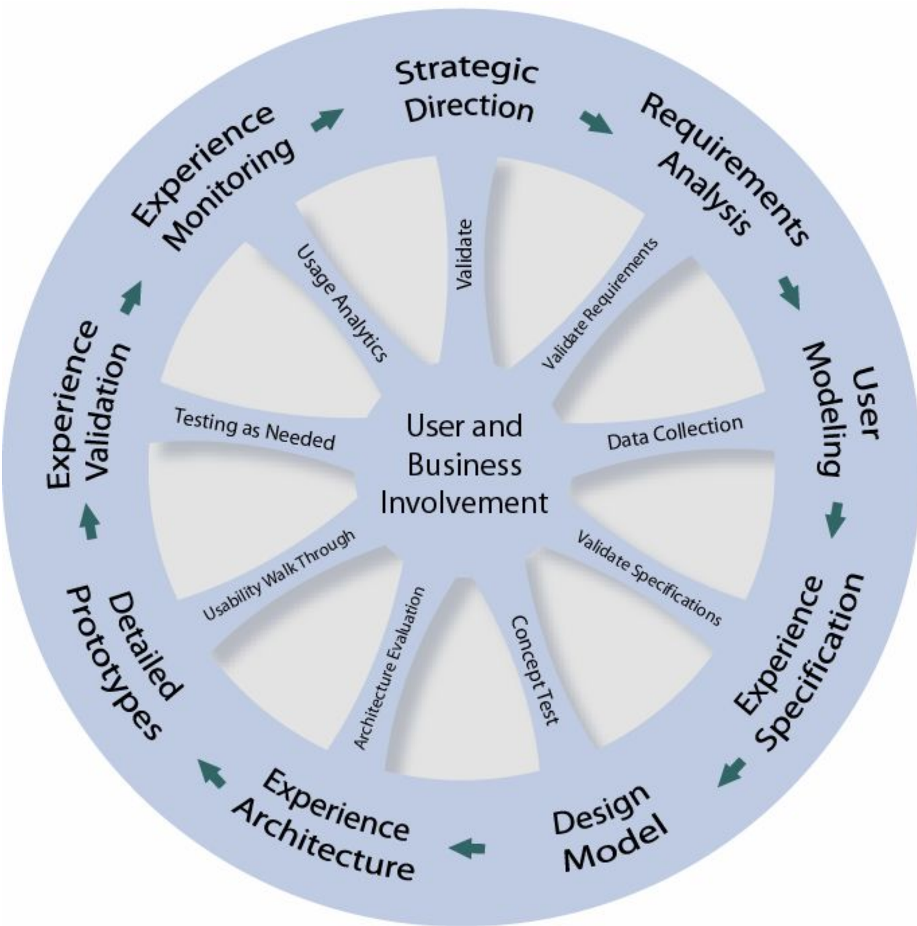

total customer relationship with the offering, and ultimately design of the total brand experience. We also use this model to clarify our role and responsibilities to our many peer functions in the development process, for example: 1) industrial design, 2) R&D, 3) marketing, 4) support, 5) quality, etc. As a community we have been gratified by the acceptance that this process model has received from these functions and the role it has played in helping others better understand the role we play in design. In essence these functions share the same basic view of what constitutes customer-centered design. What distinguishes our community is not the process itself, but the methods and deliverables we provide.

Because of the success and adoption of this model, it is perhaps natural for the community to expect that this model has validity not just for customer-centered design and development efforts occurring in the United States, but also for customer-centered design being done anywhere in the world. But this is an assumption, and it is always dangerous to assume and not verify.

Rau (2005) gave some samples in his book which show how cultural conflict may occur in China if certain symbols of Chinese culture are used in a certain way. For example, a Nike TV advertisement showing an NBA star battling a kungfu Master and dragons has provoked great controversy in China (Xinhuanet 2004a). So, too, did a Nippon Paint advertisement that showed a freshly-painted pillar with a twisting dragon coiled at the pillar's base because the dragon was unable to keep its grip on the smooth and silky Nippon Paint (Xinhuanet 2004b). A Toyota magazine advertisement depicted a stone lion saluting one of Toyota's new Prado SUVs. Toyota translates the word Prado as Badao (domineering) in Chinese (Xinhuanet 2004c). Finally, a McDonald's advertisement that showed a customer kneeling down to beg for a discount also invokes great controversy in China (Xinhuanet 2005).

To avoid design missteps due to misunderstanding or ignorance of language, culture, or regional customer needs, HP has established a customer-centered design team in the Asia-Pacific region. This team will help HP better understand where design practices and methods can be considered to be "the same everywhere" and where they cannot. Likewise we need to know when we can make generally applicable assumptions about customers and their needs, and when we need to modify conclusions and recommendations based on the special needs of a particular region or market.

What follows is a case study of a usability test that marks one of our initial steps in learning how to design effectively for the Asian market.

2 Case Study: A Usability Test

A usability test was conducted to evaluate the design decisions implemented for the Chinese version of the Business Support Destination (BSD) web site. This BSD web site provided business users and business support professionals with all the necessary resources to maintain and update their HP business systems including printers, handhelds, workstations, laptops, digital cameras, etc. The general objectives of this usability test were to evaluate the overall user experience with the Chinese website.

Eighteen representative users were sampled from two populations (10 business end users and 8 business support professionals). Two vendors were selected to recruit the participants and be responsible for the logistics, such as signing a Non-Disclosure Agreement, incentive payment, following-up and contacting the participants, etc. Human Factors Engineers from HP-Shanghai were responsible for test moderation, data analysis and report writing.

Those participants were asked to complete twelve tasks dealing with a variety of support-related issues. Six tasks were completed in the English version of the BSD website, and the remaining six were completed in the Chinese version of that website. In this way, we can compare the findings from both websites. The initial website version (Chinese or English) to which participants were exposed was counterbalanced while the order of the six tasks in each language was randomized to overcome the learning effects.

A portable usability lab which included two HP NC6220 laptops and Morae software was used to conduct the tests. The location of the tests was in the Bund Center of Downtown Shanghai. Performance and preference measures used in this test examined time on task, number of user errors, usability ratings, and participant comments.

The testing yielded some important findings for website experience design. Participants' preference was to use the local-language website but task success rates were often lower and time on task greater with the Chinese site than with the English version. There were several reasons for this. The predominant user strategy for finding support information was to first find the product and then locate the support information associated with that product. Neither the English nor the Chinese website supported this user strategy in the most optimal way when the task was begun from the hp.com homepage. In both versions, users needed to first correctly identify the product category to which their product belongs before being able to locate the specific product. Participants who found correct product category identification a hurdle to finding their product's support information then changed strategy and used the website's search function, which generally did lead them to product information including support-related content. Some inconsistencies in look/feel, behavior, and even content between the English and Chinese websites also contributed to a task performance and success advantage for the English site. Once product support information was located, the results were very positive regarding the Business Support Destination (BSD) website. There, participants did encounter some usability issues of medium and minor severity that, when addressed, should enhance the user experience for the BSD website.

In addition to the usability issues found in the test, we learned that, in China as in the United States, participants' subjective ratings do not always reflect observed task performance and experience data. For example, in spite of obvious difficulties during task performance, some users stated upon completion of the tasks that they liked the experience of using the website. They also provided many reasons to support their point of view. Yet by examining the video of the test sessions, one could clearly identify the differences between how users described their performance and experience during a post-test interview and what they actually did and experienced during task performance.

And as we have learned in the United States and elsewhere, we found that, compared with a traditional HCI research lab, a portable lab can be more convenient, cost effective, and efficient. In this test, we only used two laptops and connected via the internet. We used Morae to record and mark the video during the test. This enabled those designers who could not join the test in person to observe the test session remotely via internet. We took the lab to the Bund Center in downtown Shanghai, which was more convenient for the participant and which was effective in reducing the number of no-show participants.

3 What's Next

This case study is obviously about a single method and is representative of only the validation and monitoring phases of the Customer-Centered Design process model. Much work and exploration remains to be done in the year ahead and beyond. We will be seeking to tailor our evaluation methods to improve data collection – for example by discovering ways in which we can collect subjective data that better reflects task performance data. In addition, we plan to focus on more phases of that model, in particular the collection of primary user, task, environment, and experience data and the translation of that data into actionable design directions and requirements that will, we believe, result in experiences that can become brand differentiators for our company's products, services, and solutions. And with the Shanghai team successfully established, we are now looking at repeating this experiment in other emerging markets and thereby helping facilitate global Customer-Centered Design.

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A Study of Motivated Interface Based on Human Centered Design

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Abstract. This paper is intended to observe what factors would be most effective for motivating the use of a new function. We named the factors that motivate the use of such function "Kickers". We took up GUI of a music player, and clarified the evaluation structure, in which users might want to start using, by using the Evaluation Grid. We also had the developers make evaluation, and compared the results with those of users. As a result, it was made clear that the early step of using the function is motivated by the operation of an emotional factor of becoming <interested> in the function and of a factor concerning easiness to <understand> it. This result was verified by conducting a quantitative questionnaire survey.

Keywords: Motivation, Kicker, Evaluation Grid, Animation.

1 Introduction

1.1 Purpose

The digitization and networking of electric appliances have proceeded remarkably. When it comes to digital appliances, even the function which is cited as one of the highest users' buying motives is not utilized enough in their daily lives. We wish that the new functions of digital appliances will be used by a variety of people including the elderly and those who are not good at using a machine. For that purpose, it is not enough to remove barriers alone. In addition, it is important to develop such products and user interfaces as would induce users to "want to use" [1].

In our studies made so far, we assumed that there must be some factors for motivating the user to use a new function, which we named "Kickers" [3].

The purpose of this paper is to identify effective Kickers by analysing the users' evaluation on the GUI of a new function. We also have developers evaluate the GUI of a new function. We wish to be of service in developing more user-centered products by knowing the difference in points evaluated by users and developers.

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1.2 Viewpoints of Study

The act of using a certain function can be largely divided into 2 steps - initial use and continual use thereafter. Initial use refers to the process where a user gets inclined to start using the function for the first time and until the time when the user actually starts using it. Continual use refers to the process where the user continues using the function and until the time when the user stops using it.

We gave thought to the process of motivating such initial use by further dividing into 3 steps - becoming <interested>, <understand>, and <go ahead>. To start using a certain function, it is necessary for the users to become <interested> in and <understand> it by having multiple Kickers interacted with each other. However, that alone may not always lead to actual use; there are cases where another step of <go ahead> is needed.

Kickers refer to what are summarized in the higher conceptions from specific examples of having caused those mental transitions. By enhancing the level of abstractness, we assume that we can also apply the Kickers to other products and interfaces. We show here the Kickers that have been obtained so far from the study of digital TV users (Fig. 1).

This paper specifically focuses on the steps of becoming <interested> and <understand> among those processes.

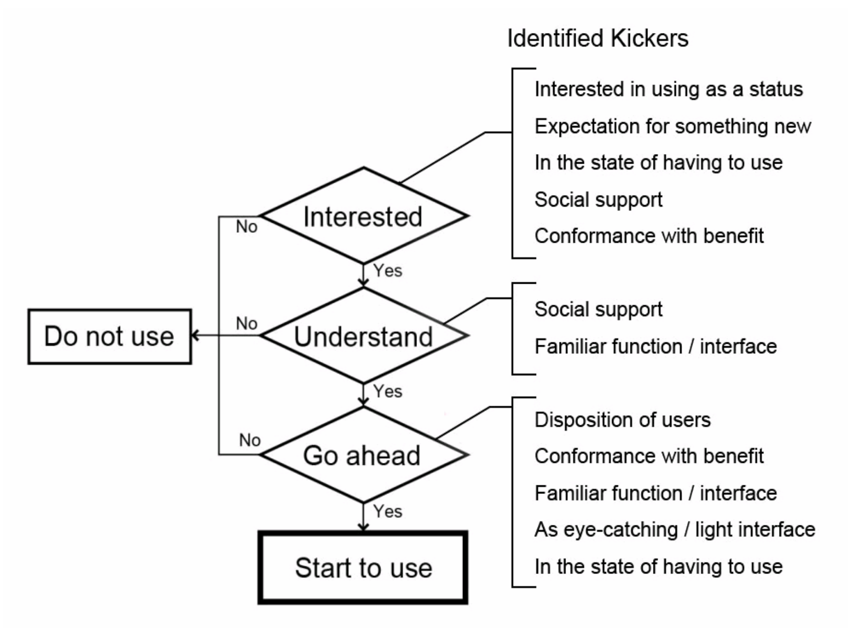

Fig. 1. Motivated process and identified Kickers

2 Survey 1 (Evaluation Grid)

2.1 Procedure of Survey

We took up the function of music player for mobile phone as an object function. The music player refers to the function that can save music in the memory of mobile phones through a PC or over the Internet and replay it.

To eliminate the preference factor of the brand name or appearance design, we prepared and presented only moving images with sound on the GUI screen for 5 different models. We assumed that this would provide the user with the same level of experience as touching a working sample of product in the store.

Those interviewees in this survey were 5 university students who are close to our target users in age and 7 designers engaged in the development of GUI.

In order to systematically clarify the factors motivating the use, we employed the Evaluation Grid. The Evaluation Grid is an interviewing method that has attracted attention in recent years. It clarifies the recognition structure regarding what users will pay their attention to and, as a result, how they will evaluate. And, this can be summarized in a tree-shaped schematic diagram of "objective, specific understanding (lower conception) => sensory understanding (evaluation item) => abstract value judgment (higher conception)" [2].

First, we presented 2 different GUI moving images each on the PC screen and asked a question, "Which one would you like to use?" And then, we asked another question, "Why would you like to use A more than B?", to extract evaluation items. Then, we raised another question about the evaluation item, "What sort of merits do you think it will provide you with?" to find out the higher conception. And we also asked a question, "Specifically, what do you think should be done to realize it?" to find out the lower conception. We repeated these questions 10 times, one for each combination of A, B, C, D, and E. We summarized the evaluation structure of those interviewees in the survey in a schematic diagram. We coordinated the students' and designers' schematic diagrams separately to make comparison between the 2 groups.

2.2 Results and Discussions

If there were any evaluation items similar or affinitive to each other, we took off one of them and unified them into one by using the KJ-Method, and summarized them into 8 evaluation items. Next, we classified the weight of each evaluation item. For this purpose, we call the number of evaluators who evaluated each item "the number of evaluation", and the proportion of the number of evaluators occupied in the total number of evaluators "the level of evaluation" (Fig. 2).

What have caused the students to be inclined to use were emotional items. The number one item was "The animation is amusing, matching well with music", and the second one was "It's a smart, nice design". These 2 items accounted for more than 60% of the level of evaluation. Cited as these higher conceptions were - "I can enjoy music better", "I 'm glad to have found something new", "It makes me want to show it to other people", etc.

What the students evaluated next were the items related to understandability - “It’s easy to see the song title and the name of the singer”, “It’s easy to operate and the buttons are easy to identify", "The screen is simple in a good way", etc. As a higher conception for these items, "It doesn't take much time" was often cited.

In comparison with the results of the designers' responses, there was little difference from the evaluation items that were obtained from the students. However, the designers showed a tendency of highly evaluating the items relating to the level of easiness in understanding. What the designers highly evaluated the most was "It's a smart, nice design", and the number two item was "It's easy to operate and the buttons are easy to identify". Also, they evaluated "A lot of information is displayed" and "The animation is rather modest", which the students did not evaluate at all.

Let's examine the reasons for the difference. The students make judgment based on their first impression at a glance. This represents that the step of becoming <interested> in the process motivating the use is the main element. On the other hand, the designers are well versed in the GUI. It seems that the designers take into account the items necessary for not only becoming <interested>, but also the next step of <understand>. It is also presumable that they, in the position of developers, try to incorporate the requirements of the organization all over.

Now we wonder if the items evaluated by the designers such as "A lot of information is displayed" and "The animation is rather modest" will not be the evaluation items that make people want to use. It remains questionable if we come to a conclusion from the consequence of the responses only because the sampling number of students was limited.

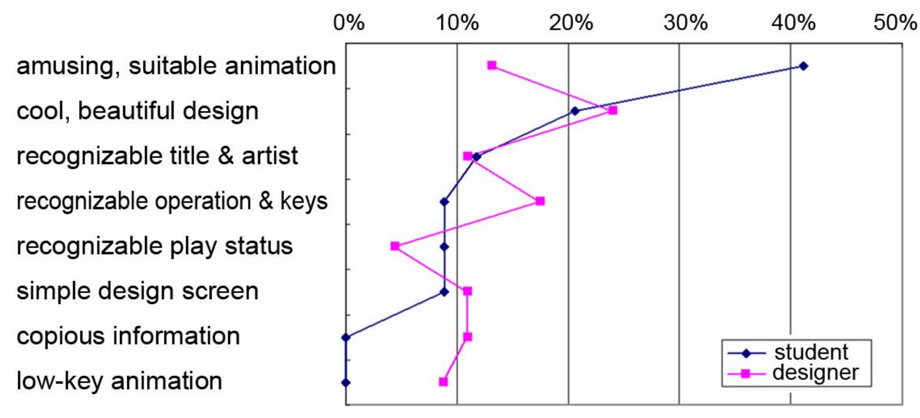

Fig. 2. The level of evaluation

3 Survey 2 (Web Questionnaire)

3.1 Procedure of Survey

In order to verify the evaluation items that were clarified in Survey 1, we conducted a quantitative Web questionnaire survey. The purpose of this survey was to find out which items have significant influence on motivating the use.

We had the company's employees in their 20's and 30's, who are close to our assumed users, participate in the survey. The sample number excluding invalid answers was 56 in 20's plus 145 in 30's, totaling 201.

The objects were same as Survey 1. They were 4 kinds of GUI moving images of the music player - A, B, C, and D. As the number of questions was limited due to the questionnaire system, we omitted E, which showed the least popularity in Survey 1.

This questionnaire survey was conducted on the Intranet. We used a method of having the alternative selected and entered while replaying the moving images of GUI on another window. 10 evaluation items were set based on the evaluation items obtained from Survey 1. To begin with, we asked which items among the 10 are applicable to each GUI (with multiple answers allowed). And then, we asked the interviewees how much they want to use each GUI in 5 levels.

3.2 Results and Discussions

We carried out 3 kinds of statistical analyses of the collected survey results.

It shows the level of desire to use by GUI (Fig. 3). This is the proportion of the answerers who chose "4. I'd like to use it rather" and "5. I'd like to use it" among the 5 evaluation levels against the question if they are interested in using. D showed the highest level of desire to use and then A as the next preference.

Next, we analysed the applicable items and the level of influence on the level of desire to use by GUI with the use of the Quantification Theory 1. Among the evaluation items, we took off one of them, if similar or correlated, and figured out the level of influence (Category score) on 7 items (Fig. 4).

As a result, we can say the followings: In GUI A, influential evaluation items were "The graphic is beautiful" and "The screen is simple in a good way". In B, "The graphic is beautiful", "The animation is amusing", and "The screen is simple in a good way". In C, "The graphic is beautiful", "The screen is simple in a good way", and "Letters and markings are legible". In D, "The graphic is beautiful" and "The screen is simple in a good way".

Finally, we conducted a correlation analysis using all the data on A, B, C, and D. We analysed the correlation between each item and the level of desire to use.

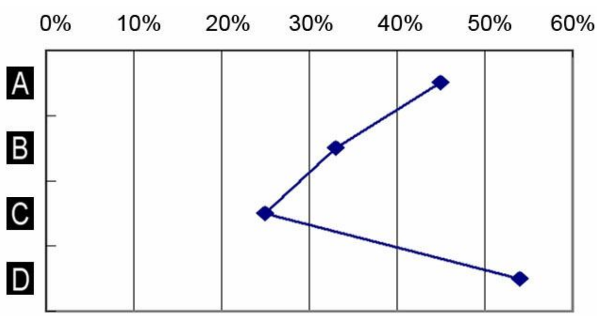

Fig. 3. The level of desire to use by GUI

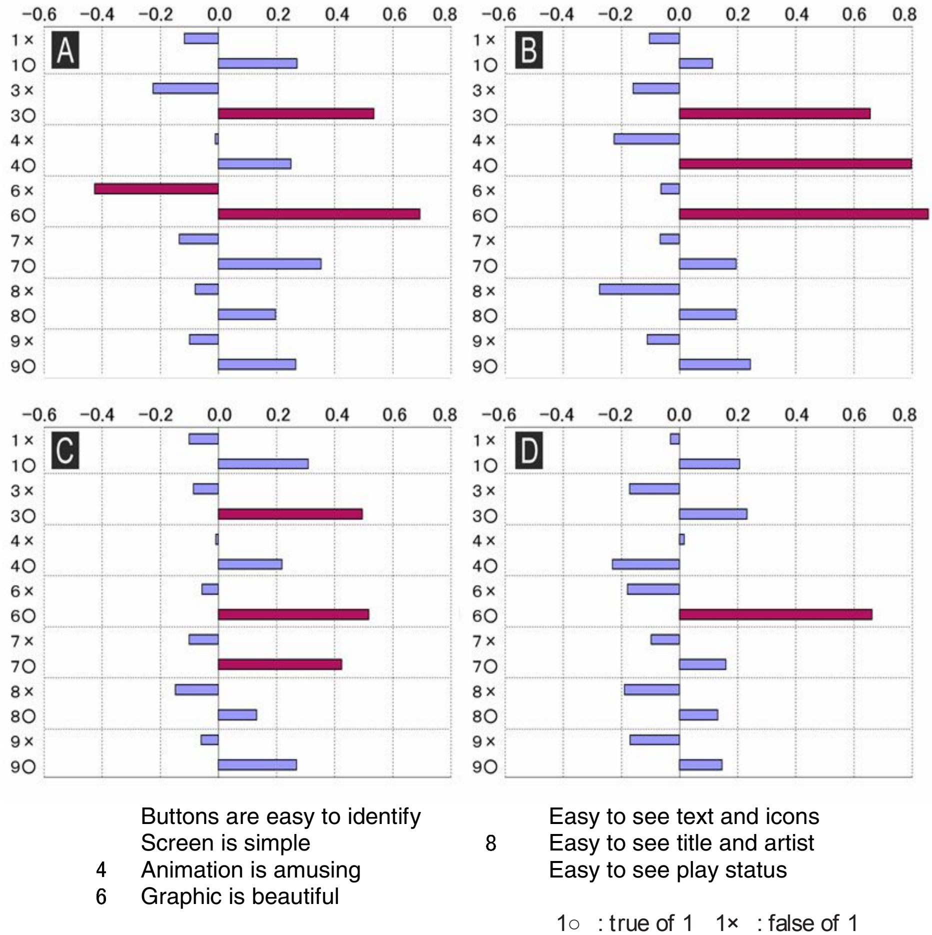

Fig. 4. The level of influence on each item

As a result, we found that there were correlations in two 2 items only (Fig. 5). Just like the results of the Quantification Theory 1, "The screen is simple in a good way" showed a high correlation. Also, as to "The animation is rather modest", it showed a negative correlation. This represents that if the animation is too modest, the level of desire to use declines.

From the above statistical analysis, we can say that the items which raise the level of desire to use are "The graphic is beautiful" and "The screen is simple in a good way". We are of the opinion that the item "The animation is amusing" does not have a significant influence as much as the results we obtained from the students in Survey 1. If "the animation is too modest," however, we assume it is clear that the level of desire to use will decline. In short, it turned out that the evaluation items, such as "A lot of information is displayed" and "The animation is rather modest", which were highly evaluated by the designers in Survey 1, are wrong when viewed from the standpoints of users.

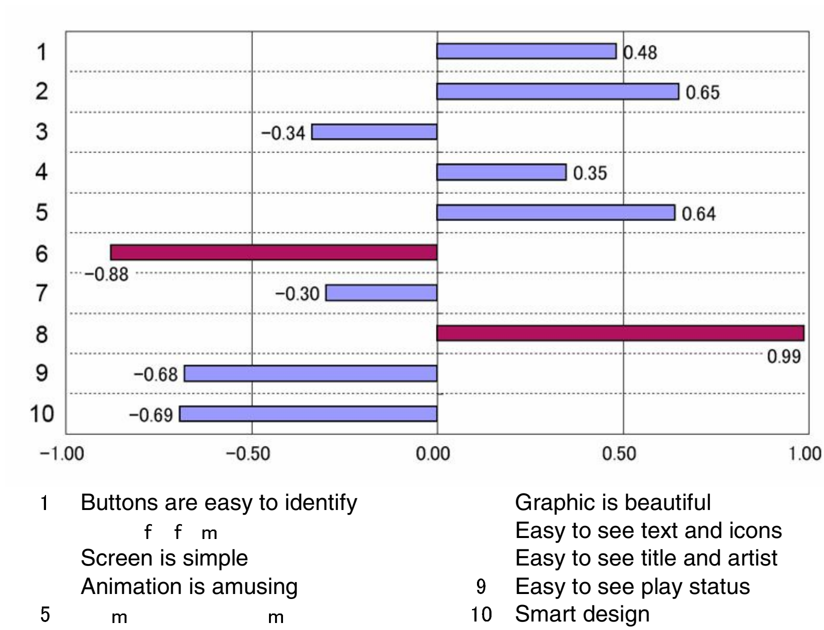

Fig. 5. The correlation between each item and level of desire to use

4 Conclusion

In conclusion, we observe the results obtained from the above-mentioned two surveys in a comprehensive manner based on the scheme of the processes motivating the use of a new function. In order to make the users to become <interested> in a new function, it is necessary to make multiple Kickers interact with each other. In order to make the Kickers, which are the higher conception, put into motion, it is necessary that specific, sensory items work with each other. Shown below are the effective Kickers and specific, sensory items which have become clear in this paper:

[Kicker (Higher conception)]		[Specific, sensory item]
Interested in using it as a status (want to show it to someone else)	<=	Smart-looking design
Expectation for something new (glad to have found a new thing)	<=	Animation being amusing
Conformance with benefit (want to enjoy music better)	<=	Animation matching well with music

Likewise, in order to have the users <understand> a new function, the following Kicker and specific, sensory item would be most effective.

Eye-catching / light interface (doesn't take much time)	<=	Screen is simple in a good way

What we took up in this paper is the GUI screens of a certain function only, and they were limited. However, we could identify common factors that motivate use across different product categories.

Also, in the comparison of evaluation points between the users and developers, it turned out that the evaluation items "A lot of information is displayed" and "The animation is rather modest", of which the developers took into account as top priorities, were not appreciated so much by the users.

As a future task, we are going to clarify the factors for determining to <go ahead> toward actual use, which were not taken up this time. In the forthcoming user interviews, therefore, we are going to focus and collect information on the factors by asking "What caused you to use the new function?" with regard to a new function of a music player.

It is necessary for us to further refine and generalize the concept of Kickers as well as the model for motivating the use of a new function. For that purpose, we wish to increase the variation of our surveys and also clarify the process of continual use.

Acknowledgments. Special thanks for the members of Soft-Design Department of SHARP Co. and Prof. Toshiki Yamaoka at Wakayama Univ.

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Children – Computer Interaction: An Inclusive Design Process for the Design of Our Future Playground

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Abstract. After observing children playing games, two design-engineering students designed a new concept for an interactive playground, the *dot°*. Its basic idea is to shift the computer screen onto the floor. In order to design optimal interfaces (hardware) and game scenarios (software) for everyone to enjoy, the *dot° team* decided to adopt an inclusive design process. This paper starts with a discussion of popularism in design, which critiques the conventional welfare designers' approach to treat 'users' as study subjects. From the design of the design workshops to the final design solution, this paper presents how a group of young design students worked with a design researcher to formulate their first user-involvement design experience in such a way that all participants in the process could engage in the inclusive experience of exchanging knowledge between designers and users. Finally, the paper documents the user-involvement process from the perspectives of different collaborators, including design students, design researcher, high school students and their school education consultant. Hence, this paper aims to advocate the relevance of designing with people rather for them.

Keywords: human-computer interfaces, inclusive design, knowledge transfer and exchange, game and urban space design.

1 Introduction

One of the main aims of the Postmodernists was to recapture the social aspects in design. They criticised the fact that modernists separated the formality and social concerns. Most modern designers and architects assign their, usually upper-middle class, values to all mankind and thereby typically design for themselves (Venturi et.al, 1977). Postmodernists questioned this modernists' practice in relation with social concerns, which they claimed started with a strong social basis. However, a lot of dominant social patterns were actually rejected by the Modernists who introduced the 'international style', claiming it was relevant for all. This leads to the philosophy of postmodernism to acknowledge users and their 'taste codes'. However, Mitchell (1997: 17-21) criticised that postmodernism, as a challenge to modernism, only takes place firmly within the academic discourse and that the fundamental canons of architectural practice are not questioned: architecture is still created as formal art objects.

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1.1 Popularism in Design

An appropriate reference to address the designer-user relationship is Alexander Tzonis and Liane Lefaivre's 1972 paper, *In the Name of the People; The Populist Movement in Architecture*, which examines the concept of populism in architecture and design (Shamiyeh, 2005:31). Tzonis and Lefaivre (1972) suggested several alternatives to the traditional 'pyramidal' decision-making process in design that emphasise a more free and pluralistic design practice to replace the ideal of 'order' and 'expertise' in architectural values. They based their thesis on the distinction between the Welfare State designers and the Populists in architecture who design with different attitudes towards 'users':

"…The Welfare State designer (such as Le Corbusier and other associate to Functionalism and the International Style), whether a planner or an architect, was an 'elite' prejudiced by his own private theories against the taste of the 'user'…

Populists saw designers as a class: a class of experts who, because of a total occupational involvement with pure design, or because of their own middle-class origins, has developed a private way of looking at the manmade environment..."

1.2 Design with But Not for People

Populism can be defined into three levels of positions (Shamiyeh, 2005:25):

1. Level 1: Architecture for people - which reflects, so to speak, either the context the vernacular forms are supposed to have been originated in, or the taste in architectural forms and the general public's sensibility with respect to them."
2. Level 2: Architecture with people - which is about "the exploration of possibilities to integrate the client or the public in the design process, and is thus one of an operative nature… the effort is made to develop concepts collaboratively with future users or residents."
3. Level 3: Anarchism - which means "architecture without architects".

This classification of popularism indicates the importance of users' creativity in design process, which can help them to create their own design. However, the most important factor is the changing roles of design experts who can respect and facilitate people's creativity. The aim of this paper is to demonstrate this implication of popularism by discussing a case study from an Inclusive Design[1] student awards programme.

2 Case Study: Designing an Interactive Playground for Our Future Selves

Over the years, the Helen Hamlyn Centre (HHC) has worked with RCA design students and help them to integrate Inclusive Design methodologies and reflect on

[1] The new British Standard BS 7000-6 (2005) defines Inclusive Design as:

"Design of mainstream products and/or services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design."

their own practice through adaptable and flexible mechanisms. One of them is the 'Design for Our Future Selves' (DFOFS) awards programme. DFOFS is a three-term programme for all Master students in their final year at the RCA. This programme is divided into three stages: Define, Develop and Delivery. In the first stage, students from different art and design disciplines can submit design proposals to address social changes. Fifty to sixty students are then short listed and invited to join the develop stage, where groups of 'critical' users, with different disabilities, ages and occupations, will challenge the design briefs and encourage the students to stretch the creative envelope in unanticipated ways. Finally, in the delivery stage, twenty-five to thirty are selected for the final challenge. They need to prove to an international panel of judges how they have transferred the user research data into creative design solutions.

2.1 Define Stage – Winner of a Design Concept Competition

Realising that physical interaction in playing is vanishing rapidly as a consequence of the increased use of digital games and computers in everyday life, two RCA Industrial Design-Engineering students decided to develop a new interactive and physical playground with children. The key idea was to 'enlarge' and 'rotate' the computer screen from the desktop onto the floor. Instead of sitting on a chair, looking at a screen and controlling the game with only fingers, the concept called *dot°* (fig. 1), aimed to introduce a new human-computer interface that would get children or any other player, to run and physically interact. In order to trigger the unlimited scope of children's imagination with the best available technology, the *dot°* team developed an interactive playground that can be unrolled like a carpet. It can be easily installed onto any outside space and uses interactive pressure sensors and lighting to illuminate game interfaces onto the surface of the playground. Different games can be uploaded and started at any time. The first result was that *Dot°* has won the Innovate to Educate Award[2] from Futurelab[3], and was supported by Cambridge Assessment and the BBC (UK).

Fig. 1. Concept diagram of *dot°* developed by Clara Gaggero and Sabine Fekete, Industrial Design-Engineering students from the Royal College of Art, London

[2] Innovate to Educate was an award run by Futurelab (in association with Cambridge Assessment), available to students doing final year degree and postgraduate (or similar) projects in multimedia, ICT or related subjects, encouraging them to work with a teacher/educator to focus their final year project on a novel digital resource to assist learning, in school or out of school.

[3] Futurelab is a UK-based not-for-profit organisation that is committed to sharing the lessons learnt from our research and development in order to inform positive change to educational policy and practice (www.futurelab.org.uk).

2.2 Develop Stage – Conducting Creative User Research Workshops

This design concept was inspired by personal childhood experience and further elaborated through interaction with children. The *dot°* team also consulted many other experts in different related fields, such as curators from the Science Museum and installation artists. After winning the award, the *dot°* team decided to develop their project further by adopting an inclusive design process. They wanted to involve future users into their design process to further develop the new playground idea for everyone. With the advice of an inclusive design researcher, the *dot°* team engaged in an inclusive design process that created a mutual benefit relationship with those who participated in the user research.

The process started with a school visit (fig.2). Originally, the team wanted to work with a group of eight to ten year old children but without any experience of working children, the inclusive design researcher advised and helped the *dot°* team to set up collaboration with the Villiers High School. An education project manager and five high school students (fifteen to sixteen years old) got involved. Three of these students became team assistants to facilitate the design workshops with the primary school children, and the other two were appointed as the reporters of the process. They filmed the workshops and interviews with the participants, and edited a short film that documents the process.

Fig. 2. The *Dot°* team presented their projects and ideas of the workshops to all the collaborators: education project manager (the first one) and high school students (three girls sitting on the right of the photo) from Villiers School, West London

The first workshop was called the Preference Workshop, in which the team observed children play with some conceptual games in order to find out what the children would wish for their future playground. A class (25 children) of seven to eight years old was invited to draw their dream playground and to explain their ideas afterwards. They were then divided into three groups and participated in three different games (fig. 3) that represented different elements of the game design the team had in mind. Game 1a was about finding how children play in teams. They were given the task to follow paper dots that their classmates were distributing. The other two games (1b and 1c) used different patterns of predictability, i.e. one randomly moved the dots and the other was pre-programmed. All the games were designed to observe how children interact with each other and with objects in the games. The games were all task-oriented and created a competitive situation for the children.

After an hour, all the children had tried all the three games. Three groups were shifted from one game to the other after fifteen minutes play time. The observed interactions helped the design team to evaluate the design document of their series of games (software) for their future playground (hardware).

Fig. 3. Preference Workshop. Three conceptual games represent three elements of game: team leading (1a), predictability (1b) and interactivity (1c). All games designed and produced by the *Dot*° team. Photos by Yanki Lee.

Two weeks later, three game prototypes (fig. 4) were developed with the information from the first workshop. The aim of the second workshop, the Perception Workshop, was to find how children would react to these games. The same group of children was invited to join this workshop. They were invited to interact with the prototypes and to perform several tasks with tangible interfaces. Game 2a was an extension of Game 1a, where the children were asked to follow dots made by their classmates with torches. In game 2b, called the 'Interactive Buttons', the children needed to switch buttons on or off by using any part of their bodies. They were divided into two teams to run to the 'Buttons' platform, and the winning team was the one who got more buttons on and was also quicker in turning them all off again. Game 2c was a programmed projection on the floor with some three-dimensional objects. The task given to the children was to move the objects while the projection of dots were on them. All these new games and prototype helped the design team to understand how children interact with the hardware and software.

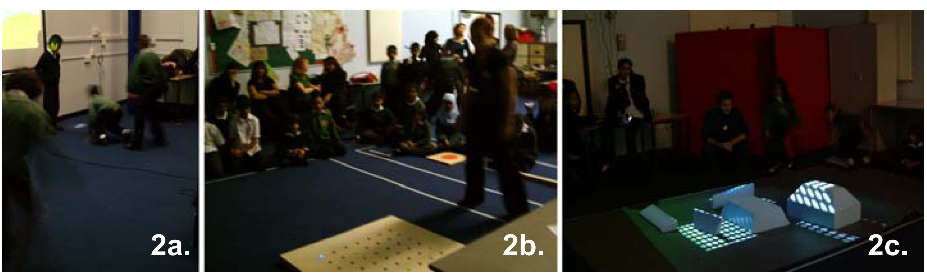

Fig. 4. Perception Workshop. Three physical games represent three elements of game: team leading, predictability and interactivity (from left to right). All games designed and produced by the *Dot*° team. Photos by Yanki Lee.

2.3 Delivery Stage – Developing a Creative Solution for All

The design solution of the project was shown in an exhibition with detailed proposal and feasibility study (fig. 5) of the new concept for the interactive playground. Based on the experience of working with the future users, the team described their project as a vehicle for children to interact with people and the environment. It also aims to help participants to improve themselves by stimulating and changing games. Its main application is suggested to be in urban space such as a public square or park where this interactive platform can encourage teamwork and group building.

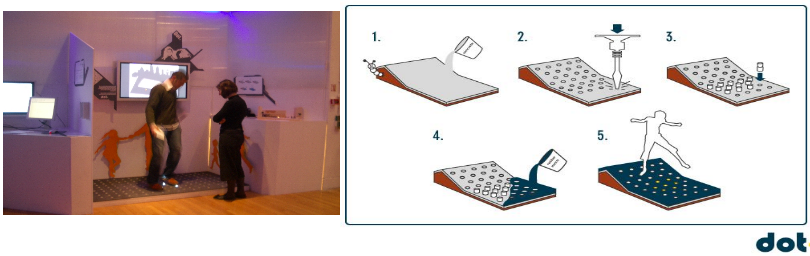

Fig. 5. (Left) The Industrial Design-Engineering department's work-in-progress show at the Royal College of Art, London, Feb 2007. (Right) Diagram to show how to install the hardware of the Interactive carpet. Photo and diagram provided by the *Dot*° team.

3 The Lessons: Participants' Perspectives

Starting from working with children, the *dot* ° becomes a thinking space for all of us to imagine, interact and play within an urban area (fig.6). During this creative process, there were three groups of participants involved:

1. User groups:
   a. A class (25) of primary school children from Blair Peach Primary School, West London;
   b. A class teacher and a few teaching assistants, who may be parents of the children;
2. Design team:
   a. Two Industrial Design-engineering students who initiated the project *dot* °;
   b. A Interaction/ game designer who was invited to join the team;
   c. Five Villiers High school students (four girls and one boy, all British Asian).
3. Facilitator team:
   a. An education project manager of Villiers High School who aimed to link external agencies and universities to aspects of the curriculum, focusing on specific cohorts of students in specific subject areas;
   b. The author, a design researcher and user research tutor who co-ordinates the 'Design For Our Future Selves' inclusive design awards at the RCA.

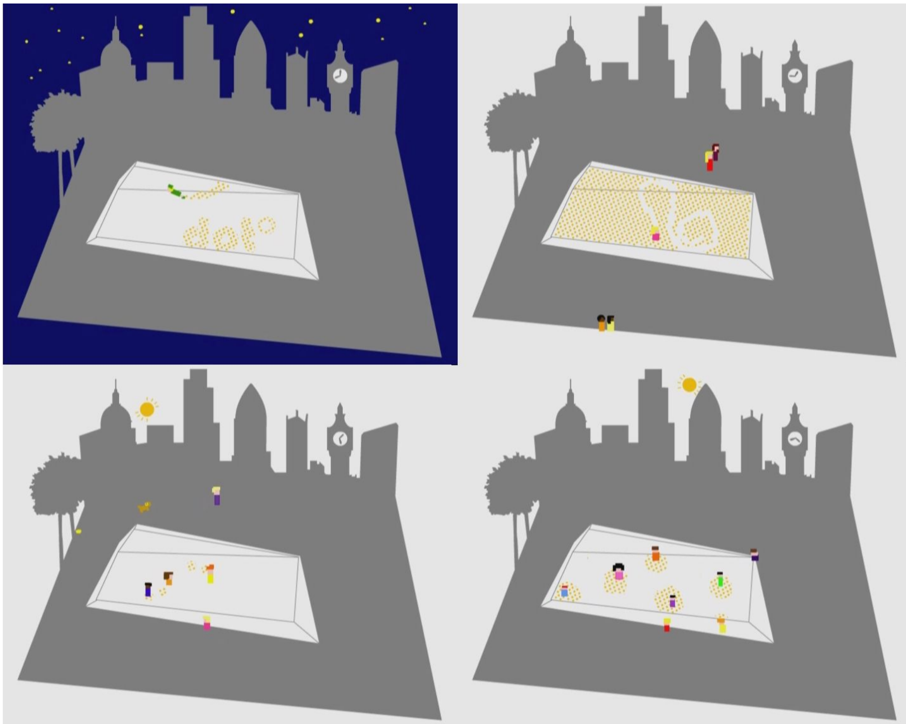

Fig. 6. The three games design of the *Dot°* project: People can 'draw' on it moving to turn the lights off. They can also follow the lights and turn them off by stepping on them. Finally, they can also create their light pattern with other people. Diagrams provided by the *Dot°* team.

Many people-centred design projects such as inclusive design and human-computer interaction design aim at improving people's lives by involving specific users in the process of creating better design for all. However, there are many possible interpretations of the appropriate methods and applications of such a 'bottom-up' approach. This paper documents the *dot°* project, which constituted a process of collaboration between different facilitators, such as the education consultant and the design researcher working intensively with children, teenagers and teachers. The main goal of this project was to contribute to the discussion on the involvement of people in design processes, by suggesting a multi-level knowledge exchange model between designers (design and research knowledge) and users (usage and everyday life knowledge).

3.1 Users' Perspectives

The first and direct knowledge exchange cycle was between designers and users. Design students designed and executed a series of design workshops for a class (app. 25 pupils) of seven to eight years-old children from a local primary school (Blair Peach Primary School, West London). The workshops aimed to demonstrate and explore the design of the future playground. They were constructed as a series of design exercises to help children to engage in and understand design language, and gradually become co-designers of their future playground. The primary school teacher and teaching assistants were around to make sure that the communication between the designers and the children went smoothly. *'Just to say thanks so much for involving us in your project. All the kids loved it! Do remember if you want to trial any further prototypes either here or at Blair Peach primary, just say', was written on* a thank note from the education manager on the behalf of both schools. This shows how welcome the collaboration with both schools was. It was an inspiring experience for them to explore an alternative teaching environment outside their normale classroom and to meet different people.

3.2 Designers' Perspectives

The design team consisted of design engineering and interaction design students. Their involvement with the children helped them to better understand the activity of playing, and inspired more user-responsiveness in both the design of the physical and the digital interfaces in their future playground design. '*The children's opinions are more important than our tutors' ones,'* said one of the design students. They expressed that the interaction with target and end users provided evidence to support their design development.

The second, indirect but long term, knowledge exchange cycle for the designers was triggered by their close collaboration with a technology high school[4]. The design students worked with five high school students, with a mix of gender and nationality, and treated them as part of their design team. Working closely with post-graduate design students enabled these local teenagers from an enclosed community to explore not only their own culture (traditional Asian culture in Southall[5] area in London), but to seek to understand the culture and design practice of others as well. The teenagers also acted as 'middlemen' to bridge the age and nationality differences between the *dot°* team and the children.

3.3 Collaborators' Perspectives

For the education manager, her work is to expose her students to the 'real world', where many of the parents from the local area will not. This realm of possibilities

[4] Secondary Schools in the UK will apply to the specialist schools and academies trust for funding to become specialist in a specific subject area. In the case of the Villiers Hign School, this is technology, which includes science, design/technology and math. The aim is to provide the best possible education within this specialist, with state of the art facilities, meeting its deadlines, developing its staff, and demonstrating improved performance and motivation in all students.

[5] Southall is the most economically and socially deprived part of the London borough of Ealing. Almost 100 % of its residents are from minority ethnic backgrounds from countries including India, Pakistan, Somalia, Afghanistan a and a number of middle eastern countries and more recently eastern Europe. There is high unemployment resulting in significant percentages of free school meals for it's socially and economically disadvantaged young people in its schools. The religious split is Hindu, Muslim, and Sikh in this order. Crime is high in the area, and aspiration low in terms of considering further or higher education.

and opportunities is important for children's development. Through the *dot°* project, a creative collaboration between tertiary and secondary education through design was demonstrated. At the same time, this project also links the high school with other local feeder schools and helps to extend the local network.

Working with RCA students is a crucial part of the practical application of Inclusive Design and provides a model of how to integrate key principles into mainstream design education. The annual student awards scheme provides chances for graduating students to explore Inclusive Design methodologies and best practices, which they can later diffuse outwards into industry. This project provided a good case study of inclusive design in a multi-disciplinary collaboration between different design fields and different levels of the education system. It also demonstrates the co-design model of user research and how this can transform design and create new design thinking.

4 Conclusions: Knowledge Exchange of Inclusive Design

'We don't need your patronising help, you designers. If you've come here to help us, you're wasting your time; we don't want to be helped, thanks just the same. Yet we do have some interesting observations to make about our daily lives, about our lifestyles, about our communication, and about all of their attendant dysfunctions. If you could kindly change your attitude and help us explore how we will live, then perhaps we can do something together.'

Thackara's (1995) quote reflects the urgency for a change of the welfare approach in people-centred design. The user-involvement process applied in this project is designed to develop the Populists' approach, by merging the Inclusive Design process with a human-computer design project. The key point is not about the terminologies or ideologies, but about the attitude; i.e. designing with people and not for them.

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Local Voice in a Global World – User-Centered Design in Support of Everyday Practices

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Abstract. The design of ICT products is at present optimized for mass manufacturing in a global scale. Yet local communities and specific users have needs that are in danger of being excluded from the benefits of new technology. We present our experience of co-designing targeted products with local stakeholders embedded in their concrete social and material context and everyday practices. Our claim is such embedded design could be achieved through combining modular global technology with local handcrafts, which contain shared cultural meanings and guaranteed affordance.

Keywords: Co-design, Participatory design, Handcrafts and ICT, Practices, Local development.

1 Introduction: A Need for Locally Meaningful Objects for Local Users

In the West, information and communication technologies (ICT) have reached most people in the form of phenomena like internet, personal computers at homes and the workplace, mobile communication and digital image, broadcasting and music solutions. The consumer electronics that enable these digital functions are sold in highly competitive markets. Thus their design is optimised for mass manufacturing with minimum cost, efficient distribution and worldwide consumer base.

Local communities or interest groups often have needs that can be quite special and specific to their community. It is impossible to make one design that is meaningful and fit for users all around the world. For instance such significant groups as small children or the ageing, or even further, the still substantial amount of illiterate people are either in danger of being excluded from benefits of new technology, or have to resort to troublesome workarounds to utilize them.[3]

This could be countered with regional, small-scale production of specialised interface products, such as communication tools, home support devices, or computer peripheral devices. Especially fruitful would be the combination of local crafts with

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the global technology, because although handcrafted objects are expensive, both the local and the visiting consumers usually hold local craft in extremely high esteem. We define craft according to Pye[18]: the craftsman is someone who is directly responsible of the quality of the outcome, depending on the skill in which they use the tools appropriate for the job. We are not proposing that all highly skilled applied arts' professionals would switch from their current interests to ICT, but this would be an alternative approach to contemporary craftsmanship. Furthermore, this workmanship is tacit knowledge, acquired through the long process of learning by making[5]. If professional craftsperson would apply their tacit knowledge in the process of ICT product design, he or she would ensure that the product is usable and aesthetically grounded to the artisan's style and heritage. Local handcrafted objects also contain shared cultural meanings and familiar connotations (perceived affordances in the terminology of design theory), which can make it easier for some users to utilise new technologies. [13] [14,15]

Vaakku is one of our design projects that illustrate the working methods proposed for the local ICT production and the creative design opportunities that follow.

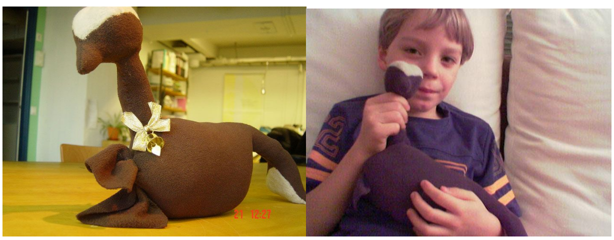

Fig. 1. Vaakku is a soft toy that sends audio messages to a pre-designated e-mail address. It was designed to enable asynchronous messaging form young children to their parents.

Vaakku is a communication device for children who are too small to be literate; it is a soft toy, enabling children to leave messages to their parents. When Vaakku's head is squeezed, it dials an answering server and children can speak out their messages. Vaakku was co-designed with and tested by 6-year-old twins, whose parents are divorced. Vaakku has enabled them to communicate with their parents any time of the day, bringing a sense of presence of both parents into the daily life. The children's messages have been articulate and consistent stories reported to their parents when appropriate in child's daily routine, not just when interrupted by a telephone. The co-design work established the family's needs, based on their lifestyle. The research and design team translated these needs into an interactive soft toy, designed to appeal to the children.[1][17]

[1] The technology is based on a modified mobile phone. Vaakku is a project at ARKI research group at University of Art and Design, Helsinki, developed in autumn 2004 by Lindblom, Oilinki and Lehtimäki. It is part of ADIK project, which researches emerging digital practices of communities (arki.uiah.fi/adik).

2 Co-design

For years researchers have been improving the design of digital interfaces by studying the way humans work with technology. Ethnography as a method originates from anthropology, while participatory design was perhaps first used in the Scandinavian labour union projects, thriving to democratically improve the workplace. [3][16] The following presentation of co-design is based on our experience from various design and research projects where we have applied and developed it. In addition to the above Vaakku project, another case is presented in chapter 5.

Co-design is an approach to participatory design, where the end-users are engaged in the design and development process. Co-design means also the collaboration of different specialists and designers (social scientists, interface designers, software designers), and other possible stakeholders such as public authorities or service providers and industrial and technology partners

The co-design approach could be utilised when designing products for the local consumption and production, as it involves all the relevant stakeholders in the product development process. Although the co-design approach is time consuming, it can improve the success rate of the end product because it removes many usability and access issues. At the same time it can utilise expert knowledge of the end users, such as the local knowledge.[22]

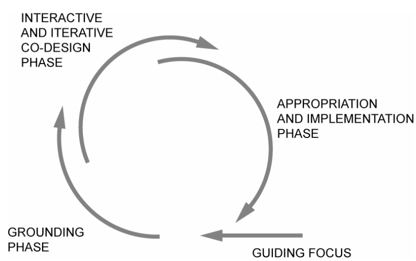

Fig. 2. The co-design can be seen to proceed through four basic stages: 1. Clear predefined focus and goal with room for flexible realisation. 2. Initial grounding in a concrete social context. 3. Iterative and interactive co-design process. 4. Implementation and appropriation by the users.

The co-design begins with contextual inquiry, followed by more in-depth ethnography to gain a thorough understanding of the chosen development themes within the concrete social context. The design work by the design and research team includes design themes, concepts and prototypes, experiments and field trials. Iterative interaction with the users and stakeholders creates a feedback loop that facilitates design team's innovative leaps that reframe or refine the design ideas, concepts, prototypes and eventual products. The iterative process consists of an ongoing process of interaction, a mutual process where themes and ideas and meanings are redefined and negotiated through concrete cases relevant to the users. [21]

Implementation is a natural final stage of a design process. In a co-design process the implementation ideally results in the appropriation of the outcome by the users and stakeholders who have participated in the process. In the final stages it is thus important to observe how the design idea or product is appropriated as part of the everyday practices of users and stakeholders in the concrete social context – to study what impact the practices have on the design and visa versa, what impact the design has on the practices. [21]

3 The Significance of Practices

The specific value of co-design is that it engages users at different stages of the design process so that the users participate also in the concept-building i.e. defining what the eventual product will be, not just testing usefulness and usability. Additionally it looks at the users as actors in their social context, not as anonymous users of a product. The design is thus grounded in the everyday practices of the users, which is a stage any application or product will have to go through in the last instance.

From the theoretical point of view, practices refer to the habitual ways of doing that give our lives continuity. Practices are also a shared activity in the sense that they are meaningful within concrete communities or reference groups, life-styles, and cultures. Practices make our lives meaningful. But practices are not rituals, repeated identically. La Cecla compares the dynamics of all human knowledge to the practice of dwelling in a place. We depart from the known to confront the unknown, returning to our proper place. In the process we gain more knowledge of the world surrounding us, making it a part of our dwelling in turn. [9] Through daily practices people appropriate their surroundings and the world, gaining knowledge and experience of it, solving problems and using innovative abilities. Repetition brings experience; the diversions innovation. Practices are thus in themselves phenomena that combine both the shared and meaningful habits, and singular or specific usage and creativity, the production by usage as defined by De Certeau [2].

Mapping people's practices is also an important method for co-design. Already since the 1980ies Lucy Suchman has pointed out that "technologies are constituted through and inseparable from the specifically situated practices of their use".[23] Through mapping people's actual practices concerning a chosen object or theme of development it is possible to understand how they are part of the user's life as a whole; going on to recognize the design potential and guidelines for design in those practices. 'Practices' is thus both the key concept for ethnographic research, and the mediating concept between research and design, enabling the designers to find innovative starting points in ethnographic data.

Practices are mapped with various probe-type methods[6], interviews and workshops,. Where the social context or the project theme is one not covered before, probe-like techniques provide insight. Where a shared understanding already exists, basic ethnographic interviews suffice to cover the necessary topics.

4 Experience with Active Seniors

An example of the kind of co-design promoting societal innovation is the collaboration with Active Seniors Association by the Arki research group in the projects Future Homes and Adik (Emerging Digital Practices of Communities), lasting approximately 5 years in all. [19]

4.1 Active Seniors

Active Seniors is an association founded in 2000 by senior citizens who want to solve problems of old age by constructing a co-operative community, that by helping each other in their senior years allows them to live at home longer. Their co-operative has commissioned an apartment building named “Loppukiri”, where each member is entitled to purchase a flat and partake in the community supporting activities such as cleaning the shared facilities and cooking for daily community dinners. The house was completed in spring 2006, and the residents have now moved in.

Active Seniors present an interesting partner firstly as their explicit goal is to change and challenge the conventional patterns of growing old in Finland. Secondly working with them means facing the challenges of developing digital technologies with ageing people. They are a very heterogeneous group in this regard, from very worried to greatly enthusiastic. The Active Seniors are also only getting older - what is designed now has to face the challenges of deteriorating eyesight, hearing, cognition, while still providing the tools for an independent living.

4.2 Co-design with Active Seniors

At the beginning stages of the collaboration we conducted many interviews of key-persons, and several probes exploring both present habits and practices, and need for design and development in the Loppukiri house and community project.

On the basis of this basic understanding we next chose a set of themes for developing co-design ideas, such as: remembering and reminding, food and food logistics, safety and security etc. The themes were explored in a series of workshops, where we mapped the Active Seniors’ current practices relevant to each theme, and explored design ideas through scenarios and discussions, and field trials of prototypes. [20]

4.3 From Safety and Security to a Community Calendar

In spring of 2005 we held a workshop on “safety and security” with Active Seniors. As background material for the workshop, the Active Seniors had written a list of safety issues in their own thematic workshop.

The workshop started off with mapping Active Seniors’ current technical and social safety issues and solutions, and their expectations of the safety solutions in their future house. When mapping their present safety related practices we discovered that even where specific devices were used – like alarms in summer cottages – their use in the final instance relied always on a social network: if the alarm went off, one would call a neighbour or a relative and ask them to check. Even more common was direct reliance on social networks in moments of need like sickness or worry. Another issue related to the practices was attention dedicated to preserving people’s privacy, not prying unnecessarily, not giving your keys to strangers but to people you trust etc. Many safety devices entail elimination of human contact and breach of privacy, while to the contrary our findings prove that their design ought to part from reliance on social networks and respecting privacy.

Being sensitive and responding to the ethnographic findings, we presented our design ideas in the same workshop. This generated excited discussion and further innovation by the Active Seniors, who gave instant feedback and detailed suggestions for each design idea, based on their own practices and projected image of their life in the house. Some design proposals were very successful, carrying the design process to a new level, implementing a new tool for community management. The outcome of the workshop was not just refining a specific safety/security product, but discovering how safety and security issues are best handled within the social context of the Active Seniors' community.

In the workshop we discussed design ideas for tools that would allow the Active Seniors' community to keep a track of its members, for their safety, but without breaching their privacy. We presented the idea that this could be united to a more general management system in the form of a community calendar, where people can announce their presence at various events such as daily meals, theatre outings or hairdresser's appointments. In the calendar each member would have to answer with a simple yes or no about his/her presence in an event. This would serve both for organizing events, and being able to check that everybody responds.

4.3 A Calendar Called Miina

Next was held a workshop 'calendar in the community' where features of the community management tool in the form of a calendar were discussed. It was decided that the tool was best implemented as digital software in order to avoid elaborate diary-keeping, or accessibility etc. problems inherent in a community calendar that would be placed at a specific location. The calendar should be persuasive by easing individuals' community tasks coordination. Through efficient information flow it should give a sense of security and independence. Furthermore, it must be suitable for the ageing residents by providing positive and easy user experience. Finally it must be scalable to the individual needs of the residents, like remote use and coordination of private engagements. Development of the tool includes thus also development of interfaces that allow use also by people who are not familiar with personal computers or have impaired vision or hearing

The Active Seniors finally gave a name to the tool: Miina. This is after a historical Finnish person Miina Sillanpää, a former maid who became a first woman Member of Parliament, a journalist and a politician; and the tool is named after her precisely because "it accomplishes so many different tasks". We see this name-giving also as an appropriation of the technology product, its adaptation in the imagery of the Active Seniors, making it more personal and easy to approach.

Another step in the appropriation of the Miina was a prioritised list of software features, written by the Active Seniors. We can see that at this stage the Active Seniors really appropriate an active part for themselves in the design process. We did not realize the feature-list in full, nor did the Active Seniors expect this, but as a functional stage in the co-design process it was a very decisive moment. With the help of the Miina's priority list, the software designers were able to start designing the basic structure of the software by writing use cases that determine the main interaction flows in the Miina calendar.

Once the Miina software was sketched into use case documents, the interface designer created graphical representations of the software functions. Co-design was a key to the design of the graphical user interface (GUI) of the Miina calendar. Multidisciplinary design workshops included the Miina designers, software developers, some representatives of the end users, and most of the time also a social scientist. Before the actual software could be demonstrated, paper prototyping was the most used tool in these sessions.[24] It enabled the Active Seniors to share all their ideas for the GUI. The multidisciplinary prototyping sessions also tested and evolved the interaction flow of the software.

In the final phase of the project, the Active Seniors had tested Miina with a small pilot group, they spontaneously produced a usability evaluation document: a list of every issue that required fixing, and the problem's severity level. In addition to this, each test person had elaborated a little why they thought this issue was a problem and gave several suggestions for fixing it. This document was another breakthrough in the development of Miina, as it showed that the end users had taken a very active role in the design process and took responsibility in the improvement of the design. The document further showed how the Active Seniors were making an effort to adapt to, and use the communication language of the software design team.

5 A Model for Local Design in a Global World of Technology

When designing for the elderly users, the fundamental starting point is the individual elderly person, who is surrounded by his/her own social context, and material world, proper to each individual and specific to each local environment, formed through his/her identity and sustaining the identity. Important elements here are trusted and familiar people, language, objects, settings, routes, practices and institutions.

Familiar objects are comforting, important for the construction of the identity, they have a place in the home, their mere appearance triggers intuitive knowledge of what to do with them. New technology products can often appear unapproachable and alien, due to their high-tech styling and streamlining. Styling that is sensitive to local cultural heritage could lead to more approachable domestic technology products, which has some of the following benefits. Firstly, if the end user is curious of their new device, they will also have interest in learning to use it and persisting in using it. Secondly, if the approachability is achieved by reinterpreting the local cultural heritage, rather than the global fashion trends, its styling will not become old fashioned as rapidly as ordinary objects. Finally, a consumer is happy to pay more for an appealing product, ensuring revenue for the local producer.

From the experience with the Active Seniors we learnt that some of the community members did not use the Miina due to their resistance towards computers. It has been shown that once a digital interactive interface is learnt, attention shifts from the tool to its uses. However, for many users it is extremely difficult to get over this learning stage, so the interface has got to be as easy as possible. Physical actions are easier to show, teach and replicate, than purely screen based software that has to be operated via keyboard and mouse.[1][8] Moreover, an inexperienced user is often afraid of 'ruining the whole machine' by pressing something wrong.[12] Thus we propose that care technologies would benefit from bespoke interface products for specific software applications and users.

When the local interest groups are heard in a product development, the application or a product can be designed to answer their needs. For example if a local community centre or a healthcare centre offers services in the local area, they should be accommodated for in the design of the home support devices for the elderly. [7] Working together with all the stakeholders in the local area ensures that the end users get more useful products. If the production would be done by a local craftsperson, then the product could be designed explicitly to suit the needs unveiled in a local co-design process. Electronic products, by the virtue of software adaptation and interface re-design, can be radically customised to suit the local needs. Thus if local practitioner undertakes these customisation tasks, they can create highly desirable, usable and meaningful products. [11]

Local production can be enabled by a modular approach to the design of consumer electronics. Already today most electronic devices, such as mobile phones, have so called “original equipment manufacturers” (OEM) who supply the functional parts of the devices to anybody who wishes to order a product from them. There is no reason why small local producers should not buy the same functional elements, assemble them and construct the casings to answer these special needs. which makes this production model ideal for the home support devices.

As an additional benefit, the tacit knowledge of a craftsman contains the cultural heritage and pride of their local community. Thus they can evoke emotions of longevity and care, as well as belongingness to, and ownership of local cultural heritage. The locally produced ICT would most likely appeal to locals and visitors alike, becoming an ambassador of the local culture; celebrating the diversity and uniqueness of human kind. As a contrast, mass produced products have little cultural variation, regardless of how they visually dominate homes. [10]

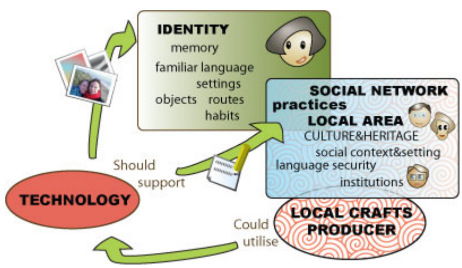

Fig. 3. Co-design for specifically the elderly reformulated as co-design in a local setting

6 Conclusions

Fundamental starting point for designing for specific users is mapping their concrete social context. The proper approach to this design is co-design that involves the end-users and their creative capabilities, embedding the design in their everyday practices. Co-design entails engaging local stakeholders in the production and development process, and local handcraft producers are natural stakeholders in local context. Local handcrafts also entail culturally shared meanings and connotations, which make the technology adaptable for specific users.

Our model for combining modular global technology and local interface design with co-design approach contains the following benefits: it allows to save costs on the basic technology, and instead to invest in interface design. Engaging local actors the investment is in part theirs. Also the implementation and adaptation by users is guaranteed, both by the familiarity of the interfaces and by the engagement of the users in the design process.

In order to test this local co-design and production model, we are proposing a new research project. The project would combine focus on the design for the elderly and involve as many local stakeholders as possible. Our goals in short are:

1. Work with some local craft practitioners in order to offer them our knowledge in designing and making ICT products.
2. Co-design ICT products for the local elderly that both support their individual identity and suit their care networks (both social and institutional)

The success of such a project would be measured by the level of commitment of the local stakeholders, as well as by the usability and acceptance of the end products. The former will be measured by the involvement in the design and development workshops. The latter will be analysed in product testing field trials and stakeholder interviews.

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Designing "Height" into Daily Used Products - A Case Study of Universal Design

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Abstract. Universal design is an approach to design daily used products that are usable by all people to the greatest possible extent. However, successful application of universal design requires an understanding of human performance. Ergonomic considerations are a part of "universal design" and should be taken into account by manufacturing engineers in product development. Integration of ergonomic considerations into the manufacturing processes becomes a major marketing strategy. Therefore, the purpose of this paper is intended to explore the relationship between body dimensions and the "height" of consumer products. A "user/product/effect" model is proposed to study how to design "height" into products and the results are discussed.

Keywords: Universal design, human factors, anthropometric data, consumer product.

1 Introduction

'Height' plays an important role in product design. Product dimensions which are too high or too low can make users uncomfortable. Thus 'height' is one of the key factors in product design that can offer most people a comfortable use and feel. The 'height' of consumer product influences product use in our daily life, such as the height of a table, chair, handle, or public telephone. For example, school furniture from manufacturers is typically not designed to accommodate different individual user dimensions. While a few desks offer an overall height adjustment and chairs of different sizes, individual adjustments for the seat, arm and back are not offered [8], [16].

Taking school furniture as an example, children are repetitively exposed to the hazards of abnormal or awkward postures due to classroom furniture that is often either too big or too small. Because children vary widely in their anthropometric measurements, both across age groups and within the same age group, all chairs and desks do not fit all children. To achieve a proper fit between school furniture and students, and to promote proper posture, the design of school furniture must recognize and reflect variations in anthropometric measurements across children of different sizes and cultures [9], [17].

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Previous studies have been shown that anthropometric measures and the performance of activities, in addition to specific design features of school furniture are all factors that influence the postural health of school children. It is assumed that chairs and desks in classrooms fit all children; however, adjustability and variability of furniture provided in the classroom is needed to satisfy a student's postural and educational needs [1], [2], [6], [10]. Ergonomic considerations are very important for school furniture design, since students most of their time performing a large number of activities. The most important consideration for designing daily-life products is "designing for human use," while the concept of universal design is "designing for all users." “Universal Design” is one of the most important issues in the design field. In the past, “Universal Design” was a concept of user-friendly design for creating barrier-free environment. Today, many people mistake ‘Universal Design’ as limited to designing for elders and the disabled. In fact, the main and original concept of universal design is ‘Design for all of people’ and ‘Allow use by more people’.][22].

The anthropometric database is used as a design reference for daily used product design. However, the most effective application of such data in product design is another important issue. Ergonomic considerations and manufacturing principles can sometimes present conflicting recommendations for design. The optimal product design must consider both of these objectives for developing guidelines that integrate ergonomics and manufacturing principles. In this way, product design can both improve response to consumers’ needs and maximize profitability for manufacturers [18]. Therefore, this study focuses on the application of anthropometric data by presenting three case studies of ‘universal design’ for developing design guidelines that integrate ‘ergonomic considerations’ and ‘manufacturing principles’ in designing ‘height’ into daily used products.

2 Ergonomic Considerations Regarding “Height”

2.1 Anthropometric Data

The most important ergonomic consideration for designing daily-life products is ‘designing for human use.’ However, cost conflicts between optimizing the design for ergonomics and manufacturing often appear, especially when the issue of applying anthropometric data is addressed. In ergonomic considerations, the requirement in anthropometric design is to determine a value for some design parameter in terms of a percentile cutoff for an anthropometric value in order to meet a target percentage for a population of interest. For example, what is the require range of seat height adjustability to accommodate 90% of the user population? In many anthropometric problems of "fitting" some design, it is necessary to consider several anthropometric variables simultaneously. For example, what will be the actual percentage of users who can be accommodated by equal 90 percentile cutoffs on ‘knee height’ (knee space) and ‘sitting height’ (head space), and what are the equal percentile cutoffs to be set if the target bivariate percentage is 90% Such design problems become more complicated because the designer needs to consider the correlations between body dimensions. [20].

2.2 Universal Design

Ergonomics has traditionally been used to decrease the number of occupational injuries by discovering those postures and tasks that create significant musculoskeletal stress. However, the principles which underlie ergonomics can potentially be used to improve productivity as well. Therefore, integration of ergonomic considerations into the manufacturing processes is a major marketing strategy [3]. For example, school furniture from manufacturers is typically not designed to accommodate different individual user dimensions. While a few desks offer an overall height adjustment and chairs of different sizes, individual adjustments for the seat, arm and back are not offered. Instead, a one-size-fits-all philosophy (universal design) has been adopted in the industry, because such furniture is less costly to manufacture and easier to sell at a lower price, and lessens the inventory problems for manufacturers and schools. Universal design can be defined as the design of products and environments to be usable to the greatest extent possible by people of all ages and abilities (the Center for Universal Design, 1997). Today, ergonomic considerations are a part of "universal design" and taken into account by manufacturing engineers in product development.

2.3 Comfort Factors

The factors involved in determining the comfort of school furniture are complicated, including ergonomic (user/product/task) and manufacturing considerations [15]. The study of the identifying factors of comfort shows that the three dimensions influencing school furniture design are "comfort factor," "design factor," and "spatial factor."[4], [5], [6], [7], [11], [24]. The comfort factor relates to the application of anthropometric values such as seat surface height, desk surface height, etc. The design factor focuses on form, material, and color features. The spatial factor relates to layout issues such as storage space. These three factors are used as references in the design of both separated and combined-type desk and chair. The designer should keep the user-product-task model in mind throughout the design process. The design development is optimized by considering the comfort factors and the relevant anthropometric variables influencing the design. The design first considers the ergonomic dimensions of the desk and chair, taking into account user/product/task analysis, and then adds manufacturing considerations.

3 Three Cases Study of “Height”

3.1 A Case Study of School Furniture

Lin and Kang [14], [15], [16], [17] conducted a series of studies of ‘height’ by combining ‘ergonomic considerations’ with health in designing high school furniture in Taiwan. Chairs and desks do not fit all children equally as well because they vary widely in their anthropometric measurements. The studies presented a paradigm for taking ergonomic considerations into human performance in health for universal design in order to achieve a proper fit between school furniture and students.

Ergonomic Dimensions. Using anthropometric data in design involves art as well as science. However, in the use of such data for designing daily-life products, there are generally two aspects: 1) determine what anthropometric design principle should be applied, and 2) how to achieve the anthropometric considerations in the most cost effective manner. When applying anthropometric data, three anthropometric design principles must be considered: extreme individuals, an adjustable range, and the average. Based on these principles, the recommendations of ergonomic dimensions for the ideal school desk and chair were proposed. For examples, some dimensions are adapted for the average, e.g. seat depth; some dimensions are adapted for the extreme individual, e.g. seat width; and some dimensions are adapted for an adjustable range, e.g. seat and desk surface height [4], [13], [19].

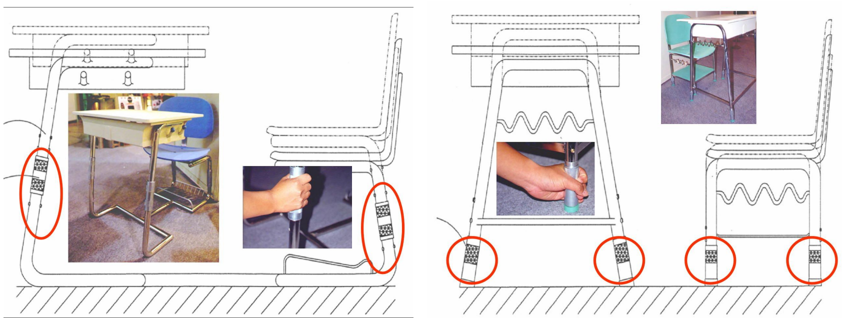

Fig. 1. Adjustable devices in combined-type and separated-type desk and chair

Adjustable Devices. Previous studies support the need for adjustability or incrementally sized school furniture in classrooms to accommodate the variation in anthropometric measures across different age groups. Generally, designing for an adjustable range is the preferred method of design, but it is not always possible. In this study, the sitting height and desk height can be adjusted to the individual occupant. Two adjustable devices are designed using a spring and screw structure to provide for adjustments to cover a wide range of users. For the separated-type design, the adjustable dimensions are seat and desk surface heights (Figure 1, right). For the combined-type design, the dynamic dimensions that can be adjusted include desk height and sitting height, and the distance from seat to desk (Figure 1, left). The range from the 5th percentile female to the 95th percentile male is divided into three different ranges. For manufacturing convenience, the same screw structure is used in the adjustable devices.

Furthermore, another design approach proposed a new way to adjust the height of desks and chairs. The previous adjustable devices for the desk and chair drawer have been changed as shown in Figure 2. The desk and chair system will vary only in the waveform of the drawer. Students can adjust the height of desk and chair by using the waveform design. With this design, using only a set of steel pipes will make it possible to meet the requirements of ergonomics and manufacturing considerations.

Fig. 2. Adjustable desk drawer for adjusting desk height

3.2 A Universal Design Case Study from Japan

Aoki Makoto [24] established a free website related to the concept of appliances for the aged, general public, and barrier free design supported by an organization of barrier free supporters in Japan. This website provides and discusses several general concepts of universal design - in particular, 'height' issues in products used daily. Appliances for the aged mean that the product is just designed for the aged. The appliances for the general public mean that the product is designed for just the general public. Barrier free appliances are products not only for general public, but also for the aged. So, barrier free appliances are a complete concept of "Universal Design" which does not target a particular group or range limit, but instead is "Design for all of people."

3.3 A Case Regarding Universal Design of 'Height'

The 'highchair' at the center of figure 3 was designed by Maartje Steenkamp who is one of designers of Droog Design and won the 2006 Red dot award. The product is a typical universal design product in that the 'height' of chair could be adjusted along with the child's growth. While the child is growing up, the chair can be adjusted lower and lower. The design allowed a child to continue using the highchair even as he continues to grow. The parent need not worry about how long the chair could be used for the child because it provides the adjustable height to fit the child's growth. The adjustable highchair could thus be adjusted to the user's need which is the main and original concept of Universal Design - 'Allow use by more people' [25].

4 The User/Product/Effect Model

Much of the research organization and design philosophy follows a user/tool/task system design model presented by Kreifeldt [18]. The model showed the interactions in a user/tool system and in particular emphasize the three-fold objects of the design: user, tool (product), task; the two interfaces: the user-tool interface (manipulation), and the tool/task interface (engagement), and a number of interactions in the system. Based on the user/tool/task model, the concept was applied to universal design by exploring the relationships between appliances for the aged, the general public, and barrier free [24]. A user, product and effect paradigm is proposed in Figure 3a where the intersection area between the user and product is the 'effect' showing the extent possible to the user's need. A larger 'effect' area signifies that the user is fit better meaning greater comfort for users in using the product. Taking the 'highchair' as an example, the moving circle represents that as the child is growing the intersection becomes smaller and smaller (Figure 3b ; if the product does not provide any ergonomic considerations to fit the user need at the same time, the effect will be from small to non-intersected as shown in Figure 3c.

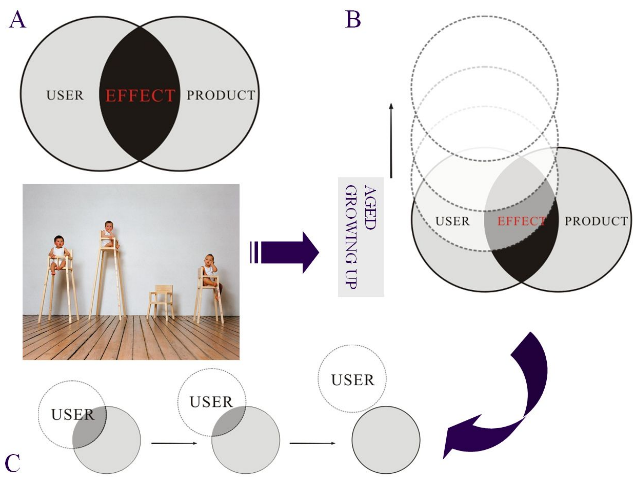

Fig. 3. The relationship of user/effect/product

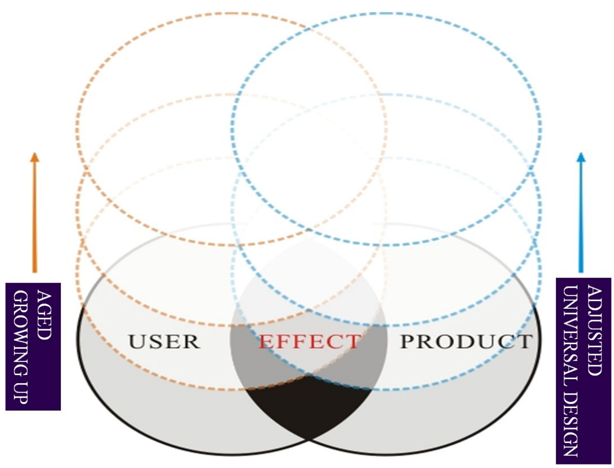

Fig. 4. The user/effect/product model

When the highchair is adjusted by changing its 'height', the child can fit that chair dimension and use it comfortably. This is a process of aging or growing up for the user side and adjusting and universal design for the product design side. The model was used to develop the design 'height' into the product as shown in Figure 4. It is known that the real situation is more complex than this. Under normal circumstances, the designer involves ergonomic considerations to design the product, which employs 'effect' to complete the product design. Therefore, the effect is the key factor for ergonomic considerations and universal design.

5 The Application of User/Product/Effect Model

The user/product/effect model is proposed to solve the variety of human dimensions, focusing on the problem of a growing user, and then on the effect of the product. In general, designers often only focus on 'usability' and 'manufacture'. Thinking within this small range limits design development. But when designers think about "human", "society", and "environment", designs could not only benefit the product, but also improve human welfare and social environment [22]. Based on the user/product/effect model, two design cases are proposed to show the subject of 'height' in our daily used product design.

5.1 Case one – School Furniture

In today's classroom, children vary widely in their anthropometric measurements, chairs and desks do not fit all children. Especially, the 'height' of school furniture is very important for school furniture design, since students perform a large number of activities and spend most of their time with them. Can the same school furniture fit all individuals who have different body dimensions? The answer is obviously negative. Based on the research of Lin and Kang [14], a new design takes 'height' into design by considering the relationships between user, product and effect as shown in Figure 5. In this design, the sitting height and desk height can be adjusted to each individual by using an easy joint to accommodate the variety of anthropometric data across different age groups.

Fig. 5. The relationship of user/effect/product for school furniture

5.2 Case 2 – Public Furniture

In today's fast-food restaurants such as Mcdonalds, and Kentucky Fried Chicken, the same public furniture is provided to the variety of customers. After ordering, consumers take their meal on a tray to find their seats. Does the variety of customers use the same size furniture when they're eating? Of course not, so the other design for public furniture uses the concept of universal design which provides three kinds of height adjustments as shown in Figure 6. The public chair is made of metal tubes which will let a consumer put the tray into the one which provides the most comfortable height to eat.

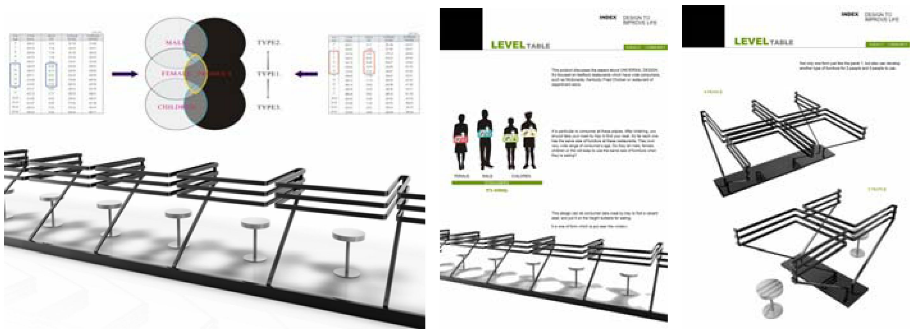

Fig. 6. Designing 'height' into public furniture

6 Conclusion

Universal design is an approach to creating everyday environments and products that are usable by all people to the greatest possible extent. By using universal design, companies can maximize their potential market. However, successful application of universal design requires an understanding of human diversity (ergonomic considerations). Design and manufacturing engineers seem well aware that the most efficient way of improving ergonomics in manufacturing areas is during the early phases of product development. This paper presents a paradigm of how to take ergonomic considerations into manufacturing for universal design. Based on the 'Universal Design', the paper focused on product height and discussed its influence on users. Furthermore, this paper uses the user/product/effect model for the concept of "Design for all of people". It will provide a model for designers and students for designing height as well as for other aspects into products in the future. Two cases show the design of products based on adjustment for user variation. Naturally, all such designs must use the relevant anthropometric data as well as testing and verification.

Acknowledgments

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Designing Data to be Inclusive: Enabling Cross-Disciplinary and Participative Processes

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Abstract. The data formats of specialist disciplines are often difficult for those from other disciplines to access, not least lay audiences, inhibiting truly participative and inclusive processes. The authors discuss the achievements and value of visualizing biomechanical data on functional demand obtained during daily activities from older adults in the 60+, 70+ and 80+ age groups which has shown the potential to provide physiotherapists, occupational therapists, designers, bioengineers, and human factors specialists much improved access to the data. Older adults have their own valuable insights and these are vital to include in developing a fuller understanding of issues that affect their quality of life. The format of visualization has the potential to be understood by this 'lay' audience. The paper discusses the design of, and pilots towards a full-scale study to try to fully engage stakeholder disciplines and older people as truly collaborative partners, together with conclusions to date.

Keywords: Visualizing data, participative processes, functional demand, older people, quality of life.

1 Introduction

Transformation design and participative design processes have much to offer the cause and advancement of inclusive design (ID) also known as universal design (UD). Transformation design is described as design that facilitates collaboration between many disciplines and ordinary people in order to solve complex problems, placing the user at the heart of new systems development (Winhall, 2006). Participative design is a form of democratic participation in the processes and methods of design.

In the UK, research councils emphasize the need for, and value of, greater inter-disciplinary collaboration to address ageing population challenges. However, the formats and domain-specificity of the languages and data of specialist disciplines are such that they can often create a barrier to, and are difficult to access by other disciplines, not least by a lay audience. One of the challenges is to make not only processes participative, but also the information and insights of individual disciplines accessible across other disciplines. This would go some way to empowering all stakeholders, including lay contributors, and may help the shift of perception from an

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individual 'user' viewed as a 'subject' who is 'consulted', to a true 'participant' viewed as a contributing 'expert' in his or her own right.

This paper provides details of a case study of a research project in progress describing the potential value of the visualization of biomechanical data in a format that will allow older adults themselves potentially equal access to the data, along with other relevant disciplines, enabling them to be true collaborators. Older adults have their own valuable insights which complement those of specialist disciplines and which are essential to consider to develop a full understanding of issues that affect their quality of life. This paper discusses the achievements of this visualization method, the design of, and pilots towards, a full-scale study, and insights to date.

1.1 Problems Associated with Ageing, Problems with Data

Adults as they grow older may have difficulties in performing normal daily living tasks, due to decreasing mobility, injury, or the chronic diseases associated with ageing. A clear understanding of the functional demand placed on the muscles and joints of older adults as they perform these tasks could provide insights for appropriate design solutions for the home (Coleman, 2001), assistive technologies and exercise (Cress et al 1999; Krebbs et al 1998; Laukkenen et al 1998); rehabilitation; and healthcare strategies to maintain independence and quality of life (Woods et al, 1999). However, data processed by bioengineers and by physiotherapists tends to be in a format that is numerical, conveyed in static graphs, and where the dynamic quality and the context in which the data is generated are not communicated effectively. This limits the ability of different subject disciplines, each with related interests, to share and discuss the information and to develop new insights related to quality of life issues of older people.

2 The Process of Envisioning Dynamic Data

The original intention of previous research (Loudon and Macdonald, 2005, Macdonald et al, 2006a) was to develop a CAD tool for designers using data calculated from the biomechanical functional demand on joints in older adults during activities of daily living. The proposition was that the presentation of this data in a format understandable to designers would lead to better designs for older people. Whole body movements of older adults in 60+, 70+, and 80+ age groups were captured using a 3D motion capture camera system, reaction forces were measured by force platforms, and translated into a 3D software model. The rationale for the selection of daily living tasks, and a description of methods of data capture and visualization are described in detail in Macdonald et al (2006b).

2.1 Animated Data

To achieve the usability and accessibility of the data, and to create visualizations which could be presented to designers for subsequent evaluation, a prototype software tool was developed, implemented in Visual C++ and OpenGL, which displayed real-time generated 3D animated visualizations of each of the individual participants each performing the 11 activities of everyday living (described in Section 3). The animated human model consisted of simple cylindrical or block representations of the body segments from the motion capture rendered frame by frame in three dimensions in light blue. The hands were displayed as 3D hand models shaded as flesh tone. The tool enables the viewer to select a participant (selection by age and gender) and an everyday living task and view a 3D animated model of the participant performing that task. Reanimating the motion capture data provides the viewer with the opportunity to alter the viewpoint to any angle and zoom in or out to examine the motion.

2.2 Visualizing Functional Demand

The researchers developed an innovative means of envisioning this data which lies in the way that functional demand data is presented in a visual manner, and in a dynamic form, based on established principles of information visualization. The level of functional demand – how hard the muscles were working relative to their maximum capability - was mapped to a colour scale, based on the analogy of traffic lights (red for 100% demand and green for 0% demand).

The colour-coded functional demand was represented by a variable-colour sphere at each of the joints of an animated digital mannequin of each older person, rendered from motion capture data (Figure 1). A green colour was shown where functional demand was below 40%. At higher functional demand, but still within acceptable limits (between 40% and 80%), the shades of colour of the sphere were in the range of green/yellow to orange. Finally, if the joint was experiencing functional demand levels deemed to be unacceptable (above 80%), the sphere was shaded red. This 'traffic light' system was thought to be a clear and immediate way of allowing the designer to understand, without specialist knowledge, the functional demands placed on individuals while performing daily activities.

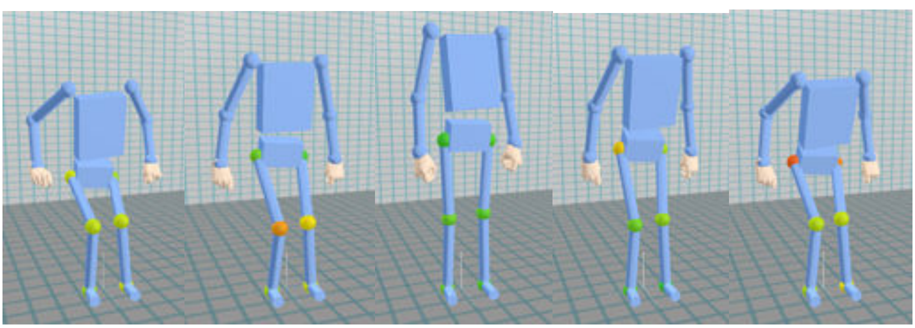

Fig. 1. Software tool displays the functional demand at the joints of the lower limbs during sitting task

The envisioning of the dynamic data allowed one to gain an insight into the relationship between the continuously changing functional demand at each of the joints and the movement of the individual. An understanding of the points at which the greatest functional demand is placed on joints during a movement cycle is easily and quickly identified through this form of visualization. If the viewer requires the details of the forces which are being represented, s/he can select the joint to obtain the numerical values, direction of the forces, etc.

3 Enabling Single- and Cross-Disciplinary Participation

The potential value of this innovative mode of envisioning dynamic data was identified through working with processed data sets for eight individuals each performing 11 separate daily living tasks, involving e.g. gait, pushing and pulling a door open, sitting/standing, lifting/setting down objects on shelves, ascending/ descending stairs - some tasks with and without the use of arms. The perspectives of those from different backgrounds, i.e., human factors consultants, physiotherapists, and biomechanics were sought in pilot evaluation studies. From these sessions it was found that while each derived new insights from the visualization method, each viewed and interpreted the data with a different emphasis.

3.1 Pilot 1: Physiotherapists' Perspective

The pilot for the physiotherapists' evaluation provides a good illustration of the potential value of this form of visualized data: "…that's fascinating actually… one can pick up different methods which they use to circumvent the demand on their hip…the positions they put themselves in… they'll come forward on their ankles more...how they change their centre of gravity…", "... he's keeping this right knee flexed, because he's probably got OA [osteoarthritis] in that knee…so he's a wee bit rotated … but there's more force going down through his left ankle. Because he's off-loading it…and then he gets to fully standing…and then there's a bit of internal rotation…you can get with hip problems as well. So with him if you were going to design something…let's assume he has OA in his right knee, clinically, and you're…he's not going to be able to put 100% functional performance through his right knee. He's only able to do 70 before pain inhibits him. So any adaptation isn't going to change anything on the affected side but may improve things on the unaffected side…reduce the loading."

3.2 Pilot 2: Interdisciplinary Perspective

An interdisciplinary pilot (bioengineering, physiotherapy and design) has also been undertaken and this again provided useful insights into the common and divergent ways of viewing the data. For instance, in one discussion facilitated by these animations, a bioengineer, who was critical of currently available chairs for older adults, queried a designer about how decisions were made about seat height and arm rests. The bioengineer could specify what would be most suitable for, say, 90% of older people to be able to push themselves out of a chair. The physiotherapist noticed a new aspect: the hands and feet of an individual were static during one of the movements and if the hands had done more or if the feet were inclined then it would have improved their performance. The bioengineer commented that if they had problems, say in their leg, then they might adapt their movement, introducing coping strategies in order to avoid soreness.

3.3 Insights from Pilots

From these initial pilots, data envisioned in this format appears to be useful to more professions than just the designers for whom it was originally intended. It appears that this format can allow those separate disciplines involved in designing for and the rehabilitation, healthcare and well-being of older people to view the data in an innovative, useful, and sharable manner. This potentially facilitates new insights informed by inter-disciplinary analysis and discussion of the visualized data. These insights have the potential, in turn, to inform any and all of the disciplines, e.g. the bioengineer (in understanding the biomechanical issues), the designer of the built environment (for the design of furniture, homes, care institutions), or the physiotherapist (deciding exercise regimes to improve muscle strength, exercise or rehabilitation equipment). This could provide a comprehensive and holistic view of individuals' needs.

Further reaction was gained from two public feedback events, one involving all the stakeholders including older people, some of whom had been the subjects of the data collection experiments. The informal response from the latter event highlighted the fact that the non-professional lay audience (i.e., the older people themselves) was enabled to make a contribution through this innovative format of data design and presentation.

4 The Design of Further Studies

The data for the 84 individuals, each performing 11 set tasks has been collected and is of good quality; the method for processing data has been proven, the software scripts have been written, and the software for processing data is in place. However, as the pilots involved data visualized from only eight individuals, the idiosyncrasies in these data sets do not allow useful generic insights to be gained and meaningful conclusions to be drawn.

The next stage will involve processing and envisioning the remaining data, and using this material (potentially some 924 animations, from which a subset will be chosen) as the basis for a series of participative workshops involving the stakeholder disciplines, and older people, both individually (discipline–specific) and collectively (cross-disciplinary).

4.1 Engaging Further Perspectives Through Participative Workshops

The study is being designed as a series of workshops structured using participative methods and which include older participants throughout the whole process. The first set will be single-discipline specific (i.e. human factors consultants, bioengineers, physiotherapists, occupational therapists, designers, etc). At each of these workshops a group of older participants will attend. The thorough briefing of all participants and the sequencing of events will be important. Ascertaining which activities of daily living amongst the older adult participants cause most problems would be cross-referenced to the those activities selected for the original data-acquisition as a result of literature review. A clear briefing on the meaning of the colour-coding used in the animations and its correspondence with the level of demand on joints during the daily living tasks will be essential, as will be any implications associated with high (i.e. amber to red) levels of demand on any of the joints. Extrapolating the implications of certain activities along with the diminution of muscle strength with age from, say, the 60+ cohort to the 70+ and 80+ cohorts may prove valuable in predicting safe practice and better-designed environments. The psychological and aspirational implications on quality of life and wellbeing from unsafe or undesirable loading on joints will be evaluated to inform recommendations for safe and meaningful work activities and exercise routines for older adults.

The second set of workshops will be cross-disciplinary in nature, again with older participants. This first phase is described as the co-research phase, to gain insights and appreciate the different perspectives.

During a further phase of the project, the co-design phase, the hope is that sufficient feedback and insights are obtained, a) at a practical level, to generate healthcare and design recommendations and possibly guidelines, b) at a policy level, to develop healthcare and design strategies, and c) at a strategic level, to develop guidelines and recommendations for the acquisition, processing and envisioning of biomechanical data.

The study being described in this section is currently being developed and results will be reported at a later date.

5 Conclusions

This project is being undertaken with the aspiration of designing data in such a way as to be ‘inclusive’, to facilitate improved participation by a range of different specialists, designers, and a lay audience (in this case the older adult), in what were previously discipline-exclusive discussions largely excluding the subjects of their research. The intriguing aspect of this research is to discover to what extent the researchers will be able to liberate normally discipline-specific data and present this in a format to elevate those individuals and groups previously regarded as ‘subjects’ to be more equal participants and partners – and ‘experts through experience’ in their own right - in the more inclusive and democratic design of those factors influencing wellbeing and quality of life, here specifically with regard to physical activities of daily living for older adults.

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The UD Phenomenon in Japan: Product Innovation Through Universal Design

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Abstract. The uptake of Universal Design (UD) by manufacturing industries in Japan has been a recent and extensive phenomenon. The sector has identified the significant market opportunities brought about by the rapidly changing needs and lifestyle aspirations of its ageing society. In this review, the author discusses innovation in products, specifically mobile phones, developed through a UD philosophy, within the context of Japanese manufacturing corporate culture and the wider national goal for a socially integrated environment. Corporate literature and product marketing material are also referenced as a means of revealing the relationship between company and customer. The author asks what value can be obtained from understanding the factors stimulating and supporting this phenomenon and if this UD approach in Japan can be translated outwith its unique corporate and national cultures for further applications elsewhere.

Keywords: Universal Design, Japan, Manufacturing, Product Case Studies, Mobile Phones.

1 Introduction

Challenges and opportunities posed by Japan's 'super-ageing' population demographic appear to have provided the initial catalyst for a strategic and national Universal Design (UD) agenda in a broad range of industries creating technological consumer products (Macdonald, 2006). Evidence suggests that Japan is making progress towards its goal of achieving a socially integrated environment through a concerted shift towards prioritizing users' stances and viewpoints rather than manufacturers, developing cross industry strategies, and making available practical and immediately useful products (Toda, 2005). In the area of IT, Japan has also endeavored to bridge the digital divide through UD (Hirokoshi, 2006). In the highly competitive market place, the UD approach appears not only to offer increasingly attractive products that accommodate a wider range of user capabilities but also to possess values which resonate with those of an increasingly diverse and sophisticated marketplace. This paper discusses some of the factors contributing to the UD phenomenon and how UD philosophy is manifest in recent generations of mobile phone products appearing in the marketplace in Japan. If there was an increased

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awareness of and a better understanding of the factors contributing to the phenomenon would this be of interest and value manufacturers and innovators globally?

The author has carried out this review in two parts: 1) factors contributing to the UD phenomenon in the manufacturing sector, and 2) case studies of recent generations of mobile phones developed through UD processes and possessing UD features. The second part is discussed within the context of the first.

1.1 Legislation and Standards

Legislation has positively contributed to accessibility both in the built environment, and in the digital and IT environments. Examples of the former include the Heartful Building Law of 1994 (an act to make buildings usable and accessible to older and disabled people), and the 2000 Transportation Barrier-Free Law. More recently (July 2005), Japan's Ministry of Land, Infrastructure and Transport's (MLIT) introduced the General Principles of Universal Design Policy. With reference to IT, the Universal Design Work group of the Communications and Information network Association of Japan (CIAJ) was created in 1999 with the aim of "making smooth access to telecommunication possible for all users including handicapped persons and senior citizens." The CIAJ is a broad alliance of more than 20 companies in the telecoms sector. In 2001, the Japanese Government developed its e-Japan Strategy through its IT Basic Law (Basic Law of the Formation of an Advanced Information and Telecommunications Network Society) with the strategic intention of becoming the world's most advanced IT nation in 2005. This was set up in parallel with implementing a u-Japan Strategy for 2010 ("u" donating both "ubiquitous" and "universal"), illustrating the move towards UD in Japanese IT policies. Japanese Industrial Standards (JIS) such as its JIS 8341-1 "Guidelines for older persons and persons with disabilities – information and communications equipment" were used in the process of developing standards across the sector and bridging the "digital divide" (Horikoshi, 2005).

2 Cross-Sector Activity

A large number of companies, now near 150, have played a significant role in the process of driving forward the 'inclusive' agenda. The extent of rich industrial collaboration, or at least a highly competitive approach that raises the quality and level of UD activity across a wide range of companies, was facilitated to a significant degree by the formation in 2003 and subsequent activities of the International Association of Universal Design (IAUD) "to address the universal-related issues of an ageing population and to better integrate disabled people" and "to promote the establishment of the foundations of a society in which more people will feel comfortable to live".

The IAUD came into existence only as recently as 2003, yet the recent and rapid uptake of UD across the manufacturing sector perhaps suggests that there are some deeper-seated factors within Japanese corporate culture, or values within its society as a whole, that have helped successfully mobilise and exploit Japan's distinctive approach to UD. Undoubtedly the IAUD forum has encouraged and facilitated the many participating companies to embrace the UD agenda, and while there is debate over the extent to which company information is openly shared, the value of and energy within this critical mass must be acknowledged. Although companies are individually competitive, they recognize the mutual advantage in sharing approaches and aspirations, understanding that by cooperation, the game-plan for Japanese products and the number of these appearing on the market that serve the inclusive needs of their society will be at a much higher level than their foreign competitors (Kawahara, 2005).

2.1 UD Business Concept

In the same year the IAUD was formed, 2003, the Nikkei Universal Design Business Forum recognized the need to move forward from a set of uniform 20th century production values with negative associations towards a "new social structure … wherein individuals have the opportunity to inhabit an environment that reflects their distinctive characteristics and values" (Nikkei Design, 2003). This Forum formulated the UD business concept a means of attaining that aspiration through four key themes: the creation of new business, the supply of products and services, potent corporate brands, and creating an accessible environment.

2.2 Achievements

Resulting from this activity and broadly shared philosophy in the manufacturing and business communities, a number of very clear and apparently successful design approaches and products can be cited, including: private vehicles, such as Toyota's Raum and Porte; domestic electrical products, such as Panasonic's tilted-front washing machine; and mobile phones, such as Kyocera's and Mitsubishi's UD phones. Products with UD qualities now appear to be evolving as a matter of course – easier to use, and with improved designs facilitating easier access to enabling technologies through more accessible and appropriate interfaces supported by associated services. The embodiment of UD principles in mobile phones is discussed in greater depth in Section 4.

3 Japanese Corporate Culture

Japanese UD models have moved on considerably beyond the starting point of Mace's 'seven principles' approach to UD (The Center for Universal Design, 2000) within a very compressed timescale, embedding evolved and individualised UD principles within corporate business structures.

3.1 Company Philosophy

While the phrase 'universal design' has come into usage only comparatively recently in Japanese industry, philanthropy has had much more of a tradition in the sense of 'corporate social responsibility', or 'social participation through mutual understanding' (Yamamoto, 2005). Companies are at pains to communicate a philanthropic heritage: phrases pepper corporate websites such as 'social contribution' and 'harmonious society'. The tradition of relatively stable lifetime employment in Japanese corporate culture, the creation and sustained support of a cohort of young and dynamic design managers informed in UD principles and philosophy, the absolute devotion to understanding and satisfying the customer, and the engagement of users through specialized user research tools are amongst factors contributing to this phenomenon. Alongside these, better-known Japanese manufacturing methods should also be acknowledged, typified by Toyota's relentless approach through 'kaizen' – continuous improvement - for their relevance and appropriateness.

3.2 The Customer Is God

'Okyaku-sama wa kami-sama desu' – 'the customer is god': Japanese corporate culture has a long and deep tradition of working tirelessly to improve products and services from a customer perspective. Recent marketing literature for the sophisticated and discerning Japanese 'baby boom' generation, now possessing considerable economic leverage, reflects the demand for choice, quality and lifestyle. Those individuals with modified capabilities resulting from the ageing process are as much a part of this sector as any other. But, this is not only a pre-occupation with older and disabled market segments as, for instance, easy-to-use children's mobile phones which help anxious parents track their children's location now receive as much attention as 'easy' phones for older people.

3.3 Lifestyle Brand

The shift in customer expectations is reflected in the terminology found in much of the corporate promotional material for UD such as: 'high amenity lifestyles; prosperity, fun, comfort; enriched lifestyles' (Matsushita-Panasonic); to 'live a variety of lifestyles', to 'able to be used and shared by all, both simply and easily' (Toshiba); 'a convenient and value-added lifestyle for as many people as possible' (Fujitsu); and 'peace of mind, pleasure, singularity, soothing, safe, affordable, easy, fun, beautiful, essential and simple' (Toyota). This is customer-oriented language reflecting the features and values sought by consumers in products and associated services.

4 UD in Mobile Phones

Rapid technological change is exemplified in the paradigm-shift in the design of interfaces and functionality for telephones from traditional landline to mobile technologies: these products very clearly illustrate the issues in design that can lead to exclusion of significant sectors of the population. Where there were once analogue interfaces, with dials or push buttons, these have now been replaced by multi-layered menu-driven interfaces with multi-function buttons. Given the evolving market, Japanese carriers have increasingly sought to provide customers with phones designed using UD principles and strategies for the most overlooked sectors: the very young and the very old. Pattison and Stedmon (2006) provide an account of the changing capabilities in individuals as a result of the ageing process with reference to the senses, motor function and cognition together with the corresponding design specifications required for mobile phones to meet these conditions and their relationship to UD principles. Tomioka (2004) discusses UD practices with reference to accessibility issues and product specifications for mobile phones. Kawahara (2005) considers UD in terms of the physical function characteristics in the range of senses of older people and these in relation to mobile phone design, revealing the extent of, e.g., eye conditions not being addressed for through current designs.

This section discusses the UD features in a number of recent Japanese mobile phone designs and in associated marketing literature: phones and marketing literature were examined and evaluated by the author in the field in Japan.

4.1 First Generation UD Mobiles: Raku-Raku 111

There had been little evidence of accessible, universally designed mobile phones until NTT DoCoMo introduced the 'Raku-Raku' (this translates as the 'Easy-Easy') phone series developed by Fujitsu from 2001 onwards. Innovations included "simple, user-friendly interfaces designed for easy use even by persons unfamiliar with mobile phones" for those "who cannot manipulate the devices intuitively" and with "various features to assist users with visual disability". It has "features to support visual functions along with audio features, as well as an easily viewable display". Fujitsu describe the process towards achieving UD in these phones (Irie, Matsunaga & Nagano, 2005). Kawahara (2005) evaluated the success of the Raku- Raku 111 phone and the market reaction to the design, "this is a hit seller that has sold over 1,000,000 units with one model, but many older people hesitate from buying one as they dislike its outer image that is obviously for seniors, even though it is easy to use." However, it was still proving to be best sellers over five years after being launched (NTT DoCoMo, 2007). Recent innovations in this category of mobile phone include variable text size (standard now across a whole range of mobiles in Japan), and for the camera on some phones to be used as a 'magnifying' device for reading text, useful for those with, for example, macular degeneration.

4.2 Second Generation UD Mobiles: TU-KA S, A101K and Raku-Raku 2006

The 2004 TU-KA S phone by Kyocera (Fig. 1) was clearly targeted at, and marketed for, the older user. The marketing literature literally and visually spells out the analogy between the TU-KA S mobile phone and more familiar (to these particular customers) larger landline-based phone interfaces. This is a mobile phone that allows one to do only four basic things: turn it on, turn it off, dial a number and accept a call. Not only is its design but also its back-up service is promoted as friendly: "you can talk to the [technical back-up] person who responds kindly and politely". The manufacturers state the phone is so simple to use it does not require a manual, one is not provided, and the sales copy on the packaging makes a virtue of this. Scenarios portrayed in advertising leaflets address anxieties that, for example, a worried daughter might have of not being able to reach her mother by landline phone, or of an older person not being able to find a public phone while traveling. In Nikkei Design (2005), the issue of its lack of a screen or camera and its attractiveness to older users was raised. A valuable insight is provided by Kawahara (2005), who reveals that within the group we might stereotypically label as 'the elderly' there are further sub-groups, each with its own preferences: "Although it has been received favourably by those over 70 it is not received well by those around or under 60 years old. Psychological and aesthetic factors that cannot be measured by operability or simplicity are thought to have contributed to its poor acceptance by those in the 60's."

Fig. 1. Kyocera's TU-KA S mobile displaying a simplified interface with enlarged buttons and characters

However, despite these criticisms of a design that challenged the not-always appropriate conventions of the current status quo, the TU-KA S appears to have been very successful. It won a Japanese 'G-mark' Good Design Award for Universal Design in 2004 and Kyocera's A101K and NTT DoCoMo's 'Raku Raku' (Fig. 2) developed this time by Mitsubishi, both from 2006, follow broadly a similar type of design to the 2004 TU-KA S. The marketing literature for all three models is exceptionally clear and easy to understand and clearly addresses the needs, anxieties and desires of this sector again through scenarios portraying typical anxieties. The A101K is promoted as a 'talk-only' mobile, while the Raku Raku's literature headline is 'real easy – what everyone has been waiting for'. All have large and clearly contrasting numbered buttons and simple colour-coding for start-call and end-call function buttons. At the top of the A101K are three buttons dedicated to, e.g., one's home number, and two other personal phone numbers of one's choice to facilitate one-button dialing. Neither the TU-KA S nor the A101K has a screen, however the 2006 Raku Raku, reintroduces a small screen allowing, e.g., dialed numbers to be seen as well as total call-time. Every time this phone is docked into its charger, a text message is sent to a selected relative or friend. The A101K also has a handy little 'drawer' that can be slid out and on which one can write phone numbers corresponding to the one-button dialing facility. Other features in this generation of phones are very clear on/off buttons (labeled talking/finish with appropriate colour-coding), and technically appropriate sound quality and volume adjustment for older hearing capabilities.

Fig. 2. NTT DoCoMo's Raku-Raku mobile by Mitsubishi, 2006, showing the 'talk' (blue) and 'end' (orange) buttons and small screen. A small internal drawer extends from the bottom end of the mobile on which the customer can write phone numbers.

4.3 Third Generation UD Mobiles: Foma D800iDS

Mitsubishi's 2007 D800iDS mobile (Fig. 3) is the world's first with screens on both halves of a 'clam-shell' design, one of which (the lower) is a touch-screen, and is visually analogous to the hand-held Nintendo DS gaming machine. This is a relatively sophisticated type of UD phone, possessing more functions than the previous generation, but the touch-screen allows the interface to be customized to suit the user's preferences and most frequently used functions. This has three operational modes based on UD principles to suit different types of users: a phone function, a mail function and a camera function, each of which is accessed by simple and clear menus and navigation. The touch panel has three different modes of text input: 1) handwritten; 2) 2-touch input relating to Japanese syllabary; and 3) 5-touch standard input. A subtle force-vibration sensation is provided for reassurance to replace the feedback one would normally expect from physical buttons. Although appearing in 2006 as a prototype at various trade shows, this has only recently appeared on the market, and its success has yet to be fully evaluated.

Fig. 3. Mitsubishi's D800iDS twin-screen prototype (as at October 2006) now available on the market. The lower screen is a touch-screen and the interface can be customized to the user's preferences.

4.4 Mobiles for Other Inclusive Needs

The UD philosophy is about 'design for the whole population', and UD is not only for older users or those with disabilities. Other types of users may require or may wish simple-to-use features: the TU-KA S model, for example, might also be appropriate for those less comfortable with advanced technology, or those who need, or indeed, prefer very simple interfaces, but in this case a different marketing strategy would be required. At the other end of the market spectrum, there are mobiles designed for children (as well as for their parents' peace of mind). For example, the 2006 NTT DoCoMo 'Kids-Keitai' (kid's mobile) featured a protection alarm and GPS functions (GPS is a standard in many current phones in Japan). Its 'imadoco' (where now?) feature allows parents to track their children by sending information from the child's handset through the service provider to the parent, to restrict who is called from the mobile, to limit call time, and to provide parents with an automatic email at set times. Some, like DoCoMo's 2006 SA800i have alarms that the child can activate.

5 The Potential for UD in Other Regions: Questions Remaining

The emergence of UD philosophy in the Japanese manufacturing sector represents the conspicuous formalisation of a revised approach to design. This is more inclusive in how it considers a much broader range of individuals' needs, capabilities, and lifestyle aspirations than that accommodated by the mid-20th century paradigm of product development and design. UD appears to provide some means to respond, using customer-centred design approaches, to a wide range of needs across the whole population, and to distinct challenges – and opportunities - facing society at this particular moment in time.

However, a number of questions remain. If the effective mobilization and sustained implementation of a UD approach is, as appears to be the case in Japan, somewhat dependent on a broad and shared corporate and philosophical response within the industrial sector, alongside a distinct cultural agenda and mindset, where does this leave the future for UD with regard to other cultures where industry may be on a very different scale, much more fragmented, and design is outsourced? Given that the technologies embedded in the Japanese UD product examples discussed above are freely available in other countries which also have ageing populations, why is there such a dearth of designs in these regions that not only meet accessibility standards but which are so radically innovative and appealing, the result of sustained development and rapid evolution through successive iterations by dedicated teams? Can the Japanese UD approach and the lessons learnt be transferred and survive outwith both the distinctive Japanese company structures and the unique Japanese national cultural mindset?

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Search String Analysis from a Socio-economic Perspective

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Abstract. Search string analysis has implications for developing better designs of Web interfaces and search engines. It is expected that millions of new users from Africa will enter the Internet arena in the not so distant future. Most of these users will be from countries with a low socio-economic standing. In order to determine the effect of socio-economic standing on the search behaviour of grade ten learners, their search characteristics were analysed. This study found that there is a difference in the search behaviour between novice users with a low socio-economic standing and those with a high socio-economic standing. These differences, however, only lasted for the first few sessions, where after all users showed the same search behaviour.

Keywords: Search strings, socio-economic status, Web searching, search characteristics.

1 Introduction

Internet access is becoming available to more and more people on a daily basis. So far people on the wrong side of the digital divide had to sit and watch as those on the other side reap the benefits of the information highway. African Internet usage has trebled to over 12 million since 2000 with 133 users per 10 000 people on the African continent [1] and 139 per 10 000 for the Black population in South Africa [2] having access to the Internet. These figures still compare very unfavourably with the world figure of 1460 per 10 000 people. It reflects even worse if it is compared with the figure of 3 680 per 10 000 for Europe and 6 800 per 10 000 for North America [1].

Maybe that is about to change. At the recent World Summit of the Information Society held in Tunis, Tunisia, the "100 dollars lap-tops for each student "- campaign was launched by the UN Secretary General Kofi Annan. The goal of this campaign is to provide the machines free of charge to children in poor countries who cannot afford computers of their own. It is hoped that the lime-green machines can be placed in the hands of millions of school children around the globe [3].

Given that the above initiatives come into fruition, millions of new users from Africa will enter the Internet arena in the not so distant future. Most of these users will eventually resort to finding information on the Web. What better way is there to do that than utilizing a search engine? Knowing the answers to questions like "Who is

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searching?", "How are the searches conducted?" and "How successful are the searches?" are all important for several reasons. It has implications for developing better designs of Web interfaces and search engines. Additionally, it has implications in the education of search techniques when the difficulties with the search process are better understood.

A reasonable body of research in respect of searching the Web has accumulated over the last decade. Most of this research focused on the developed world. As far as can been determined, this paper is a start in order to tell the story of the developing world.

In the following sections some background of relevant research in this area will be given and it will be followed by the methods used and the results of the current study. The paper will be concluded with a discussion and conclusion.

2 Previous Research on Searching the Web

The research in the area of how users search the Web can broadly be grouped into large scale studies based on the analysis of log files of prominent search engines and small scale studies that focused more on different groupings of users. The users in the large data sets from the search engines are mostly anonymous and therefore the entries in the log contain only the identification of the users' machine, the time of the entry and the query. These studies determine the number of queries in a session, the number of words in a query, the pages browsed during the query, the information searched for and advanced features used in the query. These studies have the advantage of large data sets from an operational environment, but the user demographics are not available. In the small scale studies data is captured by observation or at the client side. The different groupings of users have to perform different tasks and then their searching patterns are evaluated and compared. In these studies the demographics of the users are known, but the number of users is low. The research in this paper will be based on something in between, having the best of both worlds.

In an overview paper on search trends from 1997 to 2003, Spink and Jansen [4] reported findings from an ongoing series of studies analyzing large-scale data sets obtained from the Excite search engine. They found a steady increase from 1996 to 1999 in the mean number of terms in queries from 1.5 to 2.6 and 2.4 by 2003. An increase in the number of Boolean operators was also identified. Most users searched one query only. The average session included 1.6 queries. More than 70% of the time a user only views the top ten results. In general users view about five Web documents per query.

Another large scale study was the Alta Vista study of Silverstein, et al. [5] who studied approximately one billion search requests over a period of six weeks. They showed that Web users type in short queries, mostly look at the first ten results only and seldom modify the query.

Turning to small scale studies, Amed et al. [6] reported on the performance and satisfaction of novice and expert users with the Web of Science interface. The users had to perform seven search tasks and their performance was recorded through transaction logging and screen recording. Overall, the experienced users performed better than the novice group. They also found the number of search terms used for each task to be between 1.90 and 4.00. Hölscher and Strube [7] also used expert and novice users in their study. They compared the search queries of 12 expert participants doing web-based information seeking tasks to a large sample of average users from a German search-engine. They found a difference in the average query length of the experts (3.64 words) and the average users (1.66 words). They also found that experts made use of advanced search options much more frequently than average users.

Because the Web is a global phenomenon, it is important to determine if there are regional differences in searching behaviour. To the best of our knowledge only a few such studies are reported in the literature. Spink et al. [8] studied the search characteristics of users from the United States and Europe. They analyzed large data sets from the Excite search engine (US) and the FAST search engine (German). Their results show differences between the two populations in terms of searching behaviour and topics searched. Kralisch and Mandl [9] found that the cultural background of users have a great impact on their search strategies. They used data gathered from logs of a large international E-Health website.

Mc Donald and Blignaut [10] tested black and white university students on how successful they searched the website of the university. No differences were found between the two groups. Blignaut and Mc Donald [2] reported on the performance of black and white grade ten school children doing different tasks on the Internet. No difference between black and white experienced users was found, but significant differences between black and white inexperienced users were found. Whereas the research in that paper focused on the success of the search, this paper will focus on the characteristics of how the school children conducted the search. This paper endeavours to add to the research on search string analysis by reporting on the differences in search behaviour of different socio-economic groups. For the purposes of this study high socio-economic standing will mean those that can afford computer equipment and Internet access and low socio-economic standing will mean those that currently cannot afford computers and Internet access.

3 Methodology

All the grade ten learners from six different schools were brought to computer laboratories of the University of the Free State in order to be tested on various aspects of Internet usage. Three of the schools were from the traditionally advantaged communities with the availability of computers and Internet access (the so-called “haves”). The other three schools were from the traditionally disadvantaged schools with a lack of ICT access and located in a lower socio-economic area (the “have-nots”). The numbers from the different schools are shown in Table 1. The learners were brought to the university in groups of 50-60 and in this way 527 learners were tested. A session is defined as a task attempted by the user by supplying at least one search string. A query is a search string entered by a user in order to complete a task. A term is the words used for each search string.

Table 1. Dataset of school children tested

School	Number	Sessions	Queries	Terms
1 – have not	132	563	821	2884
2 – have not	80	201	263	1111
3 – have not	68	264	364	1402
4 – have	97	567	895	3251
5 – have	105	484	854	3467
6 – have	45	271	462	1783
TOTAL	**527**	**2350**	**3659**	**13898**

On arrival at the university, the purpose of the test was explained to the learners. Then a short introduction and demonstration of the search engine (Google) was given. This ensured that all the learners had at least a basic understanding of how to search the Web. All the machines in the laboratory were prepared to have the Google home page on the display. Additionally, an in-house developed software tool was loaded to capture all keystrokes. This application filled the bottom 10% of the screen and the Google search engine the rest. The application required the users to answer some questions on their demographic details (gender, age, computer experience, Internet experience, language and language proficiency). Thereafter, the tasks that had to be done by means of the Google search engine were displayed. After completing a task, the user had to type in the answer. The Google home page was reloaded after each task. Because each task was separately dealt with, each task can be seen as a normal search session.

The learners had to complete seven tasks. The tasks were selected in such a way that it would be of interest to the test subjects. Two of the tasks were sports related, two were political related, two were entertainment related and one was arts related. The tasks had variable levels of complexity. Three of the tasks could be considered as easy, two were of medium difficulty and two could be considered as difficult. Three of the tasks were more relevant for the high socio-economic group, three were more relevant for the low socio-economic group and one was independent of socio-economic status (SES).

The learners' demographic details, the start and end time of each task, the search strings used, all the links followed as well as the answers to each question were written to a database. From these the search characteristics of the users were calculated (see Table 2).

For each task (session) the number of search strings (queries per session) used to perform the task, the number of search strings with advanced options and the duration of the session were determined. In addition, for each search string, the number of words (terms per query) in the search string, the number of unique links followed (pages viewed) for the search string and the number of result pages viewed were determined. These measurements were then used as dependent variables and statistically analyzed to determine if there were significant differences between these variables and the categorical factors of socio-economic standing (SES) (have/have not) and Internet Experience (IE) (novice/intermediate/experienced). Users with 5 or less previous exposures to the Internet were regarded as novice users. Users who had 6-20 previous Internet exposures were regarded as intermediate users while users who used the Internet more than 20 times prior to this study were regarded as experienced. In all cases a factorial ANOVA was done. The analysis was firstly done for all users that at least attempted the task by entering a search string. Thereafter, the analysis was repeated using only the learners who had completed the task correctly.

Table 2. Search characteristics per school

Statistic	1	2	3	4	5	6	ALL
Mean terms per query	03.5	04.2	03.9	03.6	04.1	03.9	03.8
% with one term per query	10.3	13.3	12.4	03.9	02.9	01.3	06.3
% with two terms per query	37.2	30.4	34.3	27.8	17.3	24.7	27.9
% with three or more terms	52.5	56.3	53.3	68.3	79.7	74.0	65.8
Mean number of queries per session	01.5	01.3	01.4	01.6	01.8	01.7	01.6
% with one query per session	69.5	77.1	70.1	59.4	57.2	59.8	64.1
% with two queries per session	22.0	17.9	22.7	29.8	22.5	22.1	23.7
% with more than two queries	08.5	05.0	07.2	10.8	20.2	18.1	12.1
Mean number of pages viewed per query	02.9	02.3	02.4	02.0	01.7	02.1	02.2
% viewed one summary page	97.9	98.5	98.9	94.9	98.1	97.0	97.2
% viewed two summary pages	02.0	00.4	00.8	03.9	01.6	02.6	02.2
% viewed more than two	00.1	01.1	00.3	01.2	00.2	00.4	00.5
% advanced queries	03.4	01.1	01.9	01.7	02.7	01.6	02.8

4 Results

Only 102 of the 3659 (2.79%) search strings contained advanced search parameters. Because of the low number, it was not further statistically analyzed. The first part of the statistical analysis included all users who at least attempted a task. The results for the different variables are shown in Table 3.

Table 3. Statistical results of the different variable using all learners

Variable	N	Effect	F	p
Number of search strings per task	2350	SES	7.44	0.01*
		IE	2.02	0.13
		SES*IE	4.44	0.01*
Number of words per search string	3659	SES	0.00	0.98
		IE	1.04	0.36
		SES*IE	1.82	0.16
Number of pages viewed per search string	3659	SES	26.2	0.00*
		IE	2.62	0.07
		SES*IE	5.25	0.01*
Number of result pages per search string	3659	SES	5.00	0.03*
		IE	0.86	0.43
		SES*IE	0.64	0.53

For the number of search strings used per task, both the socio-economic standing and the interaction effect were significant (α=0.05). The means for the have-nots and the haves were 1.45 and 1.65 respectively. Tukey's HSD indicated that the significant interaction was because the novice have-nots differed significantly (α=0.05) from the novice, intermediate and experienced users in the haves-group.

The number of words per search string was not significant for any of the effects but the number of pages viewed per search string was significant (α=0.05) for the socio-economic standing and the interaction effect. In this case, the means for the have-nots and haves were 1.51 and 1.11 respectively. Tukey's HSD showed the interaction effect was also because of a significant difference between novice have-nots and all the have-groups. There was also a significant difference between the intermediate have-nots and the intermediate users in the have-group.

For the number of result pages viewed per search string, the socio-economic standing was significant (α=0.05) with the means for the have-nots and the haves being 1.03 and 1.05 respectively.

In the second part of the statistical analysis, only the users who had completed the various tasks correctly, were included. This was done in order to level the playing field between the have and have-not groups. The results for the number of search strings used per task are displayed in Table 4.

A significant difference (α=0.05) was found for task 1 only, specifically with regard to the effect of socio-economic standing. The means for this task were 1.40 and 1.73 for the have-nots and haves respectively.

Table 4. Number of search strings per task for each task (p values)

Task	N	SES	IE	SES * IE
1	219	0.02*	0.21	0.86
2	152	0.66	0.48	0.50
3	43	0.37	0.91	0.08
4	177	0.23	0.21	0.86
5	75	0.37	0.90	0.47
6	94	0.59	0.53	0.56
7	171	0.92	0.56	0.86

The statistical results for the number of words per search string are shown in Table 5. For task 1 socio-economic standing was significant (α=0.05) (means: have-nots 2.42 and haves 3.22). The interaction between socio-economic standing and Internet experience was also significant. Tukey's HSD post-hoc analysis test showed that the significant effect can be attributed to a significant difference between have-not novices and have-not experienced users (0.02) as well as between the have-not novices and all experience levels in the haves-group. There was also a significant difference between have-not intermediate users and novice users in the haves-group (0.02) as well as between have-not intermediate users and experienced users in the haves-group (0.03).

For task 2, Internet experience was significantly different between the groups. The means were 3.79, 3.32 and 4.52 for novices, intermediate and experienced users respectively.

Table 5. Number of words per search string for each task (p values)

Task	N	SES	IE	SES * IE
1	342	0.00*	0.07	0.04*
2	257	0.74	0.01*	0.11
3	62	0.52	0.71	0.54
4	231	0.84	0.07	0.43
5	107	0.57	0.44	0.90
6	172	0.49	0.19	0.23
7	242	0.08	0.10	0.33

The results for the number of unique pages viewed per search string are shown in Table 6. In the case of task 2 there was a significant difference for socio-economic standing. The means were 1.45 for the have-nots and 0.82 for users in the have-groups. For task 5 there is an interaction effect which can be attributed to a small number of users in some of the cells (n=1).

Table 6. Number of unique pages viewed per search string for each task (p values)

Task	N	SES	IE	SES * IE
1	342	0.13	0.68	0.70
2	257	0.00*	0.15	0.41
3	62	0.56	0.20	0.15
4	231	0.09	0.28	0.36
5	107	0.46	0.76	0.03*
6	172	0.14	0.76	0.20
7	242	0.33	0.78	0.70

The statistical results for the number of result pages viewed can be seen in Table 7. No significant differences were found for any of the tasks. This is because the large majority of the users viewed one result page only.

Table 7. Number of result pages viewed per search string for each task (p values)

Task	N	SES	IE	SES * IE
1	342	0.32	0.17	0.18
2	257	0.15	0.97	0.97
3	62	0.48	0.58	0.58
4	231	0.27	0.58	0.87
5	107	0.70	0.52	0.32
6	172	0.21	0.58	0.58
7	242	//	//	//

// No variance

5 Discussion

When comparing the search characteristics (Table 2) of learners with the results from other studies, some interesting observations can be made. The average number of search strings per session of 1.56 is basically the same as the 1.6 reported by Spink and Jansen [4] for Web search engine users. It is, however, lower than the 2.3 and 2.9 reported for US and European users as reported by Spink, et. al. [8]. In the 2004 paper they reported that two in three users submitted only one query and six in seven did not go beyond two queries. This is confirmed by this study with respective figures of 64% and 88%. Silverstein, et al [5] reported 63.7% sessions with just one request.

According to Spink and Jansen [4] the mean query length for Excite users increased from 1.5 in 1996 to 2.6 in 1999 and 2.4 in 2003. For US users and European users the figures were 2.6 and 2.3 respectively [8]. The mean number of terms per query for this study was 3.80. This figure is more in line with the figure of 3.64 found by Hölscher and Strube [7] in a small scale study for expert users. In their study the average for a large number of users from the Fireball search engine log file was 1.66. It would appear that when users are given an explicit task to search for on the Web, they use more words per query as reported by log files. There is a tendency, especially in the case of novice users, to repeat the question as the search string.

The mean number of pages viewed per query for this study was 2.21. In the study of Spink et. al. [8] the corresponding figure for European users was 2.2 and 1.7 for US users. In a different study they reported an average of 2.35 [4]. It seems the figure reported here is quite in line with those of other studies. For the number of result pages viewed (10 results per page), it is a different story. In this study 97.2% of the users viewed only the first result page. This is substantially higher than the 70% reported by Spink and Jansen [4]. In conclusion, when discussing the search characteristic, it appears that the users in this study tend to use more words in the search string and to view only the first result page. Otherwise the characteristics are basically the same as for other studies.

Turning now to the statistical analysis of the socio-economic standing of the pupils, the following observations can be made. When including all the users, the socio-economic effect was significant for all the variables, except for the number of words used in the search string. The have-not users made use of fewer queries, but followed more links to view pages. Interestingly, there was no significant effect for Internet experience for any of the variables. There was, however, an interaction effect between socio-economic standing and Internet experience. The post-hoc tests indicated that this difference was basically between novice and intermediate users from the low socio-economic standing and the rest of the pupils. The difference can be attributed to novice have-nots utilising a much lower number of search strings per session and viewing a much higher number of pages than the other groupings. It seems as if the novice have-nots, rather than changing the search string, attempt to find the answer to the task by following more links. It can also indicate that their formulation of the search string is such that the results returned by the search string do not clearly indicate the most appropriate link to follow.

Considering only the users who had the task correct, the same pattern emerged, but only for the first two tasks. In addition, there was also a significant difference in socio-economic standing for the number of words used in the search string for task 1 only. In this case the novice have-nots made use of fewer words than the other groupings. Again this can indicate that they have problems to formulate a good search string.

6 Conclusion

Many new users from Africa with a low socio-economic standing will enter the Internet arena in the near future. It is important to know if they will search the Web differently than their Western counterparts. This paper analysed the search characteristics of grade ten high school learners with different socio-economic standings. The results seem to suggest that there is a difference in the search behaviour between novice users with a low socio-economic standing and those with a high socio-economic standing. These differences, however, only lasted for the first few sessions, where after all users showed the same search behaviour. In terms of the many new African users who may enter the internet search arena in the immediate future, it may mean that they would soon be able to find their feet using the current search engines.

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A Conceptual Model of Inclusive Technology for Information Access by the Rural Sector

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Abstract. In recent years, a growing number of projects seek to address the disparity in opportunities available to people in rural versus urban areas through *Information and Communication Technologies*. When introducing such technologies, there are a number of recognised barriers to their use and acceptance specific to rural areas. We define an 'inclusive technology' as a technology which overcomes the barriers in using technology that are inherent within a community in order to increase the available opportunities. We propose a conceptual model and a set of heuristic measurements for evaluating the 'inclusiveness' of a technology with respect to a given community, and illustrate our model by applying it to an actual real-world project. With this model we hope to achieve a better understanding of the problem, and develop a systematic process and framework for designing and evaluating technologies designed to overcome these disparities.

Keywords: social inclusion, information and communication technology, inclusive technology.

1 Introduction

There is a significant disparity in the opportunities available to people in rural versus urban areas throughout the world. This disparity in economic, education and health care opportunities, often referred to as the Digital Divide, has produced a "dual economy" with opportunity and wealth concentrated in the urban centres while rural communities languish [11]. New low cost technologies offer possibilities for addressing this disparity. However, experience has shown that simply providing access to technology is insufficient. What is required is access to the literacy that will allow people to make use of technology in order to engage in meaningful and gainful social activities [15]. We consider a technology that supports such use as 'inclusive'.

In this paper, through the use of a 'conceptual model' we investigate the factors involved in making a certain technology 'inclusive' with respect to some community. When determining the inclusiveness of a technology we consider the terms inclusive and exclusive as the end points of a spectrum which characterises to what extent a given community can use a specific technology to achieve its goals. Drawing on theoretical frameworks and empirical results from the fields of sociology and rural community development, we propose a conceptual model specifically to assess the

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Information and Communication Technologies (ICT), and a set of heuristic measurements for evaluating a technology's 'inclusiveness'. We then illustrate our model by applying it to an actual, real-world project described in the literature.

We have several objectives for proposing such a model. In recent years, projects to provide marginalised communities with access to technology have met with mixed results. We believe that understanding why certain projects succeed while others fail would be useful in developing more suitable technologies and effective programs. Currently, there is no systematic way for characterising such projects. With our model we hope to develop a better understanding of the problem by representing the key concepts, their relationships and attributes; to provide the basis for a theoretical model that can be shared by the research community; and to develop a systematic process and framework for designing and evaluating such technologies.

2 A Conceptual Model of Inclusive Technology

Definition of Inclusive Technology. At a high level of abstraction, "social inclusion" can be defined as the extent to which an individual or community can fully participate in society and control their own destinies. In the information era, the ability to use the appropriate technology plays a critical role in this regard, and there are several recognised barriers to achieving this goal. These barriers consist of (a) access to the physical resources such as devices and infrastructure, (b) to the digital information resources such as software and content, (c) to the human resources which correspond to the skills people need to extract and apply knowledge, and (d) to the social resources which refers to the broader social context in which the technology is applied [15]. However, simply addressing these barriers does not guarantee that a technology will be adopted by its intended users. According to the *Unified Theory of Acceptance and Use of Technology* (UTAUT) model, a technology must be perceived as beneficial, easy to use, and socially endorsed, with an adequate infrastructure in place to support its use [13]. To meet these objectives the technology must be relevant to the needs of the community, it must expand on existing knowledge and skills, and it must be affordable and sustainable. To be part of a sustainable cycle, the benefits that can be derived from using a technology must balance the costs. Such a technology that fits into and is compatible with its environment is considered 'appropriate' [11]. All of these factors must be taken into account for an application of technology to be successful.

Based on the above, we define an 'inclusive technology' as a technology which empowers community members to achieve more full participation in society and control over their lives. Such a technology overcomes the barriers to using technology that are inherent within a community and enables that community and its members to make positive and meaningful changes in their lives that increase the opportunities available to them. What the specific changes are will depend upon a given community's needs and values. Thus the "inclusiveness" of a technology measures to what extent a given community can use a specific technology to achieve goals that it defines for itself.

Conceptual Model. Our conceptual model is based on Maslow's theory whereby needs motivate human behaviour. According to this theory, human needs are organised in a hierarchy, with basic needs having to be satisfied before an individual is ready to act upon the ones above [5]. Needs can be considered a consequence of one's social environment. Based on the literature on rural development, we characterise the rural communities in which we are interested as follows [1], [10]:

- They are remote, making the cost of transportation and communications prohibitive
- The livelihoods of community members are largely based on subsistence activities
- Household incomes are low, at or below the poverty level
- They have limited or no public services and utilities such as schools, health clinics, banks, government services, electricity, phone lines, etc.
- Most community members speak primarily local languages
- Schooling is limited, leading to low reading and writing skills
- Most community members have had limited or no exposure to computer technology

According to our model, the rural environment in which a community is embedded largely shapes that community's socio-economic activity. This in turn largely determines a community's needs. A community is composed of individuals who are connected in one way or the other. Needs motivate an individual to identify goals whose achievement will result in a quantifiable or qualifiable gain, which is the motivating factor for undertaking that activity. Achieving these goals requires both knowledge and action. Acquiring that knowledge and acting upon it, both require a set of skills, resources and tools. We divide these latter into two disjoint subsets: ICT specific and *non* ICT specific. This is depicted in the Entity-Relationship diagram presented in Fig. 1.

Within this model, a sustainable cycle is achieved by selecting goals which result in a balance between social and economic benefits for individuals and the community as a whole. This cycle can be described as follows: 'needs' stimulate the discovery of relevant 'knowledge' which leads to 'actions' resulting in 'benefits'. As the community's situation improves, its 'needs' evolve creating more 'wants' stimulating the discovery of more relevant 'knowledge', and so forth. This process is illustrated in Fig. 2.

The dynamics of the group play a critical role in both goal selection and the sustainability of this cycle over time. Structure-functionalistic system theory provides a dynamic phase model for consolidating and achieving internal stability for such a social group, namely the "forming, storming, norming, and performing" model, with certain preconditions associated with each phase [8]. A full description is beyond the scope of this paper. The need for such a group to emerge from within the local community is among the basic principles for project success identified in [9], along with the need for a trusted 'space and place' where the community can explore the potential benefits and limitations of ICTs.

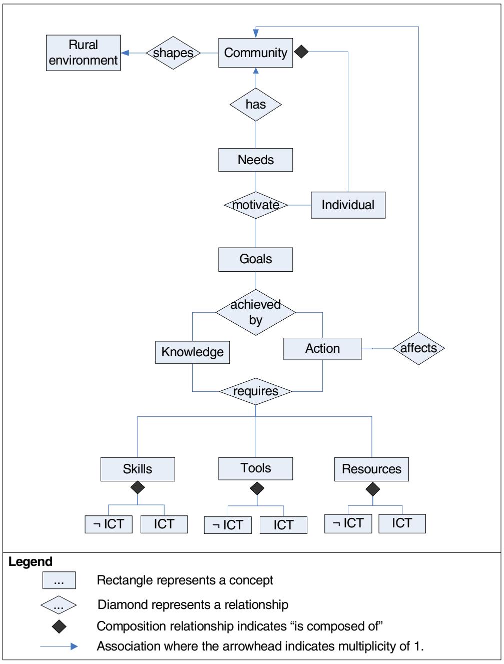

Fig. 1. ER diagram representing a conceptual model of inclusive technology

Our focus is on evaluating the ICT specific skills, resources, and tools to determine to what degree they support a community in developing the skills it needs to achieve its goals and improve its situation. Towards this end we associate certain attributes with each of the nodes in Fig.1 based on our characterisation of the rural environment and the barriers to the use and acceptance of technology described earlier. These are listed in the tables that follow.

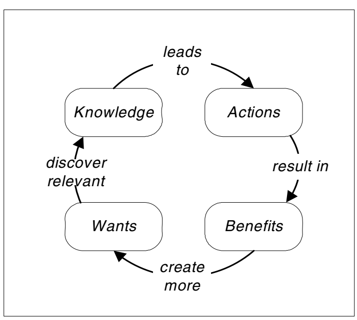

Fig. 2. Sustainable cycle

Table 1. Attributes of the environment and community

Rural environment	Community
– population density – transportation and communications – distances to other communities and urban centres – climatic conditions affecting technology	– cost of transportation and communications – availability and cost of electricity, phone lines, high-speed internet connections – current economic and social activities – organisations (political, community, social, non-governmental, private sector) – services (schools, health, banking, government, etc.) – sources of funding
Individual	
– household income – livelihood – reading and writing skills – languages – computer skills	
Need	**Goal**
– determined by the community and the individual	– defined by the community and the individual to fulfill a need

Table 2. Attributes of the ICT tools, resources and skills

ICT tools	ICT resources	ICT skills
– device – I/O and peripherals – power sources – connectivity – parts, maintenance & upgrades	– content – applications – training – peer support – maintenance and updates – consultation	– operate ICT tools – access and create content – run applications – technical and administrative support

Heuristic Measurements for Evaluating the Inclusiveness of a Technology. We have developed a set of heuristic measurements for evaluating the inclusiveness of a technology with respect to a given community. A detailed description is provided in [7]. Below we list the key questions that we use our model to answer with respect to the ICT tools, resources and skills. For each of the 7 questions, we assign a value of null, low, medium or high, resulting in a vector of 7 elements. We are currently investigating how to combine the vector elements into a single overall measurement, and how to combine the evaluations from multiple experts.

– *Is it feasible within the community's environment?* This measures how practical it is to satisfy or adapt a technology's requirements in terms of tools, resources, and skills to the prevailing conditions and constraints within a given community.
– *Is it affordable to the community?* This measures the cost/benefit of the technology with respect to the community. Here, we only consider those costs for which the

community is responsible, either on an individual basis or as a group, in terms of acquiring, operating, maintaining, using and otherwise benefiting from the technology.

– *Is it usable by the community?* This measures both the standard usability metrics as documented in the literature [12], and physical accessibility with respect to the community. Accessibility looks at whether access is restricted or open to a critical mass of people in the community, including groups that might otherwise be marginalised for political, economic or social reasons.
– *Is it relevant to the community's goals?* This measures how appropriate or significant the technology is to the community, given the community's needs and goals.
– *Is it trustworthy?* This measures the level of trust the community can place in the technology. In other words, it measures if the community can rely on the tools, can trust the resources and can have confidence in the skills.
– *Does it improve the community?* This measures to what extent the technology contributes to a positive and measurable outcome in line with the goals that the community has defined for itself.
– *Does it advance the knowledge available within the community?* This measures to what extent the technology adds to the body of knowledge that will enable the community and its members to act in the future.

3 The K-Net Services Project

K-Net is a community network that provides broadband access to 60 First Nation communities across the provinces of Ontario and Quebec in Canada. Launched in the mid-90's, it has been the subject of many well documented studies and it is considered a new model for delivering telecom services to remote, rural areas [2], [3], [4], [6], [14]. The communities served are remote, small and in sparsely populated areas, with limited or no road access. Although most people speak English, Oji-Cree and Cree are the primary languages. For decades these communities experienced high unemployment, high suicide rates, and low school completion rates. In addition, most communities lacked basic health and school services, obliging members to fly great distances for medical treatment and schooling. In 1994, a council of Northern Chiefs in partnership with the government launched a regional broadband network called K-Net Services with the goal of promoting "economic development, social capital and civic participation". In the words of one of the founders, "if the internet is the information highway of the future, then our youth should be the drivers and not passengers".

K-Net has a decentralised structure. K-Net Services negotiates with the different service providers to provide broadband services to the communities at wholesale prices. In turn each community owns, manages and maintains its own local network, buying services from K-Net according to community priorities, and offering them locally at an affordable price. Each community covers its connection costs by aggregating demand from band offices, schools, constabulary, nursing stations, businesses and subsidised on-line services along with individual use. A "champion" from the community represents local interests and is locally accountable. Champions are responsible for engaging the community in planning potential ICT projects and facilitating support for projects at all levels in the community, government and with potential partners.

The initial service offering based on extensive consultation in the communities focused on telehealth and high school education. Since then a wide range of training and capacity building programs have been developed and delivered. Current services include video conferencing, telephony, VOIP, web and email services, and e-learning applications as well as internet access for First Nation schools. Telehealth services in local nursing stations remain the most used and generate the most revenue, while VOIP provides 40% savings over standard long distance. There are currently over 38,000 email accounts and 18,000 group and hosting sites, with free registration for First Nations and members of remote communities. In addition to broad band services, K-Net also provides technical training for local network managers and technicians, on-line support and a toll free help desk. It also runs workshops for youth on web page development and content management, and hosts various community and cultural web sites and discussion forums.

4 Applying Our Model to the K-Net Project

The characterisation provided here is based on [4] which summarises an extensive archive of publicly available information on the K-Net project.

Table 3. Attributes of the environment and community

Rural environment
– Sparse population dispersed in small communities across a large geographic area. – Great distances between communities and to urban centres. – Transportation primarily by air with limited or no road access. – Prior to K-Net, communications between communities and with the rest of the world limited to community radio and public satellite television delivered by local cable. – Northern climate characterised by extreme cold in winter, high temperatures in summer.
Community
– Transportation and communications prohibitively expensive. – Electricity provided through local hydro projects or by gas-powered generator is expensive – Prior to KNet, many communities had no or one public telephone, no high speed connectivity; some dial-up connectivity in schools while very remote communities exchanged floppies. – High unemployment rates, with temporary and seasonal employment in government services, forestry and mining, supplemented by traditional economic activities that are given precedence – Communities have a tradition of sharing knowledge, pooling resources and working together – Most communities have a band office, primary school, constabulary, and nursing station. Children must leave their community to pursue higher schooling. For medical treatment and support, patients must fly to larger centres. – Government funding for access to essential services (health, education) and a variety of incentive programs to fund telecommunications access and promote economic development

Table 3. (*Continued*)

Individual	
– low household incomes – temporary and seasonal employment supplemented by traditional activities – limited reading and writing skills in English – primarily Oji-Cree and Cree with some spoken English – prior to the launch of the project little or no exposure to computer technology	
Needs	**Goal**
– health services – education – employment – social capital – civic participation	– telehealth services – high school and other education services – training programs – affordable communication between communities

Table 4. Attributes of the ICT tools, resources and skills

ICT tools
– standard devices, I/O and peripherals flown in from larger centres – powered by locally produced electricity – terrestrial, wireless and satellite connectivity within and between communities, and to external world – parts flown in from larger centres, maintenance & upgrades provided locally by a distributed network of trained community technicians. On-line help and a help desk also available.
ICT resources
– content designed for and by the communities – applications selected by and developed for the communities according to local priorities – training provided by K-Net services supported by government programmes – peer support within the K-Net community, from an emerging cross-Canada aboriginal network, and international network – maintenance and updates provided locally by a distributed network of community technicians – consultation with K-Net services, with other K-Net communities, with academia via a research institute launched by the tribal council
ICT skills
– training programmes to develop skills locally to operate ICT tools, access and create content, run applications, provide technical and administrative support

Answers to key questions. From the information available in the literature, we obtain the following answers to our questions. Based on these answers, we conclude that the technology is highly inclusive.

Feasible. The technology is highly feasible within the community's environment as the equipment and infrastructure are standard technologies, the digital resources are designed for and made available to the communities, and training and workshops are provided.

Affordable. The technology is highly affordable as by pooling resources, aggregating demand, and facilitating contact with funding sources, the services, resources, and training can be provided at an affordable price.

Usable. The technology is highly usable. Training of local management and technicians ensures that the required skills are available locally. Access to the tools is not restricted. Services are designed for and chosen by the communities.

Relevant. Communities select services according to their priorities. Resources are designed based on consultation with the communities and by community members themselves. Training addresses local needs.

Trustworthy. The network and tools are well supported through training programs and assistance. Local management and accountability provide a basis for trust while training provides a basis for confidence in the skills.

Improvement. Communities can select services according to their priorities. The resources and training provided address local community needs.

Advances to knowledge. Communities can select services according to their priorities. Resources are provided with the intent to increase the available knowledge. Training increases the knowledge available to the community.

5 Conclusion

In recent years, a growing number of projects have attempted to address the disparity in opportunities available to people in urban versus under-developed rural areas of the world using ICTs. Some of these projects have been highly successful while others have failed. Although it would be highly useful to apply the experience gained to other projects, the lack of a systematic way for characterising and evaluating these projects makes this difficult. In this paper, we propose a conceptual model that lays out the key factors involved in making a technology inclusive with respect to some community, and a set of heuristic measurements for evaluating that technology's inclusiveness, and we illustrate their use by applying them to a real-world project. By putting forward this model we hope to lay down the foundation for a theoretical framework for designing such applications of technology. With our set of measurements we hope to achieve a systematic way for characterising and evaluating these applications. Our future work includes validating our model and the set of measurements against a larger set of existing projects to ensure that they are complete and minimal, and investigating how this model can be used in the design and development of new projects intended for bridging the Digital Divide.

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Focussing on Extra-Ordinary Users

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Abstract. "Universal Access" is often focused on modifying main-stream products to respond to the demands of older and disabled people – which implies an extremely wide range of user characteristics. "Accessible" system design can produce systems which may be "accessible" but are in no sense "usable". Many system developers also seem to believe that a consideration of older and disabled people mean the abandonment of exciting and beautiful designs.In contrast, we recommend driving inclusive design from the margins not the centre, and that designers should consider a number of "extra-ordinary users" in depth as individual people, rather than as representatives of an age group and/or disability, and design for their desires, and tastes as well as their needs. This provides a reasonable design brief, and the consideration of extremes acts as an effective provocation within the design process. A number of case studies will illustrate the effectiveness of this approach. Ways in which communication with extreme users can be most effectively conducted are also described.

Keywords: older and disabled, user centred design, theatre in design, extra-ordinary users.

1 Universal Access and Older People

In 1986 CHI Schneiderman commented that " we should be aware of subtle design decisions that make usage more difficult for people with physical and mental difficulties … and not create a situation where the disadvantaged become more disadvantaged, ...[23]. In a keynote to the 1993 InterCHI, in a presentation entitled "Ordinary and Extra-ordinary HCI", [published as 11 and more recently as 14]. Newell described why this was an important research area for the HCI community. Universal Access, also called "Design for All" has been a very important concept in raising awareness amongst the human interface design community of the importance of considering a wider range of users than is traditionally the case, and has focused mainly on people with disabilities. There is no doubt that the Universal Access movement has had a very positive effect - an increasing number of HCI conferences contain papers addressing these issues, and it is heartening to see that the 2007 HCI conference has sessions which include this aspect of HCI. In addition many countries now have legislation which makes discrimination towards people with disabilities illegal, including lack of provision of, or in-accessible, equipment and services.

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Thus a great deal has been achieved, but there is much still to achieve. In particular the HCI community needs to respond to demographic trends of an increasingly ageing population, and take advantage of the challenges and advantages of designing for older people. There are now more people over sixty years of age than under sixteen in the UK and 1.1 million over eighty [24]. It is predicted that by 2030 in the UK there will be 2.3 million people over eighty, rising to 5.5 million in 2050. This pattern is a world wide phenomenon: Japan in 2002 had 18% of the population over 65, which is predicted to rise to 25% in 2014 and 35% in 2050. There is, of course, some overlap between older people and people with disabilities, and 42% of 64-74 year olds have one or more disabilities limiting their quality of life. There are, however, major differences between older people and the more traditional "disabled person" for whom assistive information and communication technology has tended to be designed.

Most older people have multiple minor impairments, which can be inter-dependent as far as HCI is concerned. The range of functionality of older people is also very great - high functioning older people have similar functionality to middle aged people, whereas low functioning older people have much lower functionality than middle aged people. There is much more pronounced minor cognitive impairments (e.g. memory and ability to learn new processes) even in high functioning older people than is found in young and middle aged people. Older people's minor impairments can make traditional assistive technology solutions to their major impairments inappropriate (e.g. hearing impairment and reduced cognitive capacity, can reduce the effectiveness of speech synthesis as an aid for severe visual impairment). Older people are much less confident with and accepting of information technology. In a recent report it was claimed that 65% of people over 65 "voluntarily exclude" themselves from new technologies [16], but Newell, argued that this "voluntary exclusion" is a symptom of new technologies not being designed for older people [12].

2 Concerns About Older People and Universal Access

On the basis both of the increasing percentage of older people in the population, and the specialist HCI requirements of this group of people, one should, perhaps, expect a greater proportion of this conference, and HCI research in general, to include these groups of users. Although "Universal Access" has had an impact on the HCI research community, there is still not sufficient serious research in the field. The community thus needs to reconsider the messages it is sending the "mainstream" research community and to designers and manufacturers of communications and information technology software and equipment.

2.1 Universal Access as an Add-On Extra

Is it possible that the message given to mainstream designers by the "universal access" concept is no longer achieving its aims, and the potential downside of this concept is that, in its full sense, it is virtually impossible to achieve for any particular system or product. If the requirement to provide a universal product is considered during the initial concept development and requirements gathering stage, the designer is faced with a user group who have an extremely wide range of characteristics and disability - very much wider than traditional user centered design is capable of including. It is difficult enough to conduct requirements gathering with a known and highly specified group of users – it can become impossible if the characteristics for which one is designing, in terms of physical, sensory, motor and cognitive abilities, to say nothing of culture, knowledge and motivation, seem to be intended to include the whole population. An additional concern is that the impression can be given universal design is focused on modifying main-stream products, recommending that, somewhere in the design cycle, designers should take account of the unusual demands of marginalized people such as older users [14] This suggests applying the "universal design" concept towards the end of the design cycle, leading to the requirements of marginalized groups being considered as an "add-on" extra to an otherwise well designed product. Not only does this patronize older and disabled people - a technological version of offering "crumbs from the rich man's table" – but is also likely to lead to significantly increased costs, and possibly to inappropriate compromises, which are bad for both the traditional and the marginalized groups of users.

2.2 Accessibility, Usability, and aAesthetics

A worrying aspect of a focus on "access" for people with disabilities, is that there is evidence that many products which have been designed to be "accessible", are in no sense "usable" by the groups for which they are apparently designed [21]. Petrie found many web sites which were claimed to be "accessible" - e.g. follow the W3C guidelines - but were virtually unusable via the accessibility options which are provided [22]. E.g. a web page, designed to be read with the eyes, which can be listened to using a screen reader – and is thus "accessible", but the text of which is incomprehensive in an auditory form.

A further concern about the concept of "universal access" is that it can bring with it some of the less useful attributes of "rehabilitation technology". In particular the lack of aesthetic considerations in the design process. Many such products show evidence that the teams that design them do not engage emotionally with the users groups and assume that older and disabled people lack any aesthetic sense, and, unlike other user groups, are motivated entirely by the functionality of products. Hocking [9] reports that in the US 56% assistive technology is quickly abandoned, and 15% are never used. It is possible that the lack of aesthetic considerations and empathy between the designers and the customers is a factor in this very high level of abandonment of assistive technology products. There can be an assumption that the additional constraints involved in considering older and disabled people mean the abandonment of novel and beautiful concepts, and, if these attitudinal constraints are over emphasized, the team will be focused exclusively on the ergonomic and technical aspects of the product.

Much computer and communications based rehabilitation technology and software based accessibility options are exclusively focused on a single disability. In contrast, an elderly user will have many minor disabilities, and may or may not have a major disability. In addition older users have reduced memory and other cognitive abilities. Although significant research effort has been put into software for people with major cognitive deficits [5] much less attention is paid to the requirements of the older user whose memory and cognitive processes have somewhat declined. The effects of these minor disabilities can be inter-dependent when they are trying to use technology. Thus, for example, speech synthesis, which is a very successful accessibility option for people with visual impairment, will not work for many older people because of reduced hearing coupled with the high cognitive load needed to cope with the reduced comprehensibility of synthetic compared with natural speech. Older users typically have reduced capacity for learning new techniques, forget them more easily, and are often much less prepared to devote a long period to learning such techniques. However, the "older user" in particular has such a wide range of characteristics that this category is not very useful as a design brief also these characteristics are subject to much more rapid change with time than is usually the case with younger people.

3 Designing for Extra-Ordinary Users

Newell [15] has raised the issue of whether it is necessary to move on from the concept of Universal Usability to a message which is more appropriate to the needs for technical support for older people in the future. He comments that true “Universal Access” - i.e. systems which can be used by everyone - is very rarely achievable, and this can have the effect of designers simply paying lip-service to an unachievable goal. Thus instead of a message which can be interpreted to say “if you are designing a new product, take account of the needs of older and disabled users (if you can) we believe that older and/or disabled users should be seen to have a different place in the design process. We argue that, rather than develop methodologies for “universal access”, we should be developing methodologies to assist in the design of products and systems for specific groups of older and/or disabled people, as an integral part of universal design. This we believe can lead better products for all users as well as for older users. In an earlier paper Newell has suggested the concept of designing for “extra-ordinary” users, and listed the advantages which this can produce not only for extra-ordinary (older and disabled) user but also for “ordinary” users in “extra-ordinary environments” (such as high work load and stress situations) [14]. Pullin uses the term “resonant design” to describe designs where the needs of the people who have a particular disability coincide with particular able bodied users in particular contexts.

It is not easy to be certain that one’s sample of users is representative even with a very constrained user group, but, for the reasons adduced above, it would be impossible to produce a set of older users who were truly representative of this population. We thus recommend that, instead of trying to satisfy the requirements of as great a variety of users as possible - and move towards a “universal” solution from this direction – design teams (which should include industrial designers, interaction designers human factors specialists and engineers working together) should be encouraged to consider a number of specific “outriders” in depth – and, initially at least, design for them in particular. These “extra-ordinary users” should contain the characteristics which are particularly relevant to user groups for whom the product is being designed. Each “extra-ordinary user” should not be considered as representing a specific disability, but should be considered as an individual person who happens to have a specific disability as well as a range of other characteristics which are important for defining them as a person, but may not be related to their disabilities. In this way the designers are given a clear picture of a person, or small group of individuals, for whom they are designing, and can develop an empathy with these potential users. Thus the design process is "user centered" in the full sense of the concept, but the lack of a truly representative sample is recognized by the team. This methodology will encourage the team to address access issues from an empathetic viewpoint. Engaging with such users can also provide a richness to the design process, and a consideration of "extreme" users act as an effective provocation within the design process, which inspires the user-centre design methodologies of design groups such as IDEO [10]

This first iteration is something of an hypothesis: if we were to design for this person (for a change!) what radical new ideas might arise? Even if the approach does not directly result in a solution for a broader population, it should challenge convention and provoke new trains of thought. As such, this process may occupy a role somewhere between traditional concept design and the techniques of critical design: "designs which ask questions rather than propose solutions"[6]. Dunne also made the point that "populations can validate a design, but individuals can inspire new thinking, therefore are invaluable at the beginning of a project"[6]. We suggest that the specific use of older people as part of the design brief can be a very powerful way of provoking designers to address important and radical issues in the design space within which they are working. Such "extreme users may have the multiple minor disabilities associated with old age, plus possibly some major disabilities, but they can also be used to provide examples of extremes of the continuum of people's knowledge of and comfort with new technologies.

3.1 From Extra-Ordinary Users to a More Universal Solution

At a later stage in the design iterations, it may become clear that the solutions the team arrive at can be brought together and provide a more universal solution, and we would argue, however, that such a design solution may well be superior to solutions based on "ordinary" users which are simply extended to take into account the requirements of "extra-ordinary" users. More radical starting points are likely to inspire more radical solutions, whereas the process of expanding or fixing mainstream products is a much more constraining. Inclusion, particularly for older users needs to be based on simplicity, and thus beginning the design process with a relatively narrow description of the user base is advantageous [19]. The alternative of having too wide a design brief leads to products with a vast array of functions and are thus bewildering and difficult to learn for everyone, but especially for older people [4]. There are many historical examples where the approach we are suggesting has been very successful.

3.2 Designs for Older or Disabled People Which Led to Mainstream Products

A number of products, which were initially designed for niche markets of older or disabled people, have led to either industry standards or universally popular product ranges. In many cases this was not a planned strategy but the products produced were so easy to use compared to conventional products that they gained a significant market share. One of the most successful of these was the cassette tape recorder, the first of which was designed specifically for blind people, and initially was not thought to have any future as a universal product because of the relatively poor sound quality [15]. The predictive typing systems now found in all mobile telephones was developed, by the authors colleagues and others, initially as an efficient alphanumeric input device for people whose physical disabilities prevented them using more than a small number of keys [1]. The UK company BT produced a large button telephone, again intended for a niche market, but which had an appeal beyond its intended user group. These are examples of products which started off with a very specific design brief, but became very successful universal products. The Ford motor company followed a version of the process suggested in this paper for their Focus car. In order to ensure that the car should be accessible to older users – the design team were provided with specially designed clothing which simulated some of the physical effects of old age by inhibiting movement. The Ford Focus is not marketed as a car for old people, but the authors would argue that, had the design team been asked to design a car and, as the final stage of the design, put on the suits to see if it was drivable by older people, and make changes as appropriate, the design process would have been more expensive and the final product, possibly less fit for purpose.

Most commercially available email and word processing packages have a great many functions. There are very few, if any users, who take advantage of the full functionality offered by such packages, and Smith [4] had calculated that it was possible to perform over 250 actions on the first page of a popular email package. The over abundance of generally unused features make finding and using a required feature difficult. There seems to be little or no evidence, however, that major manufactures are reducing the functionality, and thus increasing the usability of such packages. In contrast, a number of authors who have designed email systems, particularly for older people, have found that large amounts of functionality completely confused older people. Arnott [2], Dickinson [4], and Hawthorne [7] used techniques similar to those described in this paper, and all cases a clear design requirement was to substantially reduce the functionality. Other requirements included larger buttons, better contrast and larger font size than normal commercially available systems. All these characteristics make for an easier to use system for all but the most extreme “power users”.

The OXO Good Grips kitchen products provide another example of successful universal design based on starting at the extremes [17]. The designer wanted to produce a universal design, but the initial design brief he set was a person with arthritis and Sam Farber’s wife provided the inspiration - his first designs being specifically for her. Although a single individual was used as the initial design brief, the final product range is clearly a very successful example of universal design.

Assistive technology tends to be seen as niche products, and rarely gives the impression of being exciting and beautiful. An example of such an approach is the electronic hearing aid, which developers have attempted to make as invisible as possible. This is a major contrast to non-electronic ear trumpets, some of which were striking and beautiful. This has led to "in the ear" aids which provide greater miniaturization challenges, but are less noticeable. This designed-in invisibility has the further disadvantage of deliberately hiding the fact that the user is hearing impaired; thus conversational partners are not alerted to the need to speak more clearly and provide the conditions which facilitate lip reading. The invisible design is thought to be favored by customers, but this is particularly ironic as not realizing that a conversational partner cannot hear what one is saying can, in itself, be a significant a barrier to conversation. Walking sticks are another product where beauty plays little or no part of the design brief. There was a time when a walking stick was a fashion accessory, a very wide range of very beautiful walking sticks were available, their use indicating a person of fashion. In the 21st century, the walking stick is a symbol of incapacity or of a hill walker – both of which may be inappropriate for some users – and, on the whole, are designed for function rather than for fashion or beauty. In contrast it is interesting to note that the spectacles have moved from being prosthetic devices to fashion statements during roughly the same time period [20]

As an encouragement to re-introduce a more creative approach to design into the hearing aid market, the UK RNID (Royal National Institute for Deaf and Hard of Hearing People) in co-operation with the Blueprint design magazine and the Victoria and Albert Museum offered a competition “HearWear”, in which the design brief was to re-conceive the hearing aid and hearing technology [8] This led to a number of innovative designs some of which included the hearing aid as a piece of jewellery which people would want to wear as well as acting as an assistive device.

The HearWear entries suggested revolutionary new possibilities in hearing products for everyone, not just people who are deaf or hard of hearing, and introduced the possibility of new products which allowed everyone to control and enhance the sounds around us. For example a remote control which could block out the sound of noisy builders or a screaming child. IDEO's TableTalk concept, which allows users to hold a clear conversation in a noisy bar, was inspired by the experiences of hearing aid wearers, but helps both hearing impaired and hearing people in ways they may never have thought to ask for, despite having similar negative experiences in noisy public places. The HearWear display shows how consideration of the challenges of hearing impairment can lead to revolutionary thinking and in exciting new product designs. It also highlights the massive potential for industry to create innovative, stylish and desirable hearing products which, if they were available on the high street, would be very popular with both people with intact and impaired hearing. Such an approach would be appropriate for a wide range of assistive technology, and accessibility products.

3.3 Older People as an Integral Part of the Design Process

How then should we go about designing for older people? Because of their wide ranging physical, sensory and cognitive characteristics this group do not provide a particularly useful design brief. An alternative approach is thus needed. We suggest that, rather than aim for an unachievable “universal” solution, the design brief be restated as a small set of specific users. This is somewhat similar to the idea of developing personas which describe a particular user. However, we recommend that the designers first consider what characteristics of older users are particularly relevant for the product/system or service for which they are designing, and, rather than strive towards developing the description of "representative users", they deliberately chose to describe "extreme users". It would also be very valuable to connect the designers with real people who possess the particular characteristics of each "extreme user" such as is done, for example, in the DBA “Design Challenge” [3].

The design brief consists of a small number of users, who may seem to have very little in common, but together map out the "user space". The first design interaction may be a number of individual solutions each tailored to a specific "extreme user". It is at this point, and not until this point, that the design team attempt to bring together the various designs which they have developed to produce a final design, or limited number of designs. We suggest that this approach is likely to inspire more radical solutions and lead to designs which are truly innovative without compromising their accessibility.

Depending on the application, the design should be assessed as a product for younger, non-disabled people, as a later design iteration. This could lead to a product which does not require any modification, as occurred with the large button telephone (primarily designed for people with dexterity problems but purchased by a much wider range of people). Alternatively, a final design iteration may be needed to respond to particular requirements of a non-disabled young user, which had not previously been considered important in the design process. We suggest that, in both cases, this is more likely to lead to a product which more closely approached "universal access" than a more traditional design journey towards "universal access” may have achieved.

4 The Use of Theatre

To ensure that designers develop empathy with users with whom they do not normally interact, it is desirable for them to interact with people who embody the characteristics for which they are designing. This however may not be feasible for a range of reasons such as availability and/or cost. Newell et al [13] suggest a solution to this challenge which is to use well briefed professional actors working to a well crafted script. Versatile theatre professionals will be able to provide a personification of the particular user, or set of users within the design brief, and, if these actors are experts in improvisation, will be able to interact in character with designers, and with any prototypes which are produced as part of the design process. Newell et al point out other advantages of this approach which include a removal of ethical issues which can arise when the design brief includes fragile people, either physically, mentally, or in terms of self-confidence. An actor's ego is not involved in the character they are playing and thus the design team can be much more probing or even brutal in their questioning. An acted performance can also be a very powerful and valuable way of presenting a design to clients, with, again, the safety which comes with the use of actors.

5 Conclusion

Older people have different characteristics to those of younger disabled people for whom much assistive and accessible technology has been designed. Demographic trends show an ageing population throughout the world, for whom technological support is becoming both an economic and social necessity. The interaction challenges of older people have tended to be addressed either by a simple ”universal design” brief and/or by providing "access technology" to otherwise main-stream products as an "add-on" extra. There is an understandable tendency for designers to design for their peer group, and the unfortunate stereotypes of older people (such as them having no aesthetic sense, interest in sex, requirement to be fashionable or disposable income) make this mismatch particularly great. This paper suggests that designers be given the brief of designing for specific examples of older people, with the remit to produce a usable and beautiful product for these particular people. A number of case studies, which include very well known and respected products have been described which support these hypotheses.

As an alternative approach to the traditional approach of "universal accessibility", the authors suggest design specifically for individually specified older and disabled people, with a later design iteration which brings together alternative designs, and considers their application to young non-disabled people They suggest that this can lead to more radical, and often more appropriate, final products, and give examples where this has been the case.

The authors recommend that opportunities should be provided to encourage (usually young) designers to empathize with the user group. They recommend that the design team closely interact with people who could be considered to have the characteristics of the "extreme users" for which they are designing. They also suggest the use of theatre as a complement to direct engagement with users.

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Augmented Cognition Foundations and Future Directions—Enabling "Anyone, Anytime, Anywhere" Applications

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Abstract. Augmented Cognition is distinct from other disciplines due to its focus on using modern neuroscientific tools to determine the 'in real time' cognitive state of an individual and then adapting the human-system interaction to meet a user's information processing needs based on this real-time assessment [1], [7], [14]. Augmented Cognition systems employ the use of physiological- and neurophysiological-driven adaptive automation techniques to mitigate the effects of bottlenecks (e.g., attention, working memory, executive function) and biases in cognition. Being able to non-invasively measure and assess a human-system computing operator's cognitive state in real time and use adaptive automation (mitigation) techniques to modify and enhance their IP capabilities in any application context is a goal that could substantially improve human performance and the way people interact with 21st Century technology [9]. This paper highlights developments in the field of Augmented Cognition most relevant to future Universal Access (UA) applications.

Keywords: Augmented Cognition, human factors, ergonomics, design, neuro-ergonomics, neurotechnologies, neurophysiological, cognitive performance enhancement, training technology, adaptive automation, universal access.

1 Introduction

Augmented Cognition research and development (R&D) is distinct from other disciplines due to its focus on using modern neuroscientific tools to determine the 'in real time' cognitive state of an individual and then adapting the human-system interaction to meet a user's information processing needs based on this real-time assessment [1], [7], [14]. Such 'closed-loop' Augmented Cognition efforts seek to extend a user's abilities via computational technologies that are explicitly designed to address and accommodate bottlenecks (e.g., sensory processing, attention, working memory, executive function), limitations, and biases in cognition, such as limitations in attention, memory, learning, comprehension, decision making, and so forth. The basis of such efforts is grounded in the premise that human information processing

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(HIP) capabilities are a fundamental weak link in establishing a symbiotic relation between humans and computers and in fostering user accessibility [10]. Augmented Cognition systems employ the use of physiological- and neurophysiological-driven adaptive automation techniques to mitigate the effects of HIP bottlenecks and biases in cognition. Being able to non-invasively measure and assess a human-system computing operator's cognitive state in real time and use adaptive automation (mitigation) techniques to modify and enhance their HIP capabilities in any application context is a goal that could substantially improve human performance and the way people interact with 21st Century technology [6], [7], [8], [9], [11].

The following section highlights efforts that various government and academic labs, small and large businesses, and U.S. Science and Technology (S&T) agencies have completed or are currently pursuing in the field of Augmented Cognition. The results of these efforts have been previously presented in various conferences and journals [3], [5], [8], [10], [14] or are in press for forthcoming publications [2], [4], [9], [13], [15], [16], [17] and they represent close collaborations among scientists, developers, and practitioners from multiple disciplines, including: human factors, psychology, experimental psychology, neurobiology, neuroscience, cognitive neuroscience, mathematics, electrical engineering, and computer science. This present summary article, however, aims to present the Universal Access (UA) community with the most relevant highlights of Augmented Cognition efforts regarding research applications and tools (e.g., neurotechnologies) that could be applicable to various UA application domains. Whether the context of the UA application is an operational close-loop system (i.e., closing the loop between assessing cognitive state and initiating real time adaptive changes in the human-system interface), system design and evaluation (e.g., using neurotechnologies to enhance sensitivity and robustness of usability evaluations), education and training (e.g., using neurotechnologies to assess the transition from novice to expert or to adapt a training system in real time to meet a trainee's cognitive needs) or simply entertainment, the Augmented Cognition tools and techniques highlighted here offer the ability to create human-machine synergy and optimization never before realized with UA applications [5], [9], [12], [14], [15].

2 Highlights of Augmented Cognition S&T to Date

Augmented Cognition R&D efforts to date have resulted in a number of validated prototype and operational systems in different military application and training domains; various non-invasive physiological- and neurophysiological-based tools have also resulted [3], [9], [11]. These tools may be used in applications ranging from basic academic research to operational applications and training systems to every day computing and entertainment devices. Further, Augmented Cognition tools and techniques could also be used in the design and evaluation of most any human-system computing device, and thus enable more rapid, effective, and eventually less expensive system design and evaluation processes for such devices. Augmented Cognition R&D efforts from groups such as Boeing, Honeywell Labs, DaimlerChrysler, Lockheed Martin Advanced Technology Laboratories (LMATL), and QinetiQ, each with the aid of various sub-contractors from government, academia, and industry, have demonstrated

Table 1. Summary of Maturing Augmented Cognition Technologies and Proven Implementations to Date (reprinted and adapted with permission [9])

Sensors/Gauges (developed by who)	Use (Measures What / Implemented How)	Appropriateness for Mobile Applications
EDA (Electrodermal Activity)/GSR-based Arousal & Cognitive Workload Gauge (Anthrotronix, Inc.)	*Provides estimates of arousal & general cognitive workload* • Implemented by LMATL in a command & control closed-loop application domain	Most appropriate for stationary users; not yet tested in mobile application domains or with mobile users
EKG (ECG)-based Arousal & Cognitive Workload Gauge (Anthrotronix)	*Uses heart rate variability (HRV) measures to provide estimates of arousal & general cognitive workload* • Implemented by LMATL in a command & control closed-loop application domain	Most appropriate for stationary users; not yet tested in mobile application domains or with mobile users
Body Position/Posture Tracking (University of Pittsburgh)	*Posture shift data, head position, & head velocity are used to gauge levels of attention (i.e., engagement)* • Implemented by LMATL & Boeing in 2 different command & control closed-loop application domains • Implemented by DaimlerChrysler in a vehicular closed-loop application domain	Appropriate for stationary users in stationary or mobile application domains; not yet tested with mobile users & most likely would not be appropriate for such
Stress Gauge (Institute for Human and Machine Cognition [IHMC])	*Uses Video Pupillometry (VOG), High Frequency Electrocardiogram (HFQR ECGS), & Electrodermal Response (EDR) to track autonomic response to time-pressured, high workload tasks & to detect moment-to-moment cognitive stress related to managing multiple competing tasks & is thus good for measuring attention HIP bottleneck effects* • Implemented by Honeywell in closed-loop dismounted soldier application domains	May be appropriate for mobile users & stationary or mobile application domains
Arousal Meter	*Uses interbeat interval (IBI) derived*	May be appropriate

Table 1. (*Continued*)

Gauge (Clemson University)	*from ECG to track decrements in performance due to low arousal states in divided attention & vigilance tasks & is thus a good measure of attention HIP bottleneck effects* • Implemented by Honeywell in closed-loop dismounted soldier application domains • Implemented by Boeing in a command & control closed-loop application domain	for mobile users & stationary or mobile application domains
eXecutive Load Index (XLI Gauge) (Human Bionics, Inc.)	*Uses EEG measures to assess ability to allocate attentional resources during high workload, competing tasks & is thus a good measure of attention HIP bottleneck effects & general cognitive workload* • Implemented by Honeywell in closed-loop dismounted soldier application domains	May be appropriate for mobile users & stationary or mobile application domains
P300 Novelty Detector Gauge (City College New York [CCNY] / Columbia University)	*Uses EEG auditory P300 signals from frontal & parietal electrodes to track attentional resources used to attend to novel stimuli & is thus a good measure of attention HIP bottleneck effects* • Implemented by Honeywell in closed-loop dismounted soldier application domains	May be appropriate for mobile users & stationary or mobile application domains
Engagement Index Gauge (NASA/CCNY/ Honeywell)	*Uses EEG-based measures to track how cognitively engaged a person is in a task (level of alertness) & is effective at assessing attention HIP bottleneck effects associated with both sustained & divided attention tasks, particularly during low workload conditions* • Implemented by Honeywell in closed-loop dismounted soldier application domains	May be appropriate for mobile users & stationary or mobile application domains
New Workload Assessment Monitor (NuWAM) combined EEG, ECG, EOG sensors (Air Force	*Uses combined sensors to gauge general workload levels & estimate executive function & attention HIP bottleneck effects* • Implemented by Boeing in a command & control closed-loop application domain	Most appropriate for stationary users; not yet tested in mobile application domains or with mobile users

Table 1. (*Continued*)

Research Laboratory [AFRL])		
Fast fNIR device (Drexel University)	*Measures brain blood oxygenation & volume changes & is an effective tool for assessing spatial & verbal working memory HIP bottleneck effects* • Implemented by LMATL in a command & control closed-loop application domain	Most appropriate for stationary users but shows promise for mobile users & mobile application domains
Whole Head fNIR (Archinoetics)	*Measures brain blood oxygenation & volume changes & is an effective tool for assessing spatial & verbal working memory HIP bottleneck effects* • Implemented by Boeing in a command & control closed-loop application domain	Most appropriate for stationary users; not yet tested in mobile application domains or with mobile users
Pupillometry (EyeTracking, Inc.'s [ETI] Index of Cognitive Activity [ICA] system)	*Uses proprietary & patented techniques for estimating cognitive activity based on changes in pupil dilation & gaze & is a good measure of general cognitive workload & sensory input, attention & executive function HIP bottleneck effects* • Implemented by LMATL & Boeing in 2 different command & control closed-loop application domains	Most appropriate for stationary users; not yet tested in mobile application domains or with mobile users
Low Density EEG (Advanced Brain Monitoring, Inc.'s [ABM] 3, 6, or 9 channel cap)	*Uses a portable EEG cap, wireless transmitter, & B-Alert software to effectively estimate various types of cognitive states, namely: vigilance/arousal, workload, engagement, distraction/drowsiness, & working memory levels* • Implemented by LMATL in a command & control closed-loop application domain	May be appropriate for mobile users & stationary or mobile application domains
High density EEG (ElectroGeodesics, Inc.'s [EGI] 128 or 256 electrode net)	*Uses an event-related potential (ERP) EEG-based system to estimate which & to what degree particular brain regions are invoked during task performance; may be an effective tool for assessing both verbal & spatial working memory & general cognitive workload*	Appropriate for stationary users; not yet tested in mobile application domains or with mobile users & may be too cumbersome for such applications

Table 1. (*Continued*)

	• Evaluated but not implemented by LMATL in their command & control closed-loop application	
DaimlerChrysler's EEG system (FIRST of Berlin, Germany)	*Uses EEG combined with EOG & electromyography (EMG) to assess low versus high workload levels & is effective at assessing sensory memory bottleneck effects* • Implemented by DaimlerChrysler in a vehicular closed-loop application domain	Appropriate for stationary users in stationary or mobile application domains; not yet tested on mobile users
Event Related Optical System [EROS] (University of Illinois)	*Uses fast optical imaging techniques to identify brain region signatures resulting from cued & non-cued attentional shifts during task performance & thus may be a good estimate of sensory, attention, & executive function HIP bottleneck effects* • Evaluated for potential implemented in Boeing's command & control closed-loop application domain	Appropriate for stationary users in stationary or mobile application domains; not yet tested with mobile users
Cognitive Monitor [CogMon] (QinetiQ)	*Uses behavioral measures from interactions with cockpit controls, EEG-based physiological measures, subjective measures, & contextual information to assess stress, alertness, & various workload levels & is effective at assessing all 4 HIP bottleneck effects* • Implemented in both a military fast-jet simulation & a command & control application environment • Planned for implementation efforts in support of Boeing's AugCog program in their command & control closed-loop application domain	Appropriate for stationary users in stationary or mobile application domains; not yet tested with mobile users

enhanced cognitive performance ranging from 100% to over 500% improvement in HIP targeted bottlenecks (i.e., working memory, executive function, sensory input, and attention) when Augmented Cognition-enabled tools and techniques were implemented. These results were demonstrated with various operational prototypes, such as a U.S. Air Force unmanned aerial vehicle control station, U.S.M.C. smart vehicle system, U.S. Navy fast mover jet simulation, and U.S. Army dismounted-mobile soldier operations) [3], [9], [11]. These advanced closed-loop systems have clearly demonstrated the feasibility, functionality, and practicality of Augmented Cognition-enabled applications and neurotechnologies that have been developed in recent years and continue to be developed by the hundreds of scientists, engineers, and practitioners from diverse yet complimentary, Augmented Cognition-related disciplines.

Table 1 provides a summary of the most promising physiological (e.g., electro-oculography [EOG], heart rate [HR], galvanic skin response [GSR], blood pressure [BP], and pupillometry) and neurophysiological sensor tools currently being used in Augmented Cognition-enabled applications to detect users' cognitive functions in a variety of application domains and environmental conditions [9]. These tools include: stress and arousal meters; engagement indices; portable electroencephalography (EEG), electrocardiography (ECG, EKG), and functional near infrared (fNIR) devices, posture/body state analyses; and pupillometry. The sensors/gauges presented in Table 1 are highlighted because they have been shown to be most sensitive and diagnostic thus far in assessing or inferring cognitive state in real time, while also considering UA relevant requirements (e.g., portability, usability in the field, minimized potential intrusion on user task performance, and potential electromagnetic interference [EMI] during combined sensor/gauge implementation in operational settings). It should be noted that the list in Table 1 is by no means all-inclusive (for a thorough review of available sensors, see NATO report on Operator Functional State Assessment [18]. Furthermore, many of tools highlighted here may be used individually or combined in various ways to assess multiple HIP bottlenecks, as well as other human-system computing and UA task factors (e.g., context, environmental stress effects, individual differences, etc.).

For more detailed discussions of the various applications of the tools presented in Table 1 in a variety of UA-relevant task environments, readers are encouraged to survey the proceedings articles from the first [5] and second [14] Augmented Cognition International (ACI) conferences and the forthcoming publications and conference events highlighted in the next section.

3 Highlights of Forthcoming Augmented Cognition-Relevant Efforts

The contributing authors of the following efforts are playing integral parts in building the foundations and future of the field of Augmented Cognition.

3.1 Aviation, Space, and Environmental Medicine (ASEM) Special Supplement on Operational Applications of Cognitive Performance Enhancement (CPE) Technologies [4]

This ever-increasing rate of Augmented Cognition S&T advancements continues to challenge practitioners of this burgeoning scientific discipline to report, document, and communicate their findings [11]. This special supplement represents one of several forthcoming efforts to capture the essence of the ongoing Augmented Cognition work. It documents existing and emerging achievements in CPE R&D across agencies and institutions. Discussion topics include: operational utility for objectively classifying cognitive state or enhancing cognitive performance during biologically-stressed or increased workload conditions; guidance for the design of CPE technologies that can accommodate such real world cognitive stressors (e.g., sleep deprivation, workload, physical exertion); cognitive metrics and team cognition and performance from both a theoretical and a practical perspective; and considerations for when transferring CPE technology R&D from the lab to the field.

3.2 IEEE Engineering in Medicine and Biology Magazine Special Issue on Optical Imaging of the Intact Human Brain: Physiology, Recording Devices, Methods and Applications [2]

This special issue includes a collection of papers that address the use of optical devices to measure brain activity in humans in non-invasive manners (e.g., via fNIR devices). Although the existence of optical changes accompanying neuronal activity has been known since the 1940's, non-invasive applications to human physiology and cognition are just now emerging and maturing. The latest discoveries and advancements in operational applications of optical imaging R&D are presented.

3.3 Journal of Cognitive Engineering & Decision Making (JCEDM) Special Issue on Augmented Cognition: Past, Present, and Future [13]

This special issue presents: R&D papers in the field of Augmented Cognition, state-of-the-art in associated supporting technologies, and perspectives on future developments and applications. It follows an overarching theme that integrates fundamental research with design and implementation papers. Topics addressed include: integrating real-time physiological sensors into the context of ambulatory tasks; development of real-time physiological sensors that may be more accessible than current EEG and other sensors; effective calibration methods for identifying effective comparison conditions of users (i.e. baselines) to avoid bias in detection of cognitive state changes; establishing a conceptual framework to guide real-time event-based selection of mitigation strategies based on user physiological and behavioral responses; establishing robust architectures to coordinate adaptive automation strategies; and issues of privacy, autonomy, and culpability associated with particular types of embedded (or more *invasive*), Augmented Cognition-enabled technologies.

3.4 Augmented Cognition: A Practitioner's Guide [16]

This book provides an overview of the general approaches to Augmented Cognition R&D that have been adopted to date and describes resulting toolkits that have been developed. This book is meant to be a hands-on guide that provides frameworks and toolkits to guide the efforts of those who aim to become involved in Augmented Cognition R&D or those who simply want to develop a general understanding of Augmented Cognition R&D practices and technologies. It depicts the discoveries and challenges that most any Augmented Cognition researcher, developer, or practitioner may face in our 21st Century human-computing society.

3.5 Foundations of Augmented Cognition, 3rd [12] and 4th [15] Editions

The Foundations of Augmented Cognition series of edited books represents what have become leading references on the field of Augmented Cognition. Similar to the 1st [5] and 2nd [14] editions, the 3rd and 4th editions will bring together a diverse and comprehensive collection of works from international researchers, scientists, engineers, and practitioners working in the field of Augmented Cognition and related fields. Authors contributing to the studies in the 3rd edition will be present their work at the third ACI Conference being held in conjunction with HCI International in Beijing, China in July 2007 (see: www.hcii2007.org); the 4th edition represents studies to be presented at the 4th ACI Conference being held in conjunction with the Human Factors and Ergonomics Society (HFES) 51st Annual Meeting in Baltimore, MD in October 2007 (see www.hfes.org/web/HFESMeetings/07annualmeeting.html).

4 Conclusion

Particular emphasis in this summary article was given to how results and lessons learned from emerging and maturing Augmented Cognition S&T to date may directly impact the future of the UA field via the design of Augmented Cognition-enabled 'anyone, anytime, anywhere' applications. The aggressive goals and objectives required of U.S. government and Department of Defense funded programs [6], [8], [10], [17], [11] have fostered the development of many neurophysiological-based tools and techniques that are maturing enough to become feasible toolsets for HCI researchers, designers, and practitioners in their pursuit of improving human-computer system efficiency and effectiveness and user accessibility [9]. This summary article elucidates the premise that there is a clear link between the fields of Universal Access and Augmented Cognition and that such links should continue to be fostered.

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Privacy and Interruptions in Team Awareness Systems

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Abstract. Several evaluations of team awareness systems showed, that interruptions and privacy violations during usage often lead to the rejection of the system by users. Most authors argue that this rejection is due to a fundamental dual trade-off between sending awareness information and privacy, and between receiving awareness information and disruption or resource consumption. While the assumption of a fundamental trade-off is widely accepted in state-of-the-art research, this paper disputes the predominant hypothesis. Instead, it is argued, that the trade-off is not of fundamental nature, but caused by neglecting elementary aspects in the design process. In order to verify this line of argument, a novel interface concept for mediating socio-emotional awareness information is presented. To verify the validity of the conceptual approach, several evaluations were conducted. The evaluations verified the approach of this paper and showed, that a cautious interface design can enhance user privacy in multi-user awareness systems and minimize disruptive effects on primary tasks, without reducing awareness mediation and usability.

Keywords: Privacy, Interruptions, Team Awareness Systems, Dual Trade-Off, Evaluation.

1 Introduction and Motivation

In intellectual teamwork, implicit communication in form of mutual awareness is an important requirement for a shared understanding and knowledge about ongoing and past activities within a team [12]. Mutual awareness usually leads to informal interactions, spontaneous connections, and the development of shared cultures, all important aspects of maintaining working relationships [1]. Especially information about presence and availability of remote colleagues is of high value during the daily work process. In a local work environment, this information is continuously available and picked up by those present. Teams, which are geographically distributed, by their nature, are denied the informal information gathered from a physical shared workspace [3]. These shortcomings led to the development of a variety of so-called 'awareness systems', dedicated applications for supporting awareness between different groups and places. A number of these systems have been tested in real world situations [e.g., 8, 1, 13]. Although it was shown that the installations had some success in getting people to communicate more easily, all systems were abandoned

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after the demonstration period [7]. The rejection of the systems was due to serious usability problems caused by recurring interruptions and privacy violations.

In the literature, this problem is often referred to as the dual trade-off between the level of awareness and the potential for privacy intrusion and disruption of one's current tasks. The first trade-off of 'Informativeness vs. Privacy' is caused by the fact, that, if the current status of a person is conveyed fully enough to be useful to others, it often violates that person's privacy [5]. The second trade-off describes the problem of 'Information vs. Interruption'. In general, the more information one receives about the activities of remote colleagues, the more awareness is mediated, but the greater the chances that the transmitted information will become a disturbance to the primary task [2]. Like most other authors, Hudson and Smith [2] argue, that this dual trade-off between sending awareness information and privacy, and between receiving awareness information and disruption or resource consumption, is fundamental at some level. While the assumption of a fundamental trade-off is widely accepted in state-of-the-art research, this paper disputes the predominant hypothesis. Instead, it is argued, that the trade-off is not of fundamental nature, but caused by neglecting two elementary aspects in the design process.

First, current implementations do not take into account, that awareness information is perceived as a continuous secondary task. While content-oriented communication, like e-mail or chat, is usually performed as a primary task, the perception of environmental information is done as a secondary task. Most team awareness systems do not consider this fact and try to mediate awareness as a primary task, requiring full attention or considerable input from the user. Second, the increased local mobility of the team members requires the information to be displayed in public and semi-public areas. With the transition from an individual to a group situation, new privacy problems arise, which are not adequately approached in the design of current awareness systems. Using traditional single-user interface policies to provide personalized information in public spaces, will inevitably lead to privacy violations.

2 Goal and Concept

The goal of this paper is to show, that the problems described above are not inherent in the information itself or its processing, but caused by the way the data are collected and represented. In order to verify this hypothesis, a novel interface concept for mediating socio-emotional awareness information in group situations was developed.

The conceptual design process was guided by two goals. First, it was aimed to provide users with 'lightweight' awareness devices, that help members of a distributed team to communicate in a natural way. In contrast to most existing approaches, awareness should be provided via a natural communication channel, that enables people to be aware of each other, in a subtle, warm and expressiveness way, which can be easily perceived on a human level. Second, the interfaces should be adapted to the changing requirements of emerging office concepts as well as to the increased mobility of employees within the work environment. As office workers get more and more mobile within the office space, the conceptual system design aims to support awareness and informal communication through natural interaction in public areas, using intuitive interfaces integrated into an open office landscape.

This is achieved by combining various artefacts, which are integrated into a smart office environment and tailored to the needs of distributed teams. Ambient displays and sensors are embedded into the physical surrounding to communicate information and support implicit interaction mechanisms. These stationary artefacts are complemented by personal mobile devices, that help users to preserve their privacy in public space and access personalized information.

3 Novel Interfaces for Mediating Awareness Information

Based on the conceptual approach, different prototypes of mobile and stationary artefacts were developed, which use a common sensing infrastructure to support user interaction. The following paragraphs give a brief overview over the different artefacts and their main functionalities. For details on the developed artefacts see [10] or [11]. To enable user-controlled identification processes as well as personal role management, a mobile control device called *Personal.Aura* was developed. The *Personal.Aura* is a mobile device enabling users to control their appearance in a smart environment by deciding on their own, whether they want to be 'visible' for remote colleagues, and if so, in which 'social role' they want to appear. *The Personal.Aura* is a compound artefact consisting of a *Reader Module* and several complementary *ID Sticks* (see Fig. 1). Every *ID Stick* symbolizes a different social role and contains a unique identification code. If people want to signal their presence to remote team members, they can do so by simply connecting a specific *ID Stick* to the *Reader Module*. As soon as both parts are physically connected, the user is identified with the digital profile linked to the specific *ID Stick*. Disconnecting both parts immediately stops the identification process.

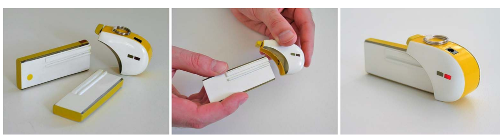

Fig. 1. Activation of the Personal.Aura artefact by connecting an ID Stick to the Reader Module

Fig. 2. Hello.Wall artefact showing different light patterns depending on the social situation

In order to represent the information in the users' environment, a wall-sized ambient display called *Hello.Wall* was developed. The *Hello.Wall* uses special light patterns to communicate information in an ambient and unobtrusive way. Sensors embedded in the *Hello.Wall* artefact enable context-dependent information representation. By restricting the reading range to a defined area around the artefact, it is ensured, that people are only sensed, when identification information is necessary in order to provide personalized services. The distance of an individual to the *Hello.Wall* determines the type of information visualized and forms of interaction, which are possible.

To demonstrate the potential of this approach, an exemplary pattern language (see Fig. 3) was developed to visualize information in an ambient and unobtrusive way. The goal was to improve workplace awareness and support opportunities for brief encounters between remote colleagues. In order to support awareness and informal communication, light patterns for the following information were designed: (1) the general mood of the remote team, (2) the general activity in the remote work space, (3) the presence and availability of certain team members, and (4) the interest for communication with a remote team member.

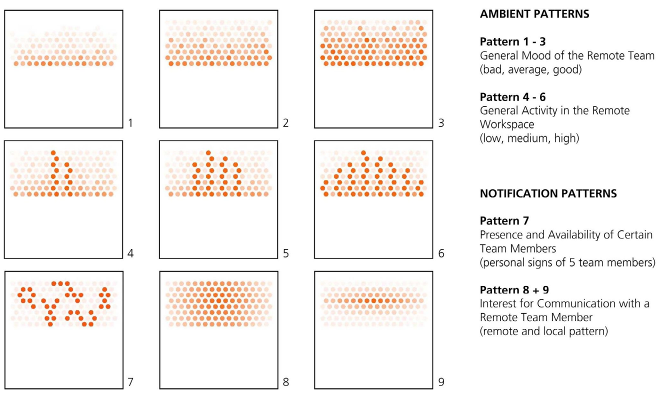

Fig. 3. Light patterns for the Hello.Wall

The functionality of the *Hello.Wall* is complemented by mobile device named *View.Port*. The *View.Port* complements the functionality of the *Hello.Wall* artefact by providing additional in-depth information depending on the individual context. Through the private nature of its display, the *View.Port* enables users to access personal information in public spaces, without violating individual information privacy.

4 Evaluations

To verify the validity of the conceptual approach, and to confirm the added value of the technical prototypes compared to related research results, the developed artefacts were evaluated in a two-step process. To capture subjective, as well as performance related aspects, a combination of qualitative and quantitative evaluation techniques was employed. In a first experimental evaluation, the pattern representation used to visualize information at the *Hello.Wall* was compared to a video representation, which is currently the most-widely used representation form in multi-user awareness systems. Both representation methods were compared regarding their suitability to provide awareness information, their disruptive effects on work, as well as privacy concerns that arise during usage. In a second step, all artefacts were tested under real-world conditions for several weeks, in order to investigate their potential for supporting awareness and informal communication in a distributed team.

4.1 Experimental Evaluation of the Representation Method

Awareness information is usually delivered as a continuous secondary task, requiring users to rapidly and frequently switch between some other primary task and the awareness task. Consequently, the information should be presented in a subtle and non-distracting way. With the design of the *Hello.Wall* artefact, a novel approach regarding the visualization of awareness information was taken. Instead of using a traditional graphical display, the awareness information is visualized in the users' environment using ambient light patterns.

In contrast to the abstract patterns used to visualize information on the *Hello.Wall*, most multi-user systems show concrete visual information to support awareness. As video-based systems have proved to provide valuable information for distributed work, the light patterns developed for the *Hello.Wall* were compared to a simulated video connection. Following the current trend of providing peripheral awareness information in public and semi-public areas, both representation forms were visualized on a large public display. In a controlled experiment, users were confronted with both representation methods, using the same information and representation device. The goal of this comparison was to show, that the approach described in this paper is superior over traditional forms of information representation. To proof this, both forms of information representation were compared regarding their suitability to provide awareness information, their disruptive effects on work, as well as privacy concerns that arise.

In a simulated work situation, presence information about a fictive remote team was shown to the participants, while they were working on a primary task. A large display was used to show a recorded sequence, using the two different representation forms. Once the awareness information was presented in form of a video link, the other time the same information was visualized using *Hello.Wall* patterns.

In the video condition, the participants were shown a pre-recorded video sequence showing a fictive office with five employees. In the pattern condition, the presence of the team members was symbolized by different personal signs, that were displayed for the time the person is inside the office. To measure the effects of both representation forms regarding distraction and interruption, a special application was developed. The program consists of a computer game and an interface to indicate the perceived changes in the presence state. The computer game was designed to be particular sensitive to interruptions and distractions. Similar to a pinball machine, the player has to avoid balls from falling down by returning them with a paddle. With a simple mouse click the game is paused and the program switches to the ‘awareness interface’. Here, the participants can indicate the presence or absence of the team members by clicking on their picture or personal sign. A second mouse click resumes the game.

The performance in playing the game and in perceiving the presence information was analyzed through log files that were recorded during the whole evaluation. A purpose-build analyzing software continuously tracked the state of every button and automatically generated a graphical overview of the button states. The software also tracked the number of lost balls and periods during which the game was paused to determine the task performance. In addition, a video analysis was performed, to find out how often and how long the participants had to look at the display to pick-up the presence information. The duration and frequency of glances to the display were used as indicators for the degree of interruption. Besides these objective, performance-oriented criteria, it was also aimed to acquire subjective user impressions as more intuitive measures of mental workload. Therefore, different kinds of questionnaires were used to examine how the participants judged their own performance and how exhausting they found playing the game. If the method of presenting the awareness information influences the atmosphere and the concentration, there are probably differences in those subjective judgments depending on the representation technique.

During a two-step experiment both sequences were shown to N=47 participants. The participants were divided into two groups, which differed only in the chronological order of the presented representation sequences. While the first group started with the pattern representation and saw the video representation in the second step, the order was the other way round for the second group. To make sure that the participants would be able to keep concentrated at a constant level, the test consisted of two parts of 23 minutes each. During this time the participants were asked to play the game and to keep track of the presence of each of the five people in the fictive remote office. Perceived changes concerning the presence of each remote team member had to be adjusted in the awareness interface immediately. After each test section, the participants filled out questionnaires, rating the recent representation concerning distraction and usefulness as well as their individual performance in playing the game and being aware of the remote colleagues. In the end, a third questionnaire was used to compare both representation forms. A detailed description of the evaluation procedure and results can be found in [4].

The evaluation showed, that the pattern representation used for the *Hello.Wall* significantly reduces distractions. The pattern representation was rated significantly more often as less distracting than the video representation. In addition, the performance in the game was less affected through the pattern representation. When using the video representation, the participants dropped highly significant more balls while receiving the awareness information, which has to be regarded as an indicator for a higher degree of distraction.

Using video for awareness mediation has the advantage, that users do not need any practice to understand the way of information representation. The log files proved, that the participants made fewer mistakes while interpreting the information when using the video representation. This might be explained by the fact, that the participants are used to remember the appearance of other humans, while they are not used to remember abstract patterns. Therefore, the participants had to cope with an additional load of learning and remembering the patterns while using the pattern representation. This additional load would be reduced, if the users already knew the patterns and their meaning. As an evaluation of the employed pattern language [6] showed a learning effect over time, it is likely, that the performance of interpreting the awareness information will improve with usage. For both representation forms, there was no significant difference in the frequency of temporal misinterpretation, where persons were perceived as 'present' although they were 'absent'. However, there were highly significant more temporal misinterpretations of 'absent' people while using the video representation.

In contrast, the recognition of persons leaving the fictive office was better, when using the video representation. But regarding the collaboration of teams, being aware of a person entering the office, and thus being available for immediate personal contact, is usually more valuable than recognizing, that someone had just left the office. One may wait for a colleague to enter the office to talk to him or to schedule something. When a team member leaves the office, information about the reason and duration of his absence are usually more helpful than just knowing, that he has gone. So, in this specific application domain, it might even be seen as an advantage, that only the more valuable presence information is perceived. This is also reinforced by the fact, that in the final questionnaire significant more participants rated the video representation as more distracting than the pattern representation. In addition, the privacy concerns, when using the pattern representation, are significantly lower. The evaluation of the questionnaire data showed further, that highly significant more participants preferred the pattern representation over the video representation, when making information about their own presence available to remote colleagues.

Hence, the evaluation supported the approach of using ambient patterns to visualize awareness information. It could be shown, that using a pattern representation significantly reduces distractions and privacy concerns, without negatively effecting the perception of awareness information.

4.2 Living-Lab Evaluation of Artefacts

In order to investigate the potential of the developed devices for supporting awareness and informal communication, all artefacts were tested in a living-lab evaluation over several weeks. The goal of the evaluation was, to create personal connections between remote team colleagues by establishing awareness moments, and supporting community interactions between both sides.

To evaluate the artefacts under real-world conditions, a symmetrical configuration of two *Hello.Wall* artefacts with additional video-conferencing facilities was installed at two remote work spaces of a distributed team [9]. The first set of artefacts was installed at Fraunhofer IPSI in Darmstadt (Germany), the second at the Laboratory of Design for Cognition, EDF R&D in Clamart (France). In each office space, five members of a distributed team were equipped with pre-versions of the *Personal.Aura* artefact. All participants had personal symbols assigned to them that were shown on the remote *Hello.Wall*, each time they entered the local common area. The individual symbols were designed to overlay the ambient patterns, which continuously display the average mood and activity level of the team.

To prepare the ground for informal face-to-face communication, the test installation aimed at supporting the team members on both sides in approaching each other by successive signals of agreement, before actually engaging in a conversation. Therefore, special 'request buttons' were installed, which could be used to express the interest for a video communication with remote users. Pressing the request button results in an attention-catching pattern, which is shown on the *Hello.Wall* at the remote site. The overall mood of each team was captured with an easy, but very effective three-button interface. After one of the 'mood buttons' (bad, average or good) is pressed, its respective value is added to the overall mood of the local team, and the updated mood pattern appears on the *Hello.Wall* in the remote common area. Thus, the *Hello.Wall* continuously presents an intuitively perceivable picture about the atmosphere at the remote site in an ambient and unobtrusive way. In addition, webcams were installed at both sides to provide short glances into the remote common area. The webcams could be accessed from the remote side using a *View.Port*, which provide users with more-detailed information about the current situation in the remote lcommon area. To avoid misuse, a special pattern is displayed at the *Hello.Wall*, if a remote colleague is using a *View.Port* to glance into the common area.

Fig. 4. Request button (left) and mood button (right)

Fig. 5. Person detected via the Personal.Aura (left), and personal signs showing the presence of two colleagues in the remote common area (right)

The members of the distributed team were engaged in a joint activity of preparing a final report for a multi-national project. Additionally to this task, all participants were also collaborating with local colleagues, who were not part of the distributed team. All employees were using the same local common area, but only the members of the distributed team were equipped with *Personal.Aura* artefacts, and were familiar with the meaning of the team patterns. The participants were asked to press one of the mood buttons every time they come into the common area, and when entering or leaving the office building.

The observation and evaluation took place over a period of three weeks for three days a week. Each morning and afternoon the participants filled out a daily questionnaire, explaining their personal mood, and judging the perceived atmosphere and activity of the remote team. In an additional weekly questionnaire, which was given to the participants at the end of the week, they were asked more general questions about the usage of the *Hello.Wall* artefact, and their communication behavior with remote team members. After the evaluation period, all team members described their impressions and experiences in a final questionnaire, and evaluated the influence of the artefacts on the communication behavior of the team. In addition to the questionnaires, a camera system, mounted at the ceiling above the common area, was used to observe the behavior of the participants. Figure 6 shows some pictures taken by the observation cameras during the field study.

The results of the field test proved the effectiveness of the developed artefacts and confirmed its positive effects on workplace awareness and group communication. The data extracted from the questionnaires showed, that more interactions between both labs took place, and that the video communication system was used more often than before. The test installation was appreciated for providing a feeling for the atmosphere at the remote site and the number of people present, without disturbing the participants' privacy and workflow. User found it very helpful to see "who is there", and seemed to gain experience of how the remote colleagues work, and the way the lab is organized. The *Hello.Wall* was described as "a good measure to establish an everyday relationship with people, who are not physically present", and to improve the atmosphere in the lab "by taking it from isolation".

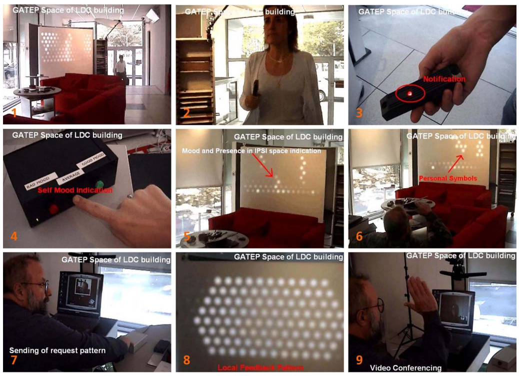

Fig. 6. Impressions of the field study: (1) common area at EDF, (2) user entering the common area, (3) identification via Personal.Aura prototype, (4) expression of current mood using the mood button interface, (5) Hello.Wall showing the overall mood and activity of the remote team members, (6) personal signs indicating the presence of two team members in the remote common area, (7) user sending communication request to remote colleagues, (8) local feedback pattern, (9) informal communication using the video-conferencing facilities

It could also be shown, that the *Hello.Wall* can serve as an unobtrusive awareness device in real-world working environments. While the members of the distributed team gained practical benefits using the *Hello.Wall*, the artefact did not attract any attention of people who were not participating in the joint activity, but eventually were spending some time in the common area around the *Hello.Wall*. Details of the evaluation can be found in [6].

5 Conclusion

The results of the evaluations led to the conclusion, that the predominant assumption of a fundamental trade-off in multi-user awareness systems is not tenable anymore. The evaluations verified the approach of this paper and showed that a cautious interface design can enhance user privacy in multi-user awareness systems and minimize disruptive effects on primary tasks, without reducing awareness mediation and usability. In addition, the developed artefacts successfully demonstrated that dedicated devices for capturing and representing awareness information in smart office environments have great potential to enhance the functionality as well as usability of multi-user awareness systems.

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On Developing Validator Software XValid for Testing Home Pages of Universal Design

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Abstract. The current development of the Internet and its growing use makes it necessary to satisfy the needs of all users including those with disabilities having accessibility problems. Therefore we developed a new validator software called XValid, which is a human controlled testing tool for specific needs in light of design for all. We used the well-known WebXACT and this newly developed XValid validator for testing governmental, commercial and e-learning web pages. We made a comparison between both testing results. Based on these results we want to open web-designer's eyes to the typical errors.

Keywords: WEB, W3C, validator, accessibility, website, checkpoint, web design, usability test.

1 Introduction

The average web-designers do not take the specific needs of the handicapped users into consideration, in spite of the fact that there are several guidelines available for a software product to be accessible with minimal requirements [1]. For example the current amount of keyboard support in most common web sites is far from being sufficient [2]. Therefore we have developed a checklist and validator software XValid [3] for testing home pages and e-learning materials from the viewpoint of universal design based on the guidelines of WCAG 2.0.

Numerous validators are available as free services, for example W3C Quality Assurance Tools [4], WebXACT [5], Opera [6]. Every one has advantages and disadvantages too.

WebXACT is a free online service that lets you test single pages of web content for quality, accessibility, and privacy issues.

Opera is an easy way to browse the Web. Opera powers the Web on any device.

The W3C Quality Assurance Tools are almost universal tools for validating Web Standards, languages and CSS style-sheets, moreover it has Specific Tools - for Specific Needs, for example: RDF Validator [7] checks and visualizes RDF documents

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- Feed Validator [8] checks newsfeeds in formats like ATOM and RSS.
- P3P Validator [9] checks whether a site is P3P [10] enabled and controls protocol and syntax of Policy-Reference-File and Policy.
- XML Schema Validator [11] is a form for checking a schema, which is accessible via the Web.
- MUTAT [12] is a human-centered testing tool (framework).

Almost all of these tools are web-based, are available both as downloadable source, and as free services on the w3.org site.

González and co-workers proposed a remote testing approach, performing navigability testing in the user's home, employing special silent data gathering software agents, which are able to measure the user accuracy when performing navigation tasks [13].

The University of Illinois at Urbana/Champaign has developed a set of HTML best practices and accessibility management and visualization tools to improve the design and verification of the functional accessibility of web sources [14].

Unfortunately none of these is universal, which controls at the same time the accessibility and usability viewpoints of the following user groups: standard users, blind people, visually impaired people, deaf people, hearing impaired people, people with mobility and movement problems, people with cognitive problems and, elderly people.

The XValid validator is a human controlled testing tool for specific needs in light of accessibility and usability. Usability in the Web design has to cope with important elements like: Perceptibility, Understandability, Operability, Memorability Efficiency, Technical robustness because accessibility and usability have technical aspects as well as human interaction aspects. [15] The XValid validator software examines these elements too.

2 Developing the XValid Validator Software

XValid was developed with .Net framework 2.0. The code license of validation core is free, so anyone can build, modify or distribute it. It's a traditional desktop application, but because the validation core is a standalone library an online version is possible. XValid's main advantage is WCAG 2.0 conformity and the free availability.

The application is divided into two parts: the validation core and the graphical user interface.

Validation core is a standalone library, and it's capable to work without the GUI, so a later online version, or a non-Windows version is possible (although, the P/Invoked FreeImage may be a problem in this case).

The process (and application usage) is very simple from the user's point of view. After starting the application, the following form is displayed (see Figure 1).

The application can analyze local files from the computer's file system, or a specific URL. In the first case the user clicks on the "Browse" button, and in the well-known Windows-way, selects a file. In the second case the user enters the exact URL into the textbox. After that the "Check" button can be pressed and some seconds later the report is appearing in the large white area. This report can be saved with the "Save Report" button.

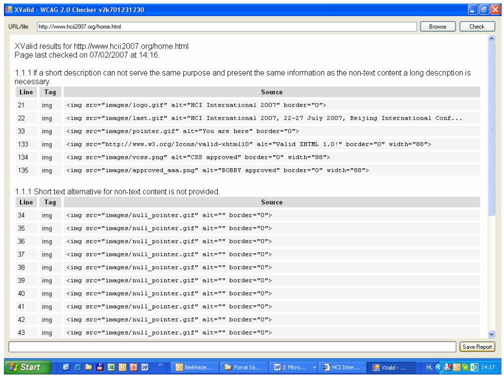

Fig. 1. Testing the HCI 2007 conference home page with XValid

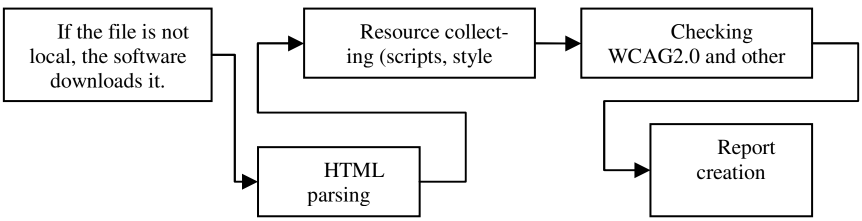

Fig. 2. The validation process

The following guidelines are checked at this stage:

1.1.1: Alternative texts, Image maps (client- and server-side), Short descriptions, Long descriptions
1.3.1: Alternative texts
2.4.3: Titles
2.4.4: Alternative texts
3.1.1: Text direction and language
3.2.5: User requestable functions
4.1.1: Tag closings, Unique ids
4.1.2: Captions, Labels

The validation core tries to analyze every image for improper sizing, every script for unsafe functions (windows.open(), window.alert(), browser-specific codes…) and every style sheet for improper styles (although not capable to cover every problem).

The application is actually growing every month. (Not every guideline can be checked (even not by software)).

The software uses the following 3rd party libraries:

- FreeImage.NET 3 - this is a free wrapper for the excellent FreeImage (which is used under the "FreeImage Public License - Version 1.0"), a free open source graphics library.
- Self-modified version of MIL HTML Parser.

3 Websites Accessibility Analysis

The Web Content Accessibility Guidelines 1.0, were created in 1999 by the W3C, aiming to explain to web designers how to make the web content accessible for people with disabilities [16]. The document includes fourteen guidelines, or general principles of accessible web design. Each guideline includes a statement and an explanation. We tested Hungarian, English and German languages journals, Web Shops, Government Sites, TV channels' sites, e-learning and further home pages with WebXACT for checking these guidelines as well as with our newly developed XValid validator. The Web Content Accessibility Guidelines 2.0 is under construction, it has four principles and 13 guidelines [17].

3.1 Categorization of the Tested Sites

The tested sites were categorized by their information content.

Table 1. Test sites investigated in this study

Language /category	Hungarian	German	English
Governmental	szmm.hu	bundestag.de	ogc.gov.uk
education	felvi.hu	focus.de	ox.ac.uk
commerce	unicum.hu	zeit.de	marksandspencer.uk
buying via the Internet	oriflame.hu	mediamarkt.de	kelkoo.uk
buying healthcare items via the Internet	patikamagazin.hu	otto.de	healthcarecomision.uk
newspapers	origo.hu	spiegel.de	250.co.uk
media-TV	rtlklub.hu	rtl.de	mediauk.uk
railway and airline time-tables	malev.hu	lufthansa.de	nationalrail.uk
banks	otpbank.hu	postbank.de	natwest.uk
entertainment	szorakozas.hu	brigitte.de	timeout.uk
museums	hnm.hu	dhm.de	londontourist.uk
chat pages	magyaronline.hu	spruchtalk.de	ukchatterbox.uk
sport news	nemzetisport.hu	spiegel.de/sport	bbc.uk/sprot

3.2 Using the WebXACT Validator for Testing the WCAG1.0 Guidelines with Home Pages

The results of testing these home pages are shown on Figure 3. As can be seen e.g. 94.87 % of all tested homepages do not conform to Priority 2.

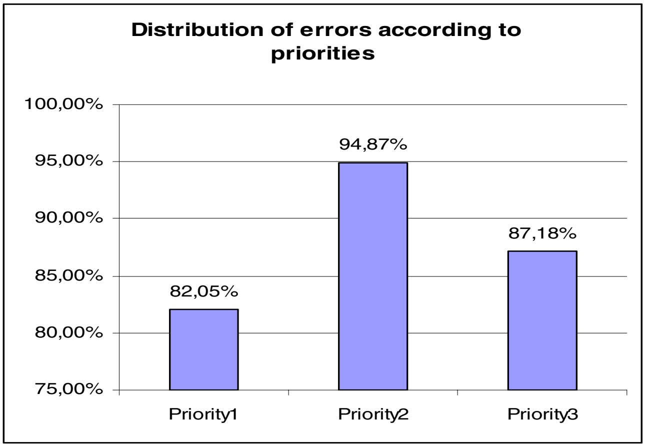

Fig. 3. Distribution of errors according to priorities

Table 2. Results of the web accessibility test

	Language	Priority1	Priority2	Priority3
Number of websites satisfying all checkpoints of the appropriate priority	English	7	0	0
	German	2	0	0
	Hungarian	3	1	1
Percentage	English	53.85%	0%	0%
	German	15.38%	0%	0%
	Hungarian	23.08%	7.69%	7.69%

Table 3. Percentage of websites with checkpoint errors of Priority 1

Priority 1 checkpoints	**Number of websites not satisfying the appropriate checkpoint**	**Percentage**	**Number of errors**
1.1 Provide alternative text for all images.	23	58.97%	441
6.2 Each FRAME must refer to an HTML file.	1	2.56%	1
12.1 Give each frame a title.	10	25.64%	12
12.4 Provide alternative text for all image-type buttons in forms.	9	23.08%	18

As we can see from Table 3 the reason for violating Priority 1 is mainly (58.97%) caused by not providing alternative text for images.

Table 4. Percentage of websites with checkpoint errors of Priority 2

Priority 2 checkpoints	**Number of websites not satisfying the appropriate checkpoint**	**Percentage**	**Number of errors**
3.2 Use a public text identifier in a DOCTYPE statement	9	23.08%	9
3.4 Use alternative sizing and positioning, rather than absolute	24	61.54%	1683
3.5 Nest headings properly	7	17.95%	13
7.4 Do not make a page refresh automatically	2	5.13%	2
9.3 Make sure event handlers do not require using the mouse	26	66.67%	456
12.4 Explicitly associate form controls and their labels with the LABEL element	25	64.10%	80
13.1 Create link phrases that make sense when read out of context.	29	74.36%	582
13.2 Include a document TITLE	1	2.56%	1

Table 4 indicates that Priority 2 checkpoints 3.4, 9.3, 12.4 and 13.1 are mainly ignored by web designers when creating a website.

Table 5. Percentage of websites with checkpoint errors of Priority 3

Priority 3 checkpoints	**Number of websites not satisfying the appropriate checkpoint**	**Percentage**	**Number of errors**
1.5 Until user agents render text equivalents for client-side image map links, provide redundant text links for each active region of a client-side image map	4	10.26%	17
4.3 Identify the primary natural language of a document	26	66.67%	27
5.5 Provide summaries for tables	26	66.67%	567
10.4 Until user agents handle empty controls correctly, include default, place-holding characters in edit boxes and text areas	26	66.67%	67
10.5 Until user agents render adjacent links distinctly, include non-link, printable characters between adjacent links	33	84.62%	2495

From Table 5 we can see that violating Priority 3 Checkpoints usually happens due to not respecting guidelines 4.3, 5.5, 10.4 and 10.5.

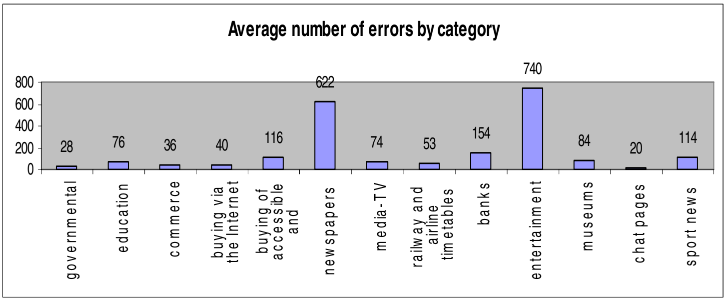

Fig. 4. Number of errors in each category occurring on a WEB page

As can be seen most errors were found in the newspaper and entertainment homepages.

3.3 Using the XValid Validator for Testing the WCAG2.0 Guidelines with Home Pages

As can be seen from the 1st and 2nd rows of Table 6 Principle 1 is violated by 87.18 % and 89.74 % of the tested homepages.

Table 6. Percentage of websites with checkpoint errors of Guideline 1.1 of Principle 1

Guideline 1.1. Provide text alternatives for all non-text content	**Number of websites not satisfying the Guideline 1.1**	**Percentage**	**Number of errors**
If a short description can not serve the same purpose and present the same information as the non-text content a long description is necessary	34	87.18%	423
Short text alternative for non-text content is not provided	35	89.74%	1195
Short text alternative for non-text content is too long	15	38.46%	35
NOEMBED tag for EMBED tag is not provided	6	15.38%	13
Short/long description for non-text content is not provided. (Use elements' body.)	6	15.38%	11
Short text alternative is part of image URL	9	23.08%	24
Short text alternative for non-text content is too short	15	38.46%	39
Alternative content for <iframe> element is not provided	11	28.21%	18
Client-side image map associated with this image, long description is necessary	3	7.69%	5
Redundant text link for some of the image maps' link is not provided	5	12.82%	12

Table 7. Percentage of websites with checkpoint errors of Guideline 1.3 of Principle 1

Guideline 1.3. Ensure that information and structure can be separated from presentation	**Number of websites not satisfying the Guideline 1.3**	**Percentage**	**Number of errors**
Use 'title' attribute to identify form controls when the <label> element cannot be used.	31	79.49%	198
Use <label> element to associate text label with form control.	30	76.92%	221
Advisory information provided with 'title' attribute is too long.	1	2.56%	2
Advisory information provided with 'title' attribute is too short.	1	2.56%	2

Table 8. Percentage of websites with checkpoint errors of Guideline 2.4 of Principle 2

Guideline 2.4 Provide mechanism to help users find content, orient themselves within it, and navigate through it	**Number of websites not satisfying the Guideline 2.4**	**Percentage**	**Number of errors**
Title tag correctly provided but it's important to check if it identifies the subject of the Web page.	36	92.31%	36
Title tag is missing.	1	2.56%	1
Title tag has too long value.	7	17.95%	7
Short text alternative for non-text content is not provided.	1	2.56%	4
Short text alternative for non-text content is too short.	1	2.56%	4

As can be seen from the 1st row of Table 8 Principle 2 is violated by 92.31 % of the tested homepages.

Table 9. Percentage of websites with checkpoint errors of Guideline 3.2 of Principle 3

Guideline 3.2 Make the placement and functionality of content predictable	**Number of websites not satisfying the Guideline 3.2**	**Percentage**	**Number of errors**
Script on page call window.open() function. Check that this is a user requestable function.	14	35.90%	38
Script on page call alert() function. Check that this is a user requestable function.	37	94.87%	40

Table 10. Percentage of websites with checkpoint errors of Guideline 3.1 of Principle 3

Guideline 3.1 Make text content readable and understandable	**Number of websites not satisfying the Guideline 3.1**	**Per-centage**	**Num-ber of errors**
The <html> element doesn't have 'dir' attribute, which specifies the base direction of directionally neutral text. (The default direction is left-to-right.)	37	94.87%	40
The <html> element altough has 'xml:lang' attribute but doesn't have 'lang' attribute.	26	66.67%	26
The <html> element doesn't have 'lang' attribute, which specifies the base language of text content.	20	51.28%	81
Script on page call window.open() function. Check that this is a user requestable function.	14	35.90%	38
Script on page call alert() function. Check that this is a user requestable function.	37	94.87%	40

Table 11. Percentage of websites with checkpoint errors of Guideline 4.1 of Principle 4

Guideline 4.1 Support compatibility with current and future user agents (including assistive technologies)	**Number of websites not satisfying Guideline 4.1**	**Per-centage**	**Number of er-rors**
This tag is not closed correctly. Assistive technologies may can't parse the content accurately.	37	94.87%	2262
The 'id' attribute isn't unique.	6	15.38%	29
Use 'title' attribute to identify form controls when the <label> element cannot be used.	31	79.49%	190
Use <label> element to associate text label with form control.	32	82.05%	228
Advisory information provided with 'title' attribute is too long.	1	2.56%	2
Using <legend> element allows authors to assign a caption to a <fieldset> and improves accessibility.	1	2.56%	4

3.4 Comparison of the Two Validating Software

Comparing WebXACT and Xvalid software we see that while WebXACT found in 84.62% of all tested homepages some mistakes, the XValid software found in the same homepages 94.87 % mistakes.

4 Summary

We developed a new validator software called XValid for specific needs in light of design for all. We used this validator for testing governmental, commercial web pages, TV channels' sites and educational web pages. XValid found 10.25% more mistakes than the WebXACT. We offer the XValid for everybody who wants to develop sites for specific needs and would like to test it an easy way.

Acknowledgments. The authors are thankful for the support of the Hungarian Sholarship Board and the China Scholarship Council that helped considerably the completion of this project.

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Accessibility, Usability, Safety, Ergonomics: Concepts, Models, and Differences

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Abstract. The purpose of this paper is to clearly point out commonly agreed definitions of the terms Ergonomics, Usability, Accessibility and Safety, their relations to each other, overlaps and differences and their influence on the design of products and services.

Keywords: Accessibility, Ergonomics, Usability, Safety; Differences between Accessibility & Usability.

1 Introduction

The purpose of this paper is to clearly point out commonly agreed definitions of the terms Ergonomics, Usability, Accessibility and Safety, their relations to each other, overlaps and differences and their influence on the design of products and services .

It is well recognized that these different terms are often mixed up unintentionally and replaced by synonyms. "Terms such as design for all, barrier-free design, inclusive design and transgenerational design are used similarly but in different contexts" (ISO/IEC Guide 71, chapter 3.2. Note 1 [2]). Also terms like "Universal Design", "Universal Accessibility" or "Accessibility for All" belong to this category, underlining the intention that products "are usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (ISO/IEC Guide 71, chapter 3.2. Note 2 [2]). A precise definition of these synonyms is often not available. Therefore they are not covered by this paper.

Further confusions arise from the word "Usability" which is mostly used in the sense of the basic "use" or "usage" of products by the user (e.g. ISO/IEC Guide 71, chapter 1.1.A [2]) but not as a terminus technicus for a design concept called "Usability" which is defined in ISO 9241-11 [5] (see chapter 2.2.).

The intention of this paper is therefore to stimulate a consistent use of the terms Accessibility, Usability, Safety and Ergonomics e.g. in standards, guidelines and regulation and to avoid unnecessary confusion and discussions of stakeholders.

2 Terminology

The concepts of Accessibility, Usability and Safety all have a foundation in or relation to the area of Ergonomics. However, they all have a different focus in their specific area e.g. user groups, requirements, methods and legal implication (see Figure 1).

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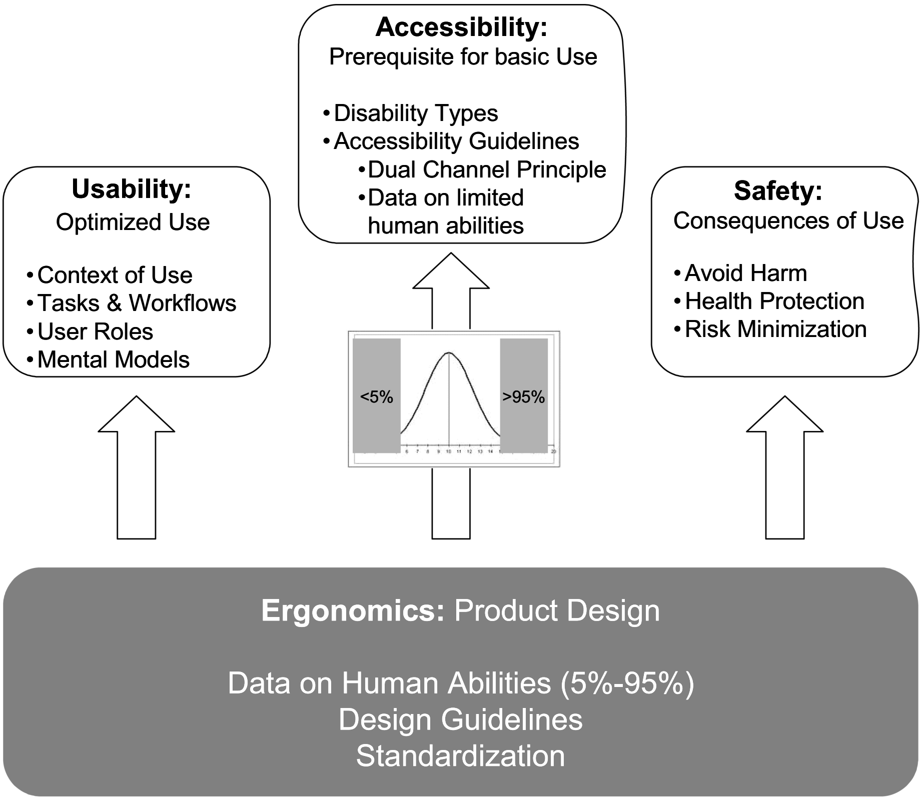

Fig. 1. Accessibility, Usability and Safety in relation to Ergonomics

2.1 Ergonomics

DIN/EN/ISO 6385 [9] defines Ergonomics as a "scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance".

Ergonomics deals with general design principles, providing design guidance by using data on human work performance. "Properly applied, ergonomics optimizes the performance and effectiveness of the work system, including the workers, without detriment to their health, well-being or safety." (DIN/EN/ISO 6385 [9])

The three areas of Accessibility, Usability and Safety can be seen as specialized facets of Ergonomic Design

2.2 Accessibility

ISO/IEC Guide 71 [2], which is equal to CEN/CLC Guide 6, defines Accessible Design as “design focused on principles of extending standard design to people with some type of performance limitation to maximize the number of potential customers who can readily use a product, building or service".

Therefore it "widens the scope of users as far as possible" and "is not limited to the 5th to 95th percentiles of working populations." (ISO DTR 22411 [3])

Accessibility is a prerequisite for basic use of products by elderly persons and persons with sensory, physical or cognitive disabilities. Generally, the Usability criteria Effectiveness, Efficiency, don't play any practical role in accessible design yet, let alone Satisfaction.

There are three main strategies (see ISO/IEC Guide 71, Chapter 3.2 [2]) to achieve accessible products:

1. "designing products, services and environments that are readily usable by most users without any modification," (Universal Design)
2. "by making products or services adaptable to different users (adapting user interfaces)," (Adaptive Design)
3. "and by having standardized interfaces to be compatible with special products for persons with disabilities." (Interoperability with Assistive Technology).

The European Commission prefers a similar definition, but uses Design for All (DFA) as a term instead of Accessible Design:
"There are three main strategies for DFA:

1. design for most users without modifications,
2. design for easy adaptation to different users (e.g. using adjustable interfaces),
3. design with a view to connect seamlessly to assistive devices."
(COM2005/425 [10])

ISO 9241-171 [7] and 9241-20 [6] define Accessibility in a very different way as "usability of a product, service, environment or facility by people with the widest range of capabilities".

"The concept of accessibility addresses the full range of user capabilities and is not limited to users who are formally recognized as having a disability."

"The usability-orientated concept of accessibility aims to achieve levels of effectiveness, efficiency and satisfaction that are as high as possible considering the specified context of use, while paying particular attention to the full range of capabilities within the user population." The mixture of the concepts of Accessibility and Usability may occur for historical reasons. But it is remarkable that even in the same standardization organization incompatible definitions are used.

Universal Design

The first approach of Accessible Design provides ergonomic data on the limited abilities of elderly persons and persons with sensory, physical or cognitive disabilities, aiming at including the widest possible range of user abilities (see ISO/IEC Guide 71, chapter 4.2.1 [2]).

This general data are e.g. provided in section 9 of ISO DTR 22411 [3]. This approach should however be limited in its application, in order to avoid disadvantages to the majority of the user group and discrimination against or stigmatization of elderly persons and persons with disabilities [13].

Additionally, conflicting requirements may occur from the different types of disabilities.

Adaptive Design

The second approach of Accessible Design provides design techniques for "compensation for impaired abilities with alternative modality(ies). This approach is called alternative format" (see ISO/IEC Guide 71, chapter 4.2.1 [2]) and is also known as Dual Channel Principle. Adaptive Design aims at allowing users to adapt the product or service to their specific individual needs (e.g. switch off the child safety lock for one hand operation). These design techniques are e.g. provided in section 8 of ISO DTR 22411 [3] (while not interfering with the majority of users). Very initial recognition of the effectiveness of use of alternative modalities can be seen in the area of software accessibility.

Interoperability with Assistive Technology

The third approach is Interoperability with Assistive Technology; allowing users with special needs to utilize their commonly used assistive devices (e.g. screen readers, wheel chairs, and hearing aids). A prerequisite for interoperability is often the support of standard interfaces by the product.

2.3 Usability

ISO 9241-11 [5] defines Usability as "Extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."

Usability deals with methods to assess the effective, efficient and satisfactory use of a product in a given context of use, i.e. looks at products in regard to their support for different roles, usage scenarios, tasks or workflows.

To transfer this usability methods to the concept of Accessible Design with its three main strategies is not possible e.g. because of the wide range of different disabilities and experience of users with disabilities and their familiarization with assistive technologies.

2.4 Safety

ISO/IEC Guide 51 [1] defines Safety as "Freedom from unacceptable risk. The area of Safety is concerned with the intended or unintended consequences of using a product, e.g. health risks, environmental protection, etc.

Safety requirements apply to the intended user group of the product. There is a tendency to extend the user group to all users, regardless of ability or age (i.e. including children or elderly persons).

3 Implementing Accessibility, Usability and Safety

There are usually very different reasons for implementing the three different principles into product design.

3.1 Why Companies Implement Accessibility

Accessibility, especially in the fields of ICT, buildings and public transport, is mandated by national laws, supported by international and national standards and guidelines, and stimulated by public procurement in many countries. Besides this, many companies strive to implement Universal Design in their mainstream products to address a wider market.

There are currently models for labeling and (third-) party certification in the field of accessibility, which are under discussion and, in some countries, in development. With the public procurement procedure required by the US rehabilitation act section 508, self declaration of conformity by the bidders is the established method for a number of years now.

A company has to consider all of these facts during the product design ideally from the very early beginning. Because of a missing international harmonisation, the resulting requirements lead to market fragmentation for companies that are active on a global market. Examples for laws and regulation in the area of Accessibility:

- the Americans with Disabilities Act,
- the US Telecomm. Act Section 255,
- the US Rehabilitation Act Section 508,
- the EU Mandate 376 (M376, 2006),
- the EU Anti Discrimination Directives,
- the EU telecomm. Directives, and
- "Behinderten Gleichstellungs-Gesetz" in Germany.

3.2 Why Companies Implement Usability

In contrast to Accessibility, Usability is often considered a competitive advantage. With technology being more and more a commodity that is taken for granted, the market demand for Usability is increasing. The implementation of usability is voluntary, i.e. usually happens for business reasons and is rarely mandated by laws and regulations. The few existing laws (e.g. the BildschArbV in Germany) are vague in the area of usability and cannot easily be tested against.

Because of the underlying economic motives, the success of usability engineering is often monitored through tests, market success or Return-on-Investment analyses. Conformity with standards is not seen as a valuable selling point, therefore standards and certification (e.g. according to ISO 9241 [4] or ISO FDIS 20282 [8]) only play a secondary role for manufacturers.

3.3 Why Companies Implement Safety

Safety is mandatory for the introduction of products, i.e. no product can be marketed without legal consequences if it doesn't meet *safety* regulation and standards of target market (e.g. CE sign).

4 Evaluation Strategies

In order to test against requirements in the different areas described in this paper, two distinctly different approaches can be taken, i.e. user or expert based. For each of the areas, there is usually a set of different usage types (e.g. different users, different settings, etc.), and the goal of user based testing is to utilize participants covering the different usage types to elicit feedback on the solution with regard to the set of requirements.

The focus here is on whether the product supports the specific usage types, and if the system model of the product matches the mental model of the users.

Expert based testing has a different focus, i.e. it mostly focuses on conformity with standards, as well as general / generic requirements for and expert knowledge of the specific area.

The evaluation can span different usage types, but will usually not yield as detailed requirements as a user based test. It does, however, usually produce more overarching results that cross usage types, which may not be as easy to elicit from representatives of a single usage type.

4.1 Accessibility Evaluation

In the area of Accessibility Evaluation, the different classes of disability constitute the usage types. There are different requirements depending on e.g. whether the user is physically or cognitively impaired. In the evaluation, representatives for each group provide feedback on whether the product supports their specific disability type, if the product fits their mental model, if it is interoperable with the assistive devices they commonly use, and if the product supports certain compensation strategies they have learned to cope with their impairment.

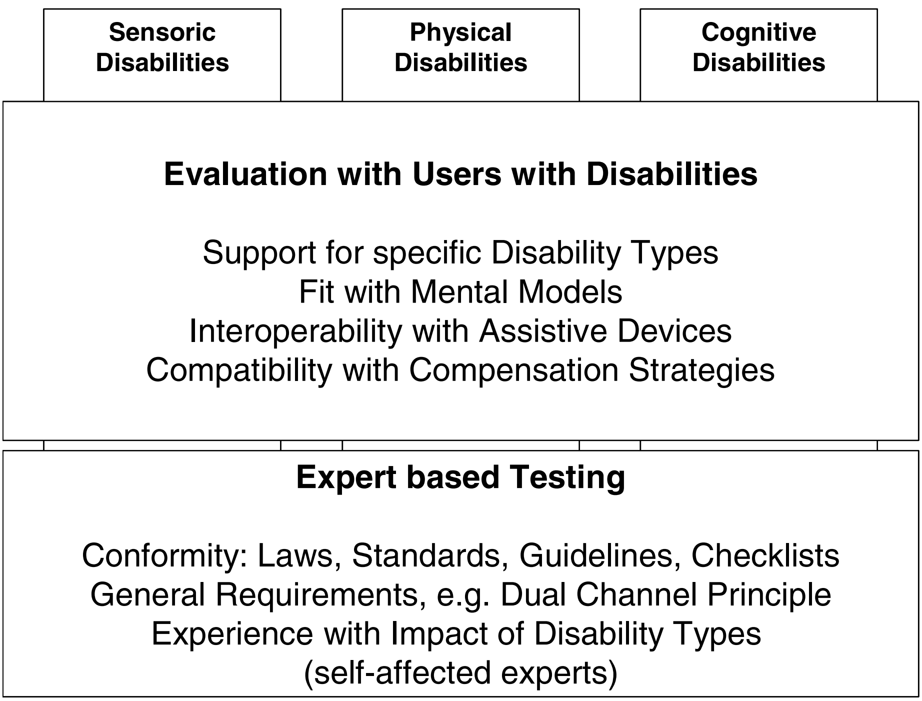

Fig. 2. Accessibility Evaluation – Focus on Disability Types

Expert based evaluation focuses on overarching aspects. Conformity with current laws, standards, guidelines and checklists is one, testing against general requirements like e.g. the Dual Channel Principle is another.

If experts are self-affected, they can also provide a broader view on the impact of certain disabilities that goes beyond the pure user role.

4.2 Usability Evaluation

For evaluating Usability, the usage types are usually defined by different contexts of use. These contexts can either be based on the type or role of the user, or the specific setting (physical, organizational, etc.) the task is carried out in. Again, the evaluation focuses on the support for the different contexts of use and fit with the mental model, but also for compatibility with general learning or problem solving strategies of the users. The DIN/EN/ISO 9241 [4] Framework for Usability Evaluation uses Effectiveness, Efficiency and Satisfaction as evaluation criteria.

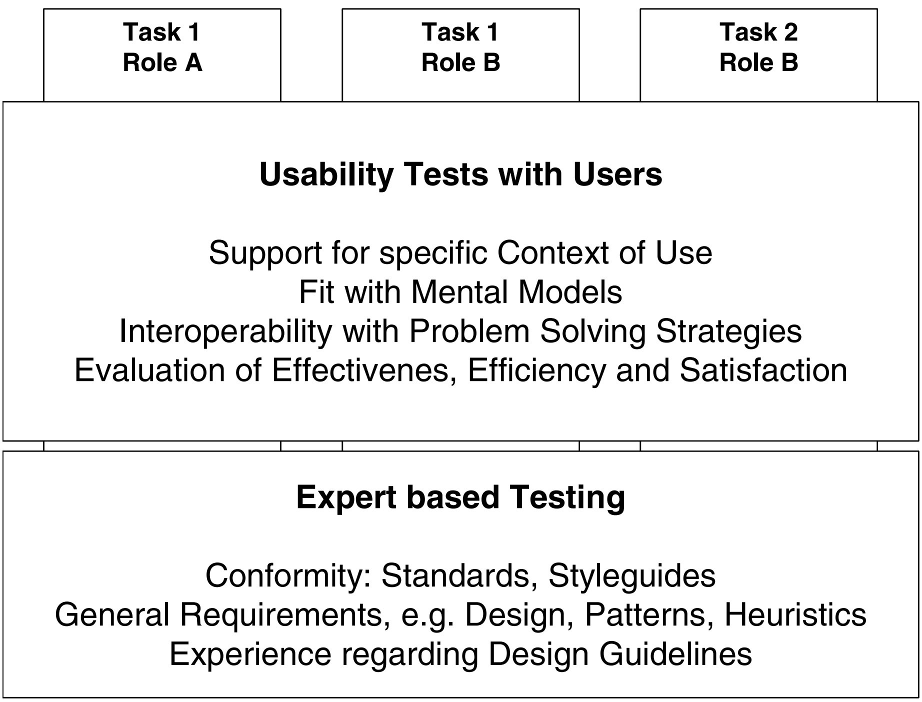

Fig. 3. Usability Evaluation – Focus on Contexts of Use

An expert based evaluation in the area of usability focuses on standard and style guide conformity and commonly known requirements, e.g. patterns or heuristics. It utilizes the expertise on design guidelines to evaluate against those as well.

5 Summary and Outlook

The accessibility of products and services is an absolute prerequisite for the inclusion of elderly persons and persons with disabilities in our modern information and communication society. Currently there are strong efforts on both, the political and industry's side to support this important goal. The started process only can be economically reasonable and really helpful for elderly and disabled persons when regulation and supporting accessibility standardization will follow an international harmonized approach. This is very important because companies are producing for a world market and the needs of persons with disabilities are nearly the same in all countries. Therefore both authors strongly recommend from their professional accessibility experience to avoid national or local solutions and fragmentation in the field of accessibility. As standards play an important role in the field of accessibility, a consistent use of terms and definitions will support implementing accessibility. Contradictory terms and requirement should be avoided to make the concept of accessibility successful, all over the world.

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How Inclusively Designed Mainstream Products Can Lead to Fresh Thinking in Home Adaptation

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Abstract. Traditionally assistive technology or environmental intervention introduced to help with independence in the home has tended to look ‘medical’ or ‘institutional’, focussing on function rather than aesthetic considerations and overlooking the aspirations of the householder. This paper describes a recent social housing project where the interior design of two newly built houses in Bradford, UK, for Habinteg Housing Association, were used to demonstrate that it is possible to balance form and function when designing to enhance independence in the home. The Bradford project builds on previous research in this area by the author and refers to the paper ‘Home Improvement for Independent Living’ (Pearce 2003). The initial research was in turn inspired by the construction of the first Lifetime Homes in Hull in 1994 by the Joseph Rowntree Foundation, in collaboration with Habinteg Housing Association.

Keywords: Inclusive Design, User Research, Design Education, Innovation, Universal Design, Home Adaptation.

1 Background

1.1 Lifetime Home Concept

The Lifetime Home concept originally identified 9 ways in which new housing design could made more accessibility and adaptable in order to suit a wide range of householders. However, the criteria tended to concentrate on the architectural fabric of buildings, such as wider doorways, level access thresholds, wider corridors and lower height window sill heights. Fitted furniture, such as in the bathroom and kitchen, tended to be of standard design, with traditional ‘institutional’ looking adaptations still being required to make the bathroom more accessible, such as grab rails and plastic seat extensions on the toilet.

Since its conception the Lifetime Home criteria have now expanded to 16 items of accessibility for the homes. Supporters of the concept tried unsuccessfully to have the criteria enshrined within the UK Building Regulations. The aim of the Bradford project was to inject fresh-thinking into the Lifetime Homes concept and demonstrate to the construction industry that inclusive design benefits not only the householder, but makes commercial sense, by widening both the usability and marketability of properties whether it be in the social or private housing sector.

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The limitations of interior design as first observed in 1994 in the Lifetime Homes, became the focus of a two year research project by the author 'Home Improvement for Independent Living' [4] which aimed to extend the accessible thinking to the whole interior.

1.2 Home Improvement for Independent Living (1998 – 2000)

The 'Home Improvement for Independent Living' research, carried out through the Helen Hamlyn Research Centre, London, aimed to demonstrate that, by careful selection of mainstream home products with inclusively designed features, the interior of any property could be made more accessible, without compromising either functionality or the interior aesthetics. The aim being to satisfy the functional needs of the householder, whilst addressing their psychological needs and aspirations for their home.

In 2005 as a direct result of the earlier research Habinteg Housing Association challenged the author to re-design the interiors of two of their Bradford properties, as a way of testing the research design assumptions and of furthering the remit of the Lifetime Home concept to include the interior fit-out of the kitchens and bathrooms.

The original research had explored how older people change the interiors of their own homes to match their own changing needs and abilities. The methodology included initial focus groups, which highlighted kitchen and bathroom design as being key issues to remaining independent at home. Through further analysis of personal interviews and observation, combined with a design survey of each of the 20 properties, the following common age related limitations were identified:

1. Reduced ability to bend & stretch i.e. rising from the bath or reaching into high or low kitchen storage cupboards
2. Reduced hand and wrist dexterity i.e. turning stiff cross-head taps and control knobs, grasping door knobs
3. Safety i.e. slipping in the bathroom, tripping hazards, leaving the gas on and danger of scalding from hot water in the kitchen and bathroom
4. Reduced vision i.e. reading appliance controls, glare and general lighting levels

Supported by an extensive product and literature search, the research went on to identify suitable mainstream household products, with inclusive design features which addressed and resolved the above issues. The products were combined in careful ways which further addressed the identified problems, such as wall-mounted bathroom sanitary ware products, which can be fixed at a height to suit the user countering physical difficulties for people who experience difficulty rising from the toilet and avoiding the psychological stigma of having to use an unsightly plastic toilet seat riser. This design solution also suits many taller people. In order to achieve the new height it was, at first necessary to fix the toilet brackets to a raised floor joist. However, following discussions with a major UK bathroom manufacturer, it was agreed to drill extra holes in the toilet brackets, to accommodate a raised-height, a tangible inclusive design outcome to the research.

Fig. 1. Left shows a toilet raised on a bracket

Fig. 2. Right shows a plastic toilet seat riser

1.3 Learning Outcomes

The research also highlighted a clear pathway for delivering information to older consumers, to encourage them to be proactive about re-designing their homes in a way which will underpin their own personal independence. It was clear that when feeding-back the research findings to the householders who took part, there was a resistance to the design solutions suggested for their own situation, which were seen as in some way challenging their ability to manage their own independence. Yet, when design solutions relating to other people's homes were shared, the information was received with interest and the designs were seen as potentially appropriate to the viewer's own situation, a form of self-determination using visualization techniques. One conclusion of this research was that 'story-telling' combined with visualization techniques are valuable tools for encouraging an autonomous and proactive response without the need for prescriptive design intervention.

2 Inclusive Design Methodology

The aim of inclusive design is the involvement of people in the design process, with emphasis not only on testing with users, but also designing with social factors such as demographic change [1].The Bradford Project, mentioned earlier, aimed to test the design assumptions and research conclusions by creating real images (rather than an artist's impression as used in the research) of future-proof [4] designs as a visualization tool to share with older consumers and housing professionals such as occupational therapists.

At the outset of the project, due to commercial constraints on time, it was decided to construct full-scale room-sets of the kitchen and bathroom designs in a 3000 sq ft warehouse, for use as a 'Methods Lab' to enable user testing to take place by different users, including those using wheelchairs. The testing the designs were adjusted and further refined and the process filmed and photographed for further evaluation, before the room-sets were dismantled and the products transferred to site for fit-out.

The methodology used on the Bradford project was a combination of product selection, using inclusive design values and user testing of the resulting designs, for functionality and aesthetic appeal. The project was unique in that it pulled together, in

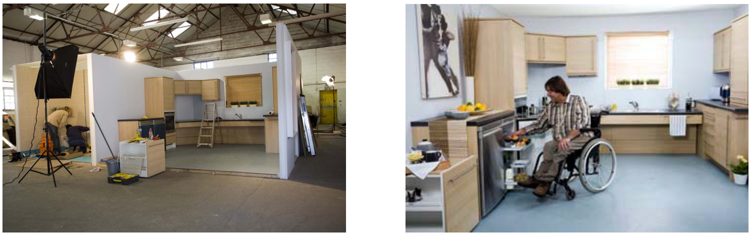

Fig. 3. A ‘Methods Lab’ was constructed to test the ‘inclusive’ designs prior to fit-out on site

an interior design setting; many examples of inclusively designed products not normally assembled in such a manner to demonstrate the wide number of inclusive products which already exist in the mainstream but which are ‘invisible’ For example, the bathroom products in one of the four bathrooms were donated by a single manufacturer, but the product were selected from not one, but from across eight different ranges within the manufacturer’s portfolio to achieve the desired aim of full exclusivity, not a process which would be easily achieved by other housing professionals or consumers themselves. It was the first time this manufacturer had experienced such a project and it demonstrated inclusive design could be a new marketing opportunity. In his book ‘The 50+ Market’ Dick Stroud comments, ‘Arguably the issues in this book (the burgeoning 50+ marketplace) and their business consequences are of greater significance than e-business.’ [6] He goes on to say, ‘It is not hyperbole to claim that any company that doesn’t consider this issue is risking its share-holders’ interests.’

Industry uptake is now the single most important aspect of inclusive design development, and will no doubt become the future measure of success [3]. For this reason the relationships forged with the 26 UK manufacturers, who were approached by the author to collaborate on the project, were considered essential, if the project was to succeed in encouraging manufacturers to design more inclusively.

Inclusion needs to be strongly represented during the prioritization of time, money and quality [5]. On site, Bradford provided a unique opportunity to identify and work alongside the various stakeholders in the process of creating a large scale inclusive design project. In doing so, it highlighted their individual requirements and priorities, which have to be addressed and communicated within the inclusive design agenda, if inclusive design is to remain a priority throughout the project. The stakeholders identified were:

1. Client
2. Architect
3. Maintenance Contractor
4. Building Contractor
5. Trades
6. Trade Suppliers
7. Manufacturers
8. Occupational Therapists
9. Householder

To support inclusive design it is necessary to understand the knowledge requirements of designers and design commissioners, both in terms of content and format [2].Working closely with the stakeholders from the design stage of the project, through to completion and ultimately hand-over of the property to the householder, highlighted how the communication of inclusive design has to be able to be translated into different 'languages' and methodologies (verbal, written and diagrammatic), in order for the key 'inclusive' design principles to survive alongside traditional and entrenched working practises, such as those in the construction industry. For example, wall-mounted frame toilets, which allow the toilet pan to be hung at different heights to suit the user, are more commonly used in commercial, rather than residential projects, and it was determined from the Project, require a far more detailed level of fitting instructions for an uninitiated plumber, than those currently provided by the manufacturer. This information was then communicated back to the collaborating manufacturer as part of the evaluation process.

The reticence of trades towards the fitting of products which are considered 'new' is a major factor in the adoption of inclusive design, especially when, as the original research found, many older people rely on trades, such as plumbers, to help them specify and order products to improve their own homes [4].

Another barrier to the adoption of inclusive home design in a wider context is that inclusively designed products tend to be 'invisible' to the untrained eye, especially when viewed out of context in a retail environment. Unless consumers understand what to look for and how products can make their lives easier, they are not going to know what to buy and 'demand-pull' in marketing terms, will remain weak. Occupational therapists (OTs) were involved in the Project because they currently specify and install aids and adaptations in the homes of older people and are considered by the author to be key drivers in encouraging the uptake of inclusive by older consumers. The current prescriptive approach home adaptation used by OTs is recognized by the OT Community to being out-dated and recent moves towards a more 'social' model of intervention in the home are supported by current changes in the relevant Government Legislation towards more 'Client Choice', where control passes to the householder and where both the user's physical needs and aspirations are central to the choices being made and implemented.

The Bradford project provided an opportunity to showcase inclusive design en-masse in different kitchen and bathroom settings, creating a unique opportunity to capture much needed inspirational images from which all the stakeholders could work. The photographs taken of the Bradford room-sets in the warehouse were used as a visualisation tool, to accompany and supplement the working drawings given to the various trades on site at the beginning of the Project. The images were also used to create a brochure for the Project launch event, detailing the inclusive elements within each room and of each product used, as a way of progressing the inclusive design agenda for all stakeholders.

In summary, the findings of the Bradford project were:

1. A large number of home products have inclusive features but few are fully inclusive
2. Even within manufacturers' own collections it is difficult to specify only fully inclusive products. For example, the bathroom products in one of the Bradford bathrooms were by a single manufacturer, but the products were selected from

across eight different ranges within the manufacturer's portfolio to achieve the desired aim of full inclusivity.
3. The way in which inclusive products are communicated by the manufacturer to the user i.e. via product 'suites' or 'families' is often too prescriptive i.e. a fixed set of products per range and not interchangeable even within the manufacturers' in-house ordering systems, for example kitchen door fronts only available with one style of handle.
4. Consumers experience difficulty in identifying inclusive products which appear 'invisible' to the un-trained eye amidst a plethora of other products
5. Manufacturers' product information and instructions to the user are often illegible. Even if the product itself is inclusive, the instructions or point of service is often lacking. For example, small print and diagrams. Inclusive design should be a thought process which considers the user at every stage; from the purchase point; through to packaging; to the instructions for use and ultimately the design and use of the product itself.

3 User Interaction with Home Products

In the same way that the stakeholders require different forms of communication in order for them to carry out their part in the creation of a fully inclusive home, this 'live' project also highlighted communication with the householder as being an important element of the inclusive agenda. For example interfaces with systems and individual appliances within the home, which can be over-looked during the manufacturers' design process, particularly within kitchens and bathrooms. For example, clarity of oven, hob and washing machine controls are essential. If an oven is wall-mounted and has a side-opening door, this is physically beneficial for the user however, if the inclusive element of the design stops at this point and does not address the appliance controls, the appliance is not fully inclusive. In the case of the Bradford project this issue was highlighted by the search for two wall-mounted ovens with side-opening doors. In the UK there are currently only three models available, one of which is in the luxury end of the market and out of reach of the Project. The other two are mid range prices, but only one had controls which could be considered 'inclusive', as shown in Image (3) its attributes were:

1. The control knobs were contrasting to the oven fascia
2. They were shaped for easy gripping and operation
3. The position of the controls could be seen from across the room as a visual clue that the oven was 'on' or 'off',
4. The shape of the controls and built-in 'stops' as the controls were turned would indicate easily to a person with a visual impairment, the position of the knob and hence the cooking temperature of the appliance.

The second oven had circular knobs in the centre of the oven facia, which required the user to turn and press the knob to work through a digital menu displayed in an LED window on the oven fascia. The design of this interface, whilst looking minimalist and uncluttered from a stylist's perspective, detracted considerably from

Fig. 4. Washing machine control panel

Fig. 5. Side-opening oven with well shaped knobs

the physical inclusivity of the appliance, requiring the user to rely solely on vision to interact with the digital display to operate the oven, with no physical clues to support the user.

Washing machine controls were similarly explored as part of the product selection process for the Project and many were also found to be lacking in full inclusivity. Machines which had larger and more inclusive apertures for the convenience of easier loading and un-loading often had single button operation of a layered, digital menu, displayed in a small window which was difficult to read. Alternatives such as machines with push button operation, which required finger strength and dexterity to depress buttons set into the appliance facia, or in-set circular dials were difficult for weak, or less dexterous fingers to push, grasp and turn.

The machine which was ultimately specified as shown in Image (4) was from a medium to low price range but was chosen for the following 'inclusive' interface features:

1. Clear contrasting text across the control panel
2. Logical layout of controls for main wash and additional features
3. Contrasting, raised buttons for additional features (which can be counted horizontally by a person with visual impairment)
4. A colour-contrasting dial with surface-mounted grip operated using a light touch
5. Built-in 'stops' on the dial to ascertain the programme positions
6. The vertical position of the dial grip represents 'off' which is easily recognised both visually and as a tactile clue for users with a visual impairment.
7. Contrasting colour clearly indicating the drum aperture

The Bradford Project highlighted other interfaces within traditional home system design, which must be addressed if housing is to become more inclusive. For example, central heating controls are typically wall-mounted, digital, with small buttons and small LED displays. They are difficult to read for most people, but particularly difficult for people who wear bi-focal spectacles, who in order to read the controls, require good lighting and for the digital display to be set at an angle, so it can be picked-up by the bi-focal element of their spectacles. Manufacturers of central heating thermostatic control interfaces also make assumptions that users are familiar with digital interfaces and the layering and sequential mode of information retrieval, required to operating such devices.

Fig. 6. More, inclusive design of bidet toilet control by Sekisui House, Japan

A more inclusive approach to interface design within the home is demonstrated by Sekisui House, in Japan, where the user's abilities have been considered during the design process. In this interface for a bidet toilet a large 'rocker' switch frames an LED screen and can be operated by depressing each corner of the switch, using fingers or alternatively the edge of the hand or elbow, to interact with the various flushing and drying modes of the appliance. The inclusive approach to the switch, including the size and positioning of the buttons, means the device considers a wide group of users. The design principles of this interface could be easily transferred to other devices within the home.

In addition to small buttons and displays, other issues such as the height of controls can be a problem for some people, particularly shorter people or those using a wheelchair. Appliances such as kitchen hob extractors often have controls which are integral to the appliance which is fixed at high level and can be out of reach for some users. Remote control versions are available, but tend to be the more luxury, expensive models. In the case of the Bradford properties the issue of kitchen extractor hood controls being too high was addressed with lateral thinking. To overcome the issue of height, an isolator switch was wired at worktop height, so the extractor could be left switched on at the appliance, but controlled by the user from worktop height. In the second house at Bradford, an alternative extractor was chosen to demonstrate how the extractor fascia panel could be used as a switching mechanism, avoiding the need to stretch to reach small operating buttons. Pulling the facia panel forward switched on the extractor and integral light whilst pushing it back, switched off the appliance. In both cases, the compromise was a lack of control over the different strength-settings of the extractor fan.

Safety was identified as being of prime importance in the original research, especially for older people. Issues surrounding safety were addressed within the fabric of the interior fit-out, but the products used were also selected for their careful balance between aesthetic values and safety attributes. For example, slip-resistant flooring was installed in the kitchens and bathrooms where the slip-resistance applied to users in shoes, but also in bare feet. The colour and tonal value of the flooring was carefully considered so it contrasted well with the colour of the walls and furniture to help users with varying levels of visual acuity, determine the scope of the room, the edge of a worktop or the positioning of sanitary ware within the space. The colours initially available within the flooring range were limited, but the Manufacturer agreed to develop further colours and expand their range according to the author's specification.

Fig. 7. Slip-resistant flooring and contrasting colours between the floor, walls and sanitary ware for additional safety and user orientation

The inclusive design of the properties also catered for issues of maintenance or emergency by installing water cut-off switches on the water mains within each property. The non-electric device is installed as an 'interruption' within a run of copper water pipe and works when a physical switch is depressed by the user, cutting-off the flow of water. The interface of the switch has been designed as a simple flick-switch using a generic design 'language', which makes its operation intuitive for the user. Within the plastic unit, the switch is also highly coloured and contrasting for added visibility.

The switch is easy to install and addresses issues of inaccessibility of traditional water main stop-cock taps, which are often sited at low level behind kitchen units. It also addresses issues of manual dexterity, where little-used water main valves become stiff to operate, especially for weaker or less dexterous fingers. One switch unit per property can be installed in an accessible place in case of emergency, or in special situations, one unit can be fitted per bathroom or kitchen, to control the use or misuse of appliances by children or people with mental impairment.

Fig. 8. Water main cut-off switch

4 Conclusion

The Bradford project demonstrated that it is possible to select and combine mainstream home products to create inclusive kitchens and bathrooms within property interiors although full inclusivity has yet to be reached. However, despite having removed many architectural barriers to full home accessibility through concepts such as Lifetime Homes, and having explored physical accessibility within the interior design, it is clear that there is still more research required and further dialogue with manufacturers, if home system and domestic appliance interfaces are to become more inclusive in their design.

A further result of the Bradford Project has been a continuing dialogue with the 26 UK manufacturers who collaborated on the project and who are now aware of the benefits of inclusive design for their businesses. The images and findings of the project have been incorporated into an 'inclusive' design course aimed at manufacturers, occupational therapists, architects, designers and other housing professionals in order to progress the inclusive design agenda. The course aims to encourage the various stakeholders to adopt inclusive principles by translating the key principles principles into their own 'languages' of design, client choice, working practices, marketing and sales. The ultimate aim is to stimulate 'demand-pull' from consumers and housing professionals and 'supply push' for inclusive home products by manufacturers. This will in turn stimulate competition between manufacturers, to the benefit of the consumer towards developing a more 'social' model of designing, where the user's physical needs and aspirations are central to the design process.

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Designing for Participation in Socio-technical Software Systems

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Abstract. Participative software systems are a new class of software systems whose development does not end at the deployment but requires continued user participation and contribution. They need to provide both solutions to users and a participation framework that entails technical and social challenges. Meta-design is a promising approach to guide the development of participative software systems. Drawing on lessons learned from a systematic analysis of Open Source Software projects, this paper described general issues that need to be addressed to enable and encourage continued user participation during the meta-design process.

Keywords: meta-design, participative software system, socio-technical environment, system evolution, community of practice, Open Source Software.

1 Introduction

We have been observing the rapid emergence of a new type of software systems that are based on the contributions by a community of users [18]. Systems, such as Wikipedia, Flickr, and Open Source Software (OSS) projects, that are created through the collaboration of many contributors who are regarded as equal partners by bringing their unique set of skills and expertise to shape the functionality and utility of the software systems. We call such software systems as *participative software systems (PSS)* whose design does not end at the time of deployment and whose success hinges on continued participations and contributions of users at use time. Participative software systems need to be evolved continuously at the hand of users to achieve the best fit between the system and its ever-changing context of use, problems, domains, users, and communities of users.

In such systems, the roles of users and developers are blurred and design extends into use time. The design of participative software systems, therefore, presents a challenge of creating new methodological frameworks that re-delineate the roles of developers and users, re-distribute the design activities over the life cycle of the software systems, and give equal importance to the design of technical functionality and the design of social conditions for wide and sustained participation of users.

Meta-design [3] is a new design methodology that we have proposed to address the above challenge. Meta-design characterizes objectives, techniques, and processes for

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creating new media and environments that allow "owners of problems" (or users) to act as *designers*. A fundamental objective of meta-design is to create socio-technical environments [7] that empower users to engage actively in the continuous development of systems rather than being restricted to the use of existing systems. Meta-design aims at defining and creating not only *technical infrastructures* for the software system but also *social infrastructure* in which users can participate actively as co-designers to shape and reshape the socio-technical systems through collaboration.

User participation, however, does not come automatically. Specific design decisions have to be made conscientiously to enable and encourage user participation and collaboration. This paper discusses the issues that need to be addressed during the meta-design process to achieve sustainable user participation. After the articulation of the concept and defining features of participative software systems in Section 2, we describe the lessons that we have learned from a systematic analysis of OSS systems. Drawing from the lessons, we present a general framework of designing for participation in Section 4, followed by a summary in Section 5.

2 Participative Software Systems

Software systems are knowledge artifacts whose creation requires a wide range of knowledge from computation domains and problem domains. Systems that require relatively little domain knowledge or in domains where requirements can be clearly articulated up front can be delegated to professional developers after the users have clearly identified the requirements. When the requirements can be only partially understood or defined previous to the construction of the system, professional software developers need to work in close collaboration with domain experts (a system design methodology pursued in *participatory design approaches* [15]).

Most complex problems are ill-defined problems that *cannot be delegated* because they require the *integration of problem framing and problem solving* [13], making it impossible to define requirements in advance. Ill-defined problems require that "back-talk" of a problem goes to the owners of the problem helping them iteratively to gain a deeper understanding of the problem [14] during the process of constructing the solution. Continued user participation and involvement in the design and development of software system is needed. We use the term *participative software system (PSS)* [11] to refer to this kind of software systems.

The development of PSS does not end at the time of deployment but extends into use. PSS is a living entity and a socio-technical system [7] capable of integrating computing infrastructure and participation process in one single platform and supporting collaboration not only about design artifacts but also about the goals of the design activity. In a PSS:

1. users can participate in the evolution of the system according to their capabilities and on the basis on their own interest or needs;
2. user participation (at various levels) not only benefits the user, but it also shapes the platform for other participants to collaborate; and
3. as a result of participation, users and the software system co-evolve to adapt the whole PSS to new social and technical demands.

2.1 Re-defining the Roles of Users and Developers

In the world of software, users and developers are conventionally regarded as two mutually exclusive groups of people. Users are those people who own a problem, and developers are those who construct software systems for the users. However, with the widespread use of, and the society's increasing reliance on, software, the distinction between users and developers is quickly disappearing. More and more people are not only using software but also getting involved in developing software to widely varying degrees (Fig. 1) to solve problems.

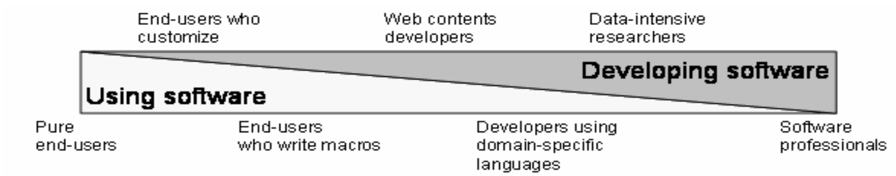

Fig. 1. The spectrum of software-related activities

To make software development easier, two major research fields have been established to attack both ends of the above spectrum (Fig. 1). *Software engineering* focuses on the group of people on the right, who call software development their profession. They develop software systems that are used by users other than themselves. *End-user development* [6, 8] aims to find ways of creating software systems that can be adapted by end-users to their own unique needs. It focuses on the group of people on the left of the above spectrum.

In the middle are people who have certain software development skills but are not interested in software per se. They do not develop software for other people; rather they are developing software to solve specific problems that they own. This group of people can be called *domain expert software developers* (or *domain experts*) [1].

2.2 Redistributing the Design Activity

In all design processes, two basic stages can be differentiated: design time and use time [4]. At *design time*, system developers (with or without user participation) create environments and tools for the *world as imagined* by them to anticipate users' needs and objectives. At *use time*, users use the system in the *world as experienced*. The bridging of these two stages into a unique *"design-in-use" continuum* encompassing an ongoing conversation both with the design material and among participants differentiates meta-design from other (more established) design frameworks.

Existing design frameworks are based on the assumption that major design activities end at a certain point after which the system enters use time. Meta-design complements and transcends these design methodologies by creating *open and continuously evolvable systems* that can be collaboratively extended and redesigned at use time *by users and user communities*. However, meta-design is not merely end-user modification and programming. Meta-designed software systems not only provide the technical means for users to customize and extend the systems but also provide social and technical mechanisms to facilitate user participation and collaboration during the design activities.

3 Designing for Participation: Lessons from Open Source Software Development

To understand how user participation can be sustained in PSS, we studied successful examples of a typical class of PSS: *Open Source Software (OSS)* systems.

OSS development is an activity in which a community of software developers collaboratively constructs systems to help solve problems of shared interest and for mutual benefit. The original designers of an OSS system do not provide a complete solution that addresses all problems of potential users, rather he or she provides an "*under-designed seed*" as a solution space that can be evolved by its users at use time via making the source code available [2, 12]. The ability to change source code, the technological means of sharing changes over the Internet, and the spontaneous social support among community members are the enabling conditions for collaborative construction of software by changing software from a fixed entity that is produced and controlled by a closed group of designers to an open effort that allows a community to design collaboratively.

However, not all OSS systems are successful in terms of active user participation. A study [10] of 90,902 Open Source Software projects hosted in the sourceforge.net has found that 66.7% of the projects have only one developer.

To understand the socio-technical factors that make some OSS development successful PSS, we have conducted studies of five OSS projects: GNU, Linux, PostgreSQL, Jun and GIMP [21, 22]. One critical factor that enables the continual evolution of an OSS project is the forming of a vibrant and sustained *community of practice* [20] of developers, users, and user-turned-developers. The right to access and modify source code itself does not make OSS projects different from most "Closed Source Software" ones. All developers in a project in any software company would have the same access privilege. The fundamental difference is the *role transformation* of the people involved in a project. In Closed Source Software projects, developers and users are clearly defined and strictly separated. In OSS projects, there is no clear distinction between developers and users: all users are potential developers.

3.1 Roles and Community Structure in OSS Communities

People involved in a particular OSS project create a community around the project. Members of an OSS community assume roles according to their personal interest in the project, rather than being assigned by someone else. A member may have one of the following eight roles [9]:

Project Leader. Project Leaders are often the person who has initiated the project. They are responsible for the vision and overall direction of the project.

Core Member. Core Members are responsible for guiding and coordinating the development of an OSS project. Core Members are those people who have been involved with the project for a relative long time and have made significant contributions to the development and evolution of the system.

Active Developer. Active Developers regularly contribute new features and fix bugs; they are one of the major development forces of OSS systems.

Peripheral Developer. Peripheral Developers occasionally contribute new functionality or features to the existing system. Their contribution is irregular, and the period of involvement is short and sporadic.

Bug Fixer. Bug Fixers fix bugs that either they discover by themselves or are reported by other members. Bug Fixers have to read and understand a small portion of the source code of the system where the bug occurs.

Bug Reporter. Bug Reporters discover and report bugs; they do not fix the bugs themselves, and they may not read source code either. They assume the same role as testers in the traditional software development model.

Reader. Readers are active users of the system; they not only use the system, but also try to understand how the system works by reading the source code.

Passive User. Passive Users just use the system in the same way as most of us use commercially available Closed Source Software. They are attracted to OSS mainly due to its high quality and the potential to be changed when needed.

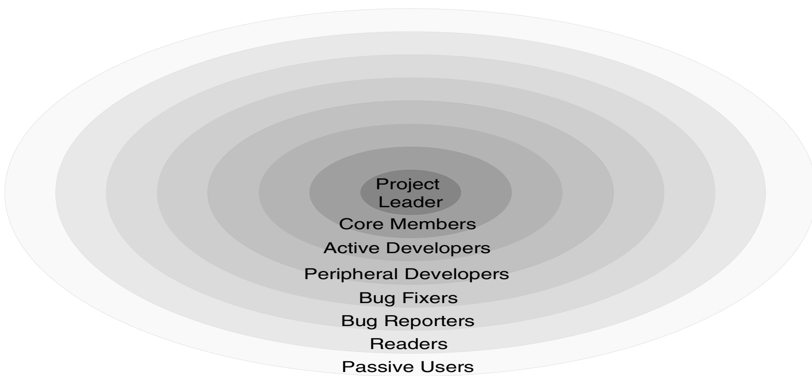

Fig. 2. General structure of an OSS community

Although a strict hierarchical structure does not exist in OSS communities, the structure of OSS communities is not completely flat. The influences that members have on the system and the community are different, depending on the roles they play. Fig. 2 depicts the general layered structure of OSS communities, in which roles closer to the center have a larger radius of influence. Passive Users have the least influence, but they still play important roles in the whole community. Although they do not directly contribute to the development of the system technically, their existence contributes socially and psychologically by attracting and motivating other, more active, members, to whom a large population of users is the utmost reward and flattery of their hard work [12].

3.2 Co-evolution of OSS Systems and OSS Communities

The roles and their associated influences in OSS communities can be realized only through contributions to the community. Roles are not fixed: members can play larger roles if they aspire and make appropriate contributions. As members change the roles they play in an OSS community, they also change the social dynamics, and thus reshape the structure of the community, resulting in the evolution of the community.

For an OSS project to have a sustainable development, the system and the community must co-evolve. A large base of voluntarily contributing members is one of the most important success factors of OSS. The evolution of an OSS community is effected by the contributions made by its aspiring and motivated members. Such contributions not only transform the role and influence of their contributors in the community and thus evolve the whole community, but they are the sources of the evolution of the system. The opposite is also true; any modification, improvement, and extension made to an OSS system not only evolves the system but redefines the role of the contributing members and thus changes the social dynamics of the OSS community (Fig. 3).

The role that an OSS member plays in the community is not pre-assigned, and is assumed by the member as he or she interacts with other members. An aspiring member can become a Core Member through the following migration path:

- New members are attracted to an OSS community because the system can solve one of their own problems.
- The depth and richness of good OSS systems often drives motivated members to want to learn more, to read the system [16]. The new members now migrate from Passive Users to Readers. As they gain more understanding of the system, they are able to fix the bugs that are either encountered by themselves or reported by others. They may also want to add a new twist to the system to make the system more powerful and more suitable for their own tasks.
- As their developed programs are made publicly available to other community members, their roles as Bug Fixers and Peripheral Developers are recognized and established in the whole community. The more contributions they make, the higher recognition they earn, and finally, they will enter the highly selected "inner circle" of Core Members.

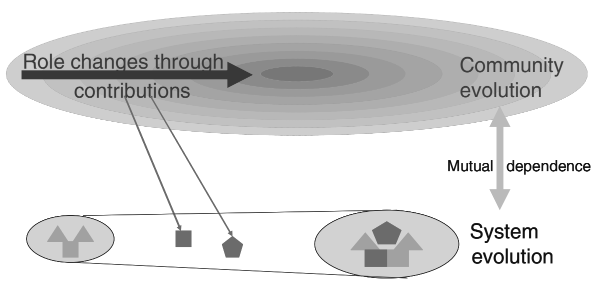

Fig. 3. The co-evolution of OSS systems and OSS communities

The above path describes an abstract model of role changes of aspiring members. Not all members want to and will become Core Members. Some will remain Passive Users, and some stop somewhere in the middle. The important point is that Open Source Software makes it possible for an aspiring and technically capable software developer to play a larger role through continual contributions and engagement

4 Designing for Participation: A General Framework

Drawing from the lessons learned by systematic analysis of OSS projects from the meta-design perspective, this section describes challenging issues that need to be considered during the meta-design process of PSS to enable and encourage continued user participation.

4.1 Embracing Users as Co-designers

To embrace users as co-designers, designers of PSS need to bear in mind that they are not only providing a solution to users, but also a solution space [18] within which users can develop new solutions to their specific needs. The solution space contains technological instruments that users can use for their design activities, and determines the degree that users can evolve the original design. Currently available technology in software systems provides a variety of choices, ranging from the modification of options, the customization of menus and functions, the plug-in structure for extension, the published services for being mashed up with other services, the publication of system API for integration with other systems, and the source code that offers the highest freedom for user development. Meta-designers of PSS have to make a conscientious decision according to how much they want to get user involved.

4.2 Providing a Common Platform

Design contributions made by one individual user are limited because one particular user is only interested in creating solutions for his or her own needs. The power of distributed user design comes from the fact that the evolution of systems is pushed by a large number of users with diversified needs and skills who each makes small contributions. For this to happen, users need to have a common platform so that they can share with each other and integrate design solutions of others. Meta-designers need to either create an associated common toolkit or utilize a set of common tools widely available to all users to facilitate easy sharing and integration. The concept of OSS has been pioneered by Richard Stallman (with the term Free Software) in the 80s but the huge success of OSS systems becomes possible only when software development tools—such as Emacs, Eclipse, and CVS—becomes widely available and the de facto standard tools for most software developers.

4.3 Enabling Legitimate Peripheral Participation

A transparent policy and procedure is needed to incorporate some of user contributions into the participative software systems. Users who made contributions need to see that their contributions make a recognizable influence on the system. In other words, user participation has to be legitimate [20] and their design activities are regarded as an integral part of shaping the direction and functionality of the system.

The possibility for newcomers to participate peripherally is another key aspect [19]. To attract more users to become developers, the system architecture must be designed in a modularized way to create many relatively independent tasks with progressive difficulty so that newcomers can start to participate peripherally and move on gradually to take charge of more difficult tasks. The way a system is partitioned has consequences for both the efficiency of parallel development—a prerequisite for OSS—and the possibility of peripheral participation. The success of Linux is due in large part to its well-designed modularity [17].

Another approach to afford peripheral participation is perhaps to *intentionally release under-designed system* to users by leaving some non-critical parts unimplemented to facilitate easy participation. The TODO list of most OSS systems creates guidance for participation.

4.4 Sharing Control

While the original meta-designers of the PSS may retain the major control of the direction of the system, active participating users need to be granted certain controls commensurate with their interest, technical skill, and contributions. The roles that a domain expert user can play in the system are different depending on their levels of involvement. Each level has its own responsibility and authority. Responsibility without authority cannot sustain users' interest in further involvement. When users change their roles in the PSS by making constant contributions, they should be granted the matching authority in the decision-making process that shapes the system. The meta-designer needs to find a strategic way to transfer some of the control to aspiring and contributing users. Granting those users controlling authority has two positive impacts on sustaining user participation: (1) users who gain controlling authority become stakeholders and require ownership in the system and are likely to make further contributions; and (2) it can attract and encourage new users who want to influence the system development to make contributions. Successful OSS projects invariably select skilful user-turned-developers and grant them access privilege to contributing directly to the source base.

4.5 Promoting Mutual Learning and Support

Users have different levels of skill and knowledge about the system. To get involved in contributing to the system or using the system, they need to learn many things. Peer users are important learning resources. A PSS should be accompanied with knowledge sharing mechanisms that encourage users to learn from each other. In OSS projects, mailing lists, discussion forums, and chat rooms provide an important platform for knowledge transfer and exchange among peer users [5].

4.6 Fostering a Social Rewarding and Recognition Structure

Motivation to participation is essential for the success of PSSs. Factors that affect motivation are both intrinsic and extrinsic. The precondition for motivating users to get involved in contribution is that they must derive an intrinsic satisfaction in their involvement by shaping the software system to solve their problems. Intrinsic motivation is positively reinforced and amplified when social structure and conventions of the community recognize and reward the contributions of its members.

The social fabric inherent in OSS communities reinforces the intrinsic motivation for participating in OSS projects. Members close to the center of the community enjoy better visibility and reputations than do peripheral members. As new members contribute to the system and the community, they are rewarded with higher recognition, trust, and influence in the community. Rewarding contributing members with higher recognition and more important roles is also important for the sustainability of the community and the system development, because it is the way that the community reproduces itself.

Developers of PSSs therefore need to establish a social norm in the user communities by recognizing publicly contributing users and promoting the social status in the community by granting matching authority.

5 Summary

PSSs represent the rapidly emerging class of software systems whose development does not end at the point of deployment and continues to evolve at the hand of participating users. The success of many such systems is mostly accidental resulting from the insights of their original designers. Existing software design methodologies that have mainly focused on engineering software systems to the needs of users at design time are not well suited for PSSs. For the past several years, we have developed the *meta-design framework* to address this challenge. In this paper, we described general issues that need to be considered to design socio-technical environments that enable and encourage user participation, drawing on a systematic study of existing OSS projects.

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Towards a Walkthrough Method for Universal Access Evaluation

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Abstract. This paper presents a walkthrough evaluation method for assessing, in a Universal Access perspective, interactive systems. The methodology is an adaptation of the traditional cognitive walkthrough used for many years in the usability engineering community. Cognitive walkthrough involves a simulation of the *problem-solving process* of an *average user*, to ensure that the user can easily learn to perform tasks that the system is indented to support. The proposed method, described here in brief along with the underlying theoretical framework, extends this approach by: (a) involving a simulation of the users' reasoned action process, to ensure that users will be in favour of accessing, exploring, utilising, and, ultimately, adopting the system; (b) addressing the diverse needs of all users, rather than of the average user, thus incorporating accessibility for all target users as an intrinsic measurement. A set of printed forms with specific questions reflecting the proposed methodology has been developed to guide the new walkthrough procedure. Early experiences with the application of the method in the domain of eServices are also discussed.

Keywords: Universal Access, evaluation, walkthrough, system acceptance.

1 Introduction

The ubiquity of Information Society Technologies (IST) necessitates progress towards the development and adoption of methods that comply with the Universal Access (UA) principles, addressing accessibility, usability and acceptance of IST by anyone, anywhere, anytime [1]. Towards the realization of this vision, previous research work has established knowledge, instruments and building blocks for ensuring that interactive applications and services are developed by taking into account the needs and requirements of all target user groups, in potentially any context of use, thus introducing profound methodological and technological innovations in all aspects of the user interface development lifecycle. In this context, design and development methods and tools for UA have been elaborated and applied [2].

Admittedly, however, no systematic approach has been proposed so far towards providing evaluation methods and tools in a Universal Access perspective. A variety of definitions and evaluation methods exist for usability or accessibility alone (for an

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overview, see [3]), but these approaches seldom take into account all human-perceived system qualities collectively and in a systematic way. For instance, they do not take into account the user's beliefs, intentions to perform, experience and expectations, and their evolution throughout the interaction with a system.

To address these issues, a UA evaluation framework has been elaborated, based on [4], that offers a holistic approach for the evaluation of the design and delivery of interactive systems. This framework has lead to the development of a walkthrough inspection method, supported by a form-based instrument, called ORIENT[1] [3]. ORIENT has been employed in the course of a large case study for the inspection of ten popular eServices in Europe [5].

2 A Universal Access Evaluation Framework

In the perspective of UA, taking into account accessibility and usability for all means assessing how individual users, with different characteristics and requirements can interact effectively and efficiently with the system throughout user experience lifecycle, both as a first experience and in the longer-term.

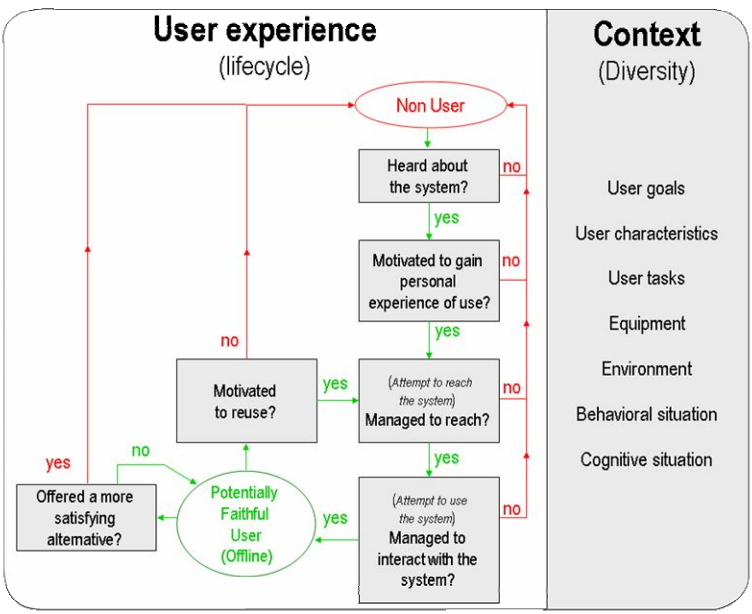

Fig. 1. Overview of the evaluation framework

In these terms, the Universal Access evaluation framework (see Fig.1) aims at taking into account individual differences and measuring the extent to which [3]:

[1] ORIENT stands for "User-orientation inspection" [2].

- a system[2] is made widely visible to non-users;
- non-users are motivated to gain a personal experience of the system;
- actual users find it easy and acceptable to reach the system;
- actual users find it useful, easy and acceptable to interact with the system;
- users are motivated to become long term users;
- users are not offered more empowering and satisfying alternatives.

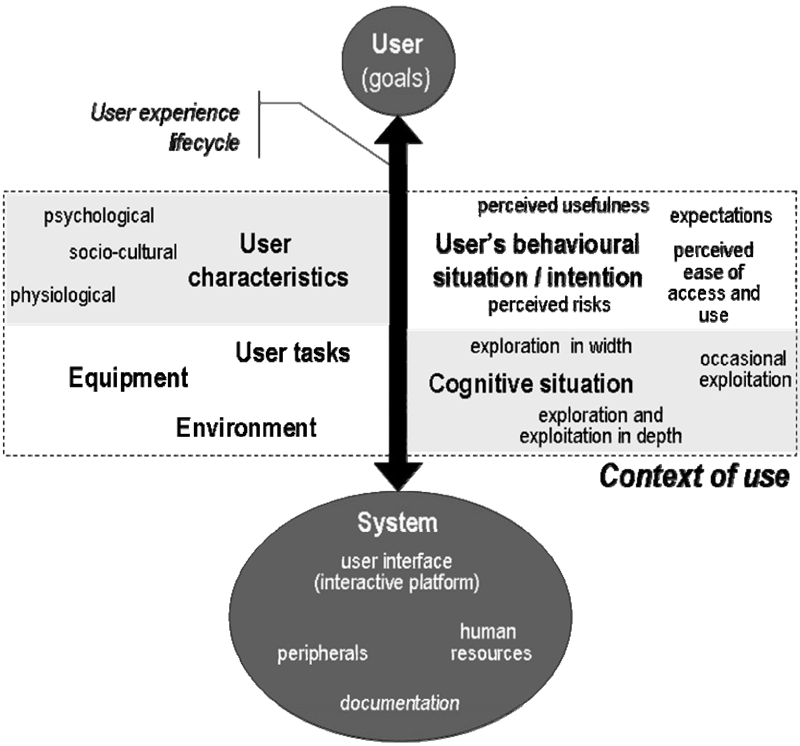

Fig. 2. Context of use of an interactive system

The framework reflects the overall system quality as a total of the following quality measurements described in [3]: visibility, perceived usefulness and perceived ease of use, availability, quality of interaction, relationship maintainability, and competitiveness. These qualities need to be granted for all target users groups and diverse *contexts of use* (see Fig.2 Fid.1), since the contextual conditions may determine the outcome of the user experience with a system. Such diversity may be induced by: (i) user goals; (ii) user characteristics (physiological, psychological,

[2] Note that the term "system" is used to refer to various types of interactive artifacts including services, software or hardware products, user interface components and their underlying functionality or any combination of these.

socio-cultural [7]); (iii) user tasks; (iv) equipment (at the user site); (v) social and environmental conditions; (vi) the user's behavioural situation; and (vii) the user's cognitive situation. In terms of user characteristics, key personal differences may involve variances in gender, physical and cognitive abilities, language, culture, experience, background, etc. In terms of the user's behavioural situation, salient factors are identified such as perceived usefulness and perceived ease of use [8], perceived risk, and expectations [9]. Finally, the user's cognitive situation builds on the theory of action [10] and on the model of learning by exploration [11]. Indicatively, different levels of knowledge structures [12] can be identified as the user's focus shifts, in the long term, from *exploration in width*, to *occasional exploitation*, and, ultimately, to *exploration and exploitation in depth*.

In terms of user interface and user dialogue with a system, accessibility can be defined [6] as the extent to which the sequences of input actions of a system, and the associated feedback that lead to successful system use, are possible to be performed by the user, with respect to the individual's limitations emerging from the particular context of use. Similarly, further to the presented UA framework, quality of interaction for all (i.e., quality of the user interface and user dialogue with a system) can be defined as the extent to which the sequences of input actions of a system, and the associated feedback that lead to successful system use, achieve all the quality measurements described above (visibility for all, etc.), thus granting subjective accessibility, usefulness, ease of use, and satisfaction with respect to the individual's limitations emerging from the particular context of use.

3 A Walkthrough Method

The methodology discussed here is an adaptation of the cognitive walkthrough method that has been used for many years in the usability engineering community. Cognitive walkthrough [13] involves an explicitly detailed process to simulate an average user's problem-solving process at each step in the human-computer dialogue, cheeking to see if simulated the simulated user's goals and memory for actions can be assumed to lead to the next correct action [14]. The method presented here, extends this approach:

- from the level of human-computer dialogue, to the level of user-experience lifecycle (see Fig.2);
- from a simulation of the user's problem-solving process (can the user use the product? i.e., cognitive perspective), to a simulation of the users' reasoned action process (i.e., does the user want use the product? i.e., behavioural perspective).
- from the simulation for the average user, to the simulation of diverse contexts of use (i.e., from usability evaluation for the average user to UA evaluation);
- from ensuring that the system design is appropriate for users to learn and use, to ensuring that system design is appropriate for users to get motivated, access, explore, utilise, and, ultimately, adopt the system.

The main objective of the method is to facilitate the rapid assessment by experts of interactive systems in terms of the factors discussed in the previous section. In brief, the method involves inspecting the user-perceived characteristics of a system and deriving conclusions about the design and delivery features of the system that affect it's UA qualities (i.e., visibility for all, etc.). The proposed method can be applied from one individual (called "the inspector"). Nevertheless, in order to achieve less subjective and more exhaustive results, it is suggested that a group of at least three inspectors work independently of each other and, ultimately, have their reports combined (i.e., group inspection). The input to such a walkthrough session includes a detailed incarnation of the system (e.g., design, interactive prototype or final product), a task scenario, and explicit assumptions about the user population and the context of use. During the inspection, the experts, having in mind the appropriate instances of the context of use, step through the user-experience lifecycle (to any desired depth) and attempt to examine at each step whether users can and intend to identify a sequence of actions that lead to the next lifecycle step and, ultimately to successful and satisfying task completion. Claims that a given step will not lead the user to abandon the process should be supported by theoretical or normative arguments, experimental data or relevant experience of the inspection team members.

In order to support experts in applying the presented methodology in practice, without the need for extensive training, a number of printed forms with specific questions have been developed. These questions guide the walkthrough and reflect the described model. The forms employ open-ended questions that accept narrative responses supplemented by scores ranging from -4 (assigned to UA catastrophes) to 4 (reserved for good practice examples). An example of the forms adapted for the inspection of eServices, constituting the ORIENT tool, is available in [3].

4 The Walkthrough Procedure (ORIENT)

The proposed walkthrough involves four phases, start-up, preparation, inspection, and reporting. In the start-up phase, the general and specific objectives of the inspection are identified, the limitations of the inspection are specified (e.g., available time, budget, and the required size and expertise of inspection team). The preparation phase is collaborative and comprises mainly the documentation of background information regarding three different aspects: inspection background information, information about the system, and assembly of the respective context of use. During this important phase, the user groups (i.e., reflecting distinct user goals and tasks) of the system are identified, and a prioritised set of system functions (task scenarios) for each group is elaborated. Depending on the desired depth of evaluation, it is possible to further break down the analysis and cover sub-functions or smaller interaction items. Then, the context of use for each user group is elucidated and analysed (see Fig.2 Fig.1.). Section 5 presents in detail an example of analysis of the context of use for eServices. At this stage, inspectors are ready to start working individually and undertake the actual inspection process. Each inspector follows a step-by-step procedure to assess the system as a whole, inspecting the perceived system qualities (see section 2) for each individual user group. In order to assess the quality of interaction, inspectors evaluate and summarise the assessment results for all functions in each user group, by implementing for each function separately the same step-by-step process that applies to the whole system.

Once all individual inspectors have examined the system, a member of the group (e.g., the inspection leader) gathers all comments and scores and produces summary forms, initially for each user group and, as final step, for the system as a whole. The outcomes of the inspection produced by means of the printed forms are mainly a list of problems identified along with their corresponding severity scores and, potentially, the recommendations for fixing problems (redesign) and improving universal access to the assessed system. A detailed description of the process is available in [3].

5 Experience with the Method in the Eservices Domain

The method has been tried and tested under full inspection circumstances in an effort to refine the process of inspection, identify gaps, locate problems or misconceptions that may affect the work of the inspection team and in general calibrate the step-by-step procedure. To this aim, a pilot application of the method was conducted for a well-known eGovernment service of a European member State.

After obtaining preliminary results and consequently refining the method, an extensive pilot application of the method was conducted. The full inspection results are reported in [5]. The inspection was held on a sample of ten online public services from both new and old member states, indicative of three major public service domains, namely eGovernment, eHealth and eLearning. Of the selected eServices, eight were inspected by means of selected task scenarios, due to various limitations, while two underwent a fully-fledged application of the method that allowed deriving comprehensive and full assessment results.

For the purpose of the above study, a detailed investigation of the context of use of eServices has been carried out identifying the factors that are likely to impact UA, and which should therefore be taken into account during the walkthrough of such systems.

5.1 Context of Use for Universal Access to Eservices

The context of use for UA (anyone, anytime, anywhere, any system) was examined through various dimensions of diversity, leading to the identification of corresponding interaction requirements induced by:

- user characteristics, which encompass physical and mental user characteristics;
- user task characteristics, which include various real-life user tasks in terms of task characteristics and conditions, e.g., often interruptions, duration, interrelations with other tasks;
- user equipment characteristics, e.g., compatibility and performance;
- user environment characteristics, e.g., noise, luminance and privacy issues;
- user expectations and perceived risks, which concern user expectations that may emerge, for example, from previous experience, personal needs, implicit service communication, values and beliefs, views about the provider, explicit service communication, and word-of-mouth communication;
- any combination of the above (for the needs of this pilot study, requirements of this type were not elaborated).

Concerning user characteristics and accessibility to people with disability, a number of interaction requirements have been identified. A major group, gathering three types of users is persons with visual impairments. These include blind users, who can only receive information though alternative channels (e.g., auditory and tactile) or though third parties. For instance, in terms of interaction with technology, they cannot use visual displays, therefore system information, messages and output should be offered in a “non-visual” form (e.g., in Braille). Low vision users may need their magnifiers to work well with the system, related pieces of information to be presented close together (since the user might miss elements due to a narrower field of view), and critical information and messages to be rendered in a non-visual form to increase visibility. When it comes to colour blind users, colour alone cannot not distinguish items (e.g., for signalling information). A second major group is that of motor impaired users, who may need minimal, if none, physical activity. For instance, in terms of interaction with technology, they may not be able use keyboard and mouse and, therefore, require interaction through binary switches and keyboard simulation software. A third group is users with some kind of hearing or speech impairment. For instance, deaf users, any audio information is restricting and thus should be given in alternative visual or tactile forms. Cognitively impaired users, who have difficulties in understanding complex information, require simple syntax and vocabulary, and navigation should also be kept simple. Furthermore, low literacy users, who plod text rather than scan it, should have short messages and sentences. For instance, in terms of technology, menu, button labels, etc. should be short. Dyslexic users should be able to alter presentation elements such as font size, background colour, contrast, line spacing, etc. Another specialised case are photosensitive epileptics whose health may be endangered by certain repetitive visual stimuli, thus the system should avoid flashing banners and flickering lights. Furthermore, a common user category is persons with low familiarity to the Internet and computer technologies that may encounter difficulties in understanding technical jargon, and following complex procedures. A final group of users that joins together all previous requirements in combination and in variant degrees is elderly users.

In the second category of requirements, the specific characteristics that apply to specific user tasks according to the type of service in question have been analysed. Thus, in a series of user tasks specific to eGovernment, including information retrieval, public databases, questions about administrative procedures, obtaining and sending forms, online transactions, registrations, declarations, etc. there are some major recurring user requirements: need for updated information, transparency in transactions, impartiality and equal rights, security and privacy of personal data, control over administrative procedures, participation in administrative and political actions, efficiency of procedures and last but not least personalisation of rendered services. eHealth related tasks include simple tasks such as finding information on health matters, looking up pharmacies, hospitals or medication online, as well as more advanced ones such as online consultation with a doctor and/or diagnosis, communication and advice, maintaining a health record. All these tasks require advanced structures for communication, security of transactions, reliable and up-to-date information, timely system response and personalisation of services. The eLearning sub-group involves tasks related to getting information about the eLearning offer, participating in computerised courses – whether self-or-employer-initiated – and accessing online material. The induced user requirements give great emphasis to the need to control the process of learning, such as being able to monitor one's performance and keep track of essays, exams, etc. and the need to have equal treatment of all students. Also, all sorts of transactions should be secured and privacy of students needs to be guaranteed.

In the third category of requirements, various types of equipment that users may utilise when accessing the system have been reported, namely various types of operating systems, visual or other displays such as PDAs, mobile phones, etc., assistive technologies such as screen readers, low rate connections and various (types of) web browsers. Disabled users who can only access a service through a public system (e.g., a kiosk) should be able to configure the accessibility of the platform.

In the fourth category, the environment in which the system is accessed has been examined in terms of external conditions (lighting and noise), security and privacy. For instance, mobile phone presupposes the following requirements for users: sound alerts should also be available in visual form, and colours and contrast should be in appropriate forms for various lightening conditions. In addition, when a service is accessed through a public device privacy of data is crucial, since users do not want sensitive information to be stored locally in the computer.

The fifth category addressed user requirements related to expectations and concerns sensed by all users, regardless of the type of service used. More specifically, this category gathers perceived user risks related to cost, time, privacy, accidents and errors during system manipulation, user or system performance, system accessibility and lastly, security of financial transactions.

5.2 Results and Discussion

For each of the inspected services, a comprehensive presentation of the results was prepared, revealing the strengths and weaknesses of the service in question with respect to the qualities addressed by the framework (visibility, perceived usefulness and perceived ease of use, availability, quality of interaction, relationship maintainability, and competitiveness), and providing suggestions for improvement. Additionally, a summative analysis of the results has also led to the identification of recurring positive and negative issues for each of these aspects in the three application domains of eHealth, eGovernment and eLearning [3]. Considering the above, it is deemed that these results may be of relevance to stakeholders involved in the design, development and evaluation of eService, as well as to service providers.

Overall, the conducted study has demonstrated both the usefulness and the applicability of the method and of the ORIENT tool in the domain of eServices. The inspection was conducted by a team of twelve experts, two of which acted as inspection leaders. The entire process was also supervised by the developers of the method. The background of the inspection team included user-centred design, web design, accessibility and usability evaluation, and Design for All. However, only the two supervisors were initially familiar with the method and the ORIENT tool. The required time was of two weeks for the set-up, preparation and inspections, and other two weeks for result reporting. The experience of the assessment team was positive, and the study allows drawing the conclusion that the application of the method is feasible and requires minimal training. An aspect which may require improvement concerns redundancy in forms. This is planned to be addressed through the development of an on-line tool supporting the conduct of assessment experiments.

6 Conclusions and Future Work

This paper has presented a framework that provides a holistic approach for expert-based or user-based evaluations of interactive systems under a UA perspective. In particular, the paper has focused on the deployment of the framework in defining an UA evaluation walkthrough method, as an extension of the cognitive walkthrough.

The paper has then presented an inspection tool based on the proposed method, named ORIENT, for conducting expert-based walkthrough assessments of eServices and predicting potential adoptability by their target users. In general, the proposed model can be applied at various evaluation depths, and can be used to inspect clusters of systems, stand-alone systems, system sub-components, and / or system functions, user interfaces, devices, interaction controls, etc. This work is intended to contribute to UA by providing a theory-based method that (a) involves a simulation of the user's problem-solving process as well as reasoned action process to ensure that users will be motivated and able to access, explore, utilise, and, ultimately, adopt a system; and (b) addresses the diverse needs of all users, rather than of the average user, thus incorporating accessibility for all target users as an intrinsic measurement.

Future work will include testing the evaluation capacities of the method with systems other than eServices. There are also plans to create an online interactive version of supporting tool with many steps of the evaluation and reporting phase automated. Finally, further studies are required to examine the issues involved in repeated system usage in the long run, and to incorporate them into the design of the interactive tool.

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An Architecture for Adaptive and Adaptable Mobile Applications for Physically Handicapped People

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Abstract. Context-awareness is an important capability needed in devices in a ubiquitous computing environment. Ubiquitous computing devices use different types of sensors along with the user's interaction history in order to collect and store data. This data is then used to adapt the user's behavior to suit the current environment. In addition to the explicit modifications by user control, the behavior of these computing devices along with the interaction amongst one another depends on the continuously changing environment conditions. These characteristics require the development of systems that have both, adaptive and an adaptable nature. Context-awareness is particularly important for physically handicapped people. This is due to the fact that context-aware ubiquitous devices are able to help them detect changes in the surrounding, which handicapped people can not do for themselves. In this research paper we suggest a general architecture of Context-Aware Adaptable System (CAAS). We exemplify this architecture with an Ambient Service prototype that we have developed.

Keywords: Context-Aware Adaptable System (CAAS), Ambient Service (AS), End User Development (EUD), Adaptivity, Adaptability, Mediation.

1 Introduction

"Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and application themselves." [1].

Context-awareness is the most important feature of the ubiquitous and pervasive computing [1] [2]. It simplifies the interfaces we present to our mobile users, adapting them to the current situations [3]. Context-awareness is also the key characteristics of new smart and context-aware information services. It includes all kinds of situational properties like spatial and temporal contexts, task context, collocation context,

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historical context etc. These systems also exploit their surrounding context to increase the suitability of a service or an application to the user's needs.

Context-aware systems support users in dealing with complex systems of technologies and devices. This is possible because they aim to understand the user's current task, location and time contexts and provide situation adequate support.

These characteristics make context-aware systems an interesting technology for physically handicapped people.

Physically handicapped users of communication technology face slow, labor intensive user interfaces, which make interactive conversations tedious and difficult [5]. Advancements in research on user interfaces and conversational prediction have made it feasible for devices to be developed that can assist users [6] [7] [8], particularly those with physical limitations, to communicate. Despite these advancements there are still opportunities for improvements. Users need decreased input load and significantly increased output speed without sacrificing intended conversational topics.

Designing context-aware systems for physically handicapped people is a complex task. Standard designs are based upon the active user's involvement for requirement capture and user testing to establish workable design [9]. Physically handicapped people can not participate actively during requirement capture session. They are also not able to take part in the extensive testing session.

Studying context-awareness systems in a real life setting demonstrates that the contexts sensed by these systems are often ambiguous. Although some of these ambiguities may be resolved using automated problem-solving techniques, many cases still require the user's involvement for the correct handling of the ambiguous context [4]. This leads to system approaches that have to have accurate and reliable adaptive services as well as adaptable concepts in order to allow users to intervene in a simple and transparent way whenever necessary.

Therefore new design challenges in context-aware systems are to interpret the context correctly not only to inform adaptive services, but also to empower the end users to understand and configure the behavior of the system [10] – to perform meta-design activities.

The research field of End User Development (EUD) has empowered the end users to adapt their own computer systems [11] [12] [13]. Some of the concepts already have been transferred to the construction of context-aware systems, for example, Programming By Demonstration (PBD) [14] [15]. Another interesting concept of EUD, namely Meta-Design Activity, can be applied in the context-aware systems. Meta-design activities empower end users by enabling them to act at designers at use time. It allows users to use domain oriented language to re-design and adapt current features to their own needs [11].

This paper focuses on the technical aspects which build a context-aware system that supports ubiquitous fitness, by presenting the architecture for mobile application [16]. The architecture explicitly addresses the idea of a combined approach for adaptable and adaptive services. By developing architecture with adaptable services, we allow end users to act as designers at use time. It is done by empowering them to redesign and adapt current features of the application, based on the architecture, to their own needs.

Thus our proposed architecture allows end users to perform meta- design activities. We will also exemplify this architecture with an Ambient Service prototype.

The research paper is organized as follows: in the second section, the core concepts of context-aware adaptations will be discussed. The third section will suggest general software architecture for implementing Context-Aware Adaptable System (CAAS). In the fourth section we will present a research prototype based on this CAAS architecture. Finally, we will give a conclusion of our work.

2 Context-Aware Adaptation

The use of ambient services is a common way to demonstrate the behaviors and activities of context-aware systems. An ambient service represents a high level concept that allows us to construct complex services out of primitive ones by connecting them with each other via data flows.

Service applications, i. e., software components that are available over a network, promises both accelerated software development and a more flexible and less erroneous application.

In the course of time, the ambient service may change. Firstly, the user develops himself as he uses the service and then performs adaptations to the service on his own. Secondly, the ambient service automatically recognizes changes in the environment and usage behavior or performance of the user and makes the user aware of the potential improvements to his service. Thus, ambient services offer both user and context driven adaptation. In dealing with the adaptation of ambient services, two different aspects of contextualization of the application can be seen: adaptivity and adaptability [17].

The aim of the adaptivity is to have systems that adapt themselves to the context of use with respect to their functionality, context selection and presentation and user interpretation. Systems displaying such adaptive behaviors regarding the context of use are called context-aware systems. The objective of context-aware system is to assist the users by proactively supplying what is actually needed.

The aim of adaptability is to empower end users to customize or tailor computer systems according to their individual context specific requirements. Such approaches allow for adaptations to dynamically changing unanticipated requirements. Such approaches allows for the end user to customize their domain specific expertise to the system.

We believe that the potential of context-awareness systems for physically handicapped people can only exploit, when we take the special expertise of these people into account. Therefore the core concept of context-aware adaptation is to develop applications based on the shared initiative of human and computer intelligences.

The concept of context-aware adaptation is grounded on the work of FreEvolve, a component based tailorable system [13] [18] [19] [20], and a design of context-aware system [21] [22].

Component based tailorability is an approach to transfer the connectional ideas of EUD to the field of component based systems [23] [24]. According to O. Stimmerling [20], a software system owns the meta property of component based tailorability, if the representation elements of its tailoring architecture are descriptions of its compositions.

The main challenge for ambient intelligent environment is that the context changes rapidly, which means that the system has to dynamically adapt to the servers and components that can abruptly appear and disappear at any time. Dealing with dynamic context creates a new field of EUD, whereas the use of the intelligence of the user to interpret the context creates a new field of context-aware systems.

A Context-Aware Adaptable System (CAAS) is defined as a system that enables the end user to adapt the application or application unit by taking the context of use into consideration.

The role of EUD in context-aware adaptable software is to provide a software design that is accountable to the users. The design also develops tools that make the adaptation of the system easy to the end users [11] [13]. With the help of EUD, end users will be empowered to configure and compose these information technologies according to their diverse and changing needs.

In component based architecture, context-awareness is used to reduce the burden of context adaptation. In context-aware systems, the context is used as a filter to determine which building blocks and available services are relevant in the context.

3 The General Architecture of CAAS

In the following section we would like to discuss the general software architecture for CAAS. The OSGi standard[1] has been used as the basis for setting up the context-aware adaptation.

The proposed software architecture for CAAS shows the three core concepts, i. e., Context-awareness, End User Development (EUD) and OSGi Service Management. The Mediated Adaptation Manager is the most important functionality in the CAAS architecture. It maintains the mediators and coordinates the adaptation process.

3.1 System Architecture

The following subsections present the main parts of the CAAS architecture.

- **Context Manager**

The context manager provides the CAAS application with a rich context model with an associated quality of information. It is responsible for acquiring context information from various sources and through a variety of communication protocols. A significant increase in the expressiveness, complexity and quality of the represented context can be achieved by transforming the acquired context data in several ways.

The context manager merges the various aspects of the acquired information into a coherent entity. The context derived by the context manager is any information that can be used to characterize the situation of a person or a computing entity and to identify the need for adaptation.

[1] Cf. http://www.osgi.org

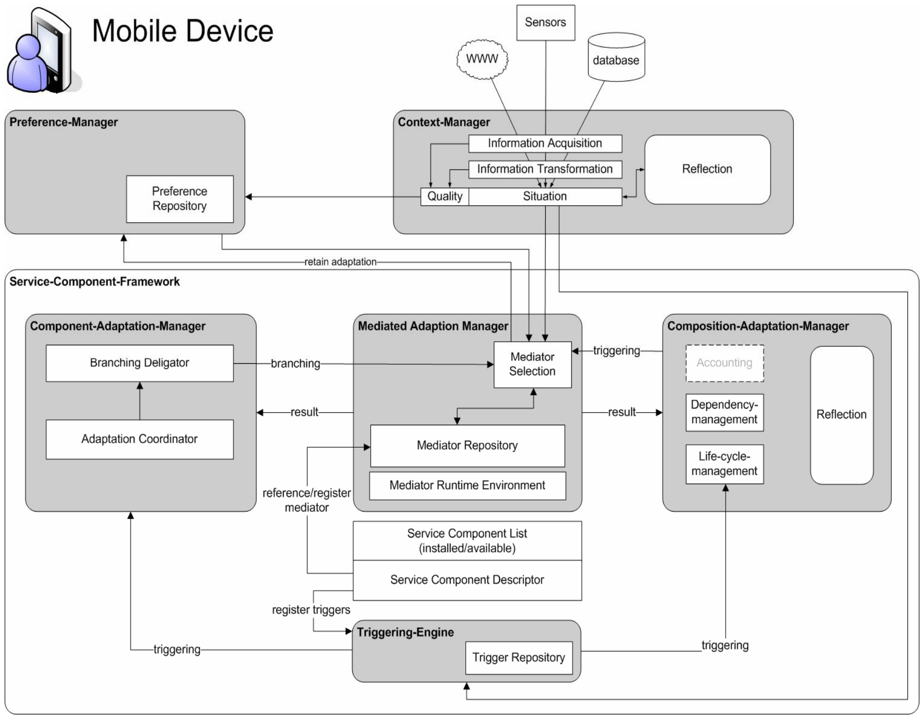

Fig. 1. Software architecture for Context-Aware Adaptable System (CAAS)

- **Reflection and Transparency Components**

The users need to understand and investigate the system's mode of operation in order to decide which modifications are needed to carry out. Inspection requires the application to externalize its current state, as well as its composition. Externalization or reflection means the provision of a human readable description of components which are plugged into the system, information about the current state of these components, and configuration settings needed for launching and operating the system.

- **Preference Manager**

The preference manager is responsible for storing the completed adaptation processes. It maintains a repository of user preferences. Each preference takes the form of a named pair that consists of a scope and a scoring expression. The scope describes the situation in which the preference is applied. A situation is described in predicate logic and may be evaluated as true or false. A preference is considered applicable within a given context only if the scope expression is true. The scoring expression assigns a score to a choice, which is a numerical value in the range [0 to 1].

- **Composition Adaptation Manager and Component Adaptation Manager**

In the proposed software architecture, adaptation works on two different levels of granularity. The coarse grained level adaptation is comprised of addition and removal of entire blocks of functionality and is realized by the composition adaptation manager. The fine grained adaptation is the adaptation of a component itself, which is achieved through the component adaptation manager.

- **Mediated Adaptation Manager**

The mediated adaptation manager is responsible for delivering appropriate mediator functions in both adaptation phases, namely the composition and component adaptation phases.

Mediated adaptation describes an adaptation technique which separates the adaptation process from the operating software artifacts. The start of a mediated adaptation can be triggered by either the system or the end user. The completion of a mediated adaptation results in an accomplished and retained adaptation of the system. A mediated adaptation may be accomplished automatically, driven by the end user, or may be a sequence of both can occur in combination.

Every adaptation service component lists its required mediator in its own descriptor. For more specific mediators, it is also possible for service components to contribute component specific mediators in the mediated adaptation manager.

- **Triggering Engine**

The CAAS application developers create a set of rules, each consisting of an event and a corresponding action. These sets of rules are kept in a triggering repository. The triggering engine detects the occurrence of significant events and invokes actions in accordance with the rules. In some cases, the rules are associated with constraints as additional preconditions for the execution of actions that are evaluated following the events.

- **Service Component Description**

The service component description defines the behavior of a service component and specifies state transitions in the life cycle of the component in one or more situations. This enables the framework to build rules for the triggering engine to install, start, stop and uninstall a service component with respect to the actual situation. For the component adaptation, the triggering engine can use the same information for building rules for a situation dependent adaptation of the internal behavior of a component. The descriptor also defines the data required by the service component in order to reference the appropriate mediators from the mediator repositories or to register its own specific mediators.

4 Ambient Service Prototype

This section presents a prototypical implementation of the Ambient Service (AS) architecture. The prototype is part of a EUD research project in the health/fitness area.

We will describe the main parts of the architecture and their interactions. The heart of the architecture is the AS container. It is realized as an OSGi bundle[2]. It contains a view, presenting the main functionality to the user.

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[2] We use Eclipse eRCP to realize our concept using some features of Eclipse which are not part of the official OSGi standard, e.g. the Eclipse workbench features (cf. http://www.eclipse.org/ercp).

Fig. 2. The action bar of the Service Component Framework

An omnipresent action bar shows the main menu of an AS application. Several icons are available to control the framework (cf. fig. 2).

The first icon from the right side is the power-off button. This icon closes the AS application.

The second button allows the user to inspect the machine captured context. It opens a dialog which shows the actual hierarchical graph of the captured sub- and super-contexts of the current situation.

The third button allows one to switch the user-interface to the "backside" presenting the actual adaptation opportunities of the AS application. The backside stands for the access to the "maintenance hatch" of the application, which means access to the adaptation and configuration of the application.

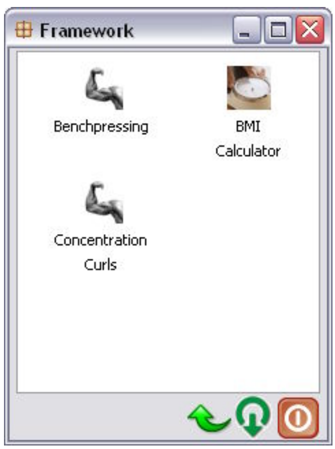

Fig. 3. The desktop with active services in the current context

Fig. 3 shows the initial graphical user interface of the Ambient Service application. It shows the available services for the actual contexts represented by the desktop symbols. If the context of the user changes the desktop will change accordingly. New available services will appear on the desktop and services, which got unavailable, will disappear. To consume a service, the user simply has to tip on the related symbol.

Fig. 4 shows the two different parts of the user interface after the complete flip to "backside" is done.

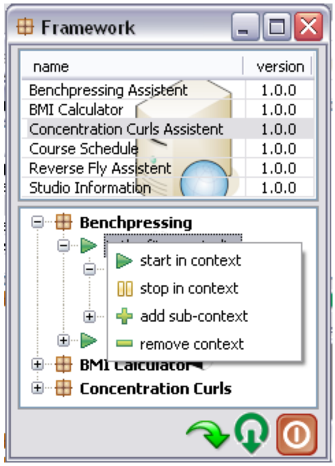

Fig. 4. The "backside" of the AS application, which is used for composition issues

The upper part of the "backside" shows a table representing all available AS components in the service component repository. In the lower half of the adaptation mode interface, those service components are displayed which are currently installed in the Ambient Service application. In the spanning tree underneath each Service-Component represents the contextual behaviour. It is the tree-representation of the content of the XML deployment descriptor.

We tested our prototype on a *context simulator*. We developed a small web application to substitute the context manager. With this application, we can simulate context changes, which generate output like the real context manager.

As the dummy context manager can not interpret sensor data we use a "Wizard of Oz" technique. A user will use the AS component framework as if there is a context manager. The human Wizard interprets the actual situation and uses this application to switch the context.

We use this technique to simulate a context change. i.e., moving from context A (e.g. benchpressing) to context B (e.g. going into refreshing area).

The Wizard of Oz recognizes this change in context and chooses context B in his web application. The information about change in context is immediately informed to the trigger engine. The Ambient Service component framework now has the necessary input to trigger context driven behavior of the installed service components.

5 Conclusion

Context-aware systems offer a great opportunity for handicapped people to perform those activities that they could not do under usual circumstances. . However, it is difficult for the software developers who are not in the same life situation like the handicapped people, to anticipate all the necessities of the physically handicapped people.

We put forward the idea of Shared Initiative, which brings the concepts of context-awareness and end user development together.

We have given a first outline of on architecture for Context-aware Adaptable System (CAAS) to address adaptivity and adaptability. In this architecture, the concept of mediation is the core issue.

In the EUD research project we have developed three prototypes based on the CAAS architecture. In this research paper we have described one of them, namely, Ambient Service. The prototype can adjust itself automatically to different contexts, and it allows for the end users to tailor the software according their needs.

We have primarily focused on the technical concepts of a Context-aware Adaptable System (CAAS). However, we believe that a real life testing is necessary to evaluate the context-awareness. Based on the experiences and comments made from the end users, such an evaluation will produce reliable results on the appropriation of context-awareness technology.

To conduct these tests, we have to realize a "Wizard of Oz" suite in order to simulate sensor behavior in an early stage of the design process with low cost (in respect to a proprietary sensor solution)

As a next step of our research, we will perform a formative evaluation on the Ambient Service prototype in a real world fitness setting. From there, we want to use the flexibility of a "Wizard of Oz" technique to experiment on different design concepts in cooperation with users in a Participatory Design manner.

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Real-Time Image Correction for Interactive Environment

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Abstract. In recent years, projectors are undergoing a transformation as they evolve from static output devices to portable, or communication systems. However, the projection images appear distorted unless the projector is precisely aligned to the projection screen. Generally many projection-based systems are corrected for oblique projection distortion using calibration methods (e.g., warping function). Computing a warping function uses fiducials or a special pattern projected to the screen. These methods are unable to automatically calibrate in real-time especially when a projector is moving. In this paper, we proposed an automatic calibration system in real-time. Our system makes up of a function to correct images that are only based on the degree angle of a mirror set up in front of the projector without attaching fiducials to the screen. Therefore the system can be used to display regardless of screen condition in parallelepiped room. This operation process is very simple and fast. Therefore our system provides a function of correcting movies during the movement of the projector (27.3fps). An advantage of the proposed method is the system can be easily applied to ubiquitous computing like interactive presentation or game.

Keywords: ubiquitous display, real-time calibration, projector systems, computervision.

1 Introduction

The three-dimensional (3D) environment or real-world needs a new set of interface components: new devices, new techniques, and new metaphors. Some of these new components may be simple refinements of existing components; others must be designed from scratch. Many researchers study 3D user interface (UI) for the 3D interaction in realistic interactive environment or 3D environment.

A necessary component of any 3D UI is the hardware that presents information to the user. This is called 3D output interface or display, present information to one or more of the user's senses through the human perceptual system.

Many different approaches to displays [1] which are Display Walls (Tiled Display), Steerable Projector Camera Systems (Everywhere Display) and Mobile Projectors are

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being investigated, ranging from display walls and steerable projectors to new display materials. There are many approaches to address geometric calibration. Table 1 shows an overview of the calibration method for ubiquitous displays.

Display Walls (i.e., Rear-Projected Display and Front Projected Display Walls) appear to offer large scale high resolution display, a solution to the small display area problem. However, these systems are not suitable for the future office as the tiled display systems are employing to take up a large floor space, time consuming for calibration and they are fixed, not portable because the projected pattern image is needed for calculating calibration method of the Display Wall [3-8].

Steerable Projector Systems surfaces can dynamically change if its projection becomes occluded and also creates the potential for novel display types such as user following displays [9-12]. Everywhere Display[1] is an environment developed by Pinhanez [9]. This system is to couple a LCD/DLP projector to a motorized rotating mirror and to a computer graphics system that can correct the distortion caused by oblique projection. The Steerable Projector System can not correct the distortion in real-time, because the calibration parameters of the virtual 3D surface are determined manually by simply projecting a special pattern and interactively adjusting the scale, rotation, and position of the virtual surface in the 3D world.

Table 1. A Comparison of Display Technologies for Ubiquitous Display

Display	Display Technology	Mobility	Image Calibration Method		
			Calculation Method	**Device Requirement**	**Processing Time**
Traditional Computer Monitors	CRT and LCD	Fixed	-	-	-
Rear-Projected Display Walls [3-5]	Projection	Fixed	Off-line (automatic)	With Camera	Not Real-Time
Front Projected Display Walls [6-8]	Projection	Mobile, ad-hoc creation	Off-line (automatic)	With Camera	Not Real-Time
Steerable Projected Display Walls [9-12]	Projection	Fixed but steerable image	Off-line (manual or semi-automatic)	With Camera and Marker	Not Real-Time
Mobile Projectors [13-14]	Projection	Portable	On-line (automatic)	With Camera and Marker	Real-Time
Our System	**Projection**	**Steerable Projected**	**On-line (automatic)**	**No**	**Real-Time**

Mobile Projector System [13-14] is a project developing a mobile projector-camera system that fit into a large toolbox. Despite this achievement the system still relied on a connected main cable for powering the video projector. However, the promise of Laser and LED projectors that can run for hours on batteries heralds a new era in

[1] Steerable Projector Camera System was initially developed by Pinhanez at IBM.

mobile display technology. Raskar [13] describes object augmentation using a hand-held projector[2]. This system does object recognition by mean of markers attached to the object of interest. The markers are "piecodes", colored segmented circles. These markers are used to compute camera pose (location and orientation) and hence the oblique projection is calibrated. Mobile Projector is determined automatically in real-time during a change of location and orientation of projector by marker because the marker is used to compute camera pose (location and orientation) and hence the oblique projection is calibrated. However, this system can not calibrate in projection space which is not attached to a marker. Generally, many calibration methods for oblique projection needs a camera and projector pose (location and orientation).

1. The method cannot automatically calibrate in real-time, like when projector is moving.
2. The method needs some device like markers or camera.
3. The method cannot offer to play movies because the system spends a lot of time on the step of geometric calibration.(10fps and less)

In this paper, we propose an automatic calibration system in real-time without attaching fiducials to the screen. Our idea is make up similar virtual camera with a field of vision to real-project with a field of projection. The system's operation process is very simple and fast. So our system provides a function of correcting movies during the movement of the projector (27.3fps). And our system has a camera for automatic focus function and catch up with user. Automatic focus function finds best degree of definition. And user tracing function makes projector follow the user during presentation. An advantage of the proposed method is the system can be easily applied to ubiquitous computing like interactive presentation or game.

2 Projector-Based System for Real-time Automatic Calibration

The real-time geometric calibration system is mounted up on a side of the parallelepiped(Fig. 1). The system project images which user prefers on any five sides of the display wall, except on the side which the system is mounted.

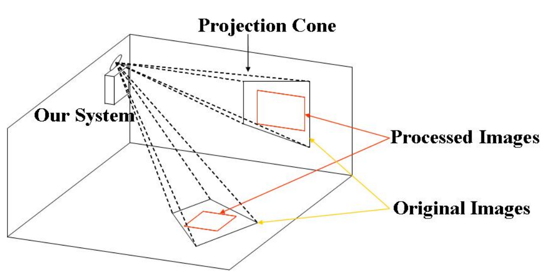


Fig. 1. Sketch of our system

[2] Raskar at the Mitsubishi Electric Research Labs (MERL) popularized the idea of handheld projector-camera system.

2.1 Overall System Architecture

The real-time geometric calibration system is composed of a DLP projector and an inexpensive mirror. The projector is fixed, but the mirror is unfixed. The first is connected to the display output of a computer that performs geometric calibration. And the second is controlled by serial communication message which is send by the computer. The Fig. 2 shows the construction of a proposed system.

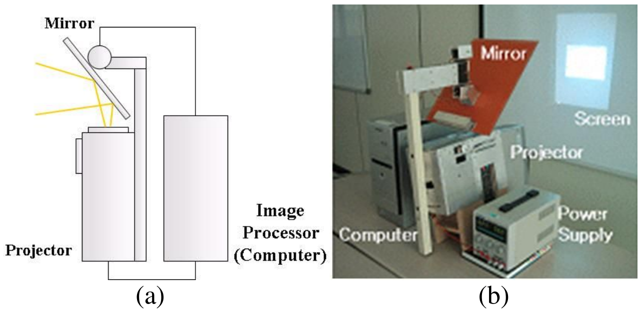


Fig. 2. Construction of the system: (a) simplification, (b) real picture

Our system is made into three parts; image processor, projector and mirror controller. First is image processor that makes distorted images to rectilinear images, second is projector that projects images to screens like walls and tabletops, and the third is mirror usage which, you can control the throwing course that user wants. Fig. 3 shows the architecture of a proposed system.

Fig. 3. The real-time geometric calibration system architecture

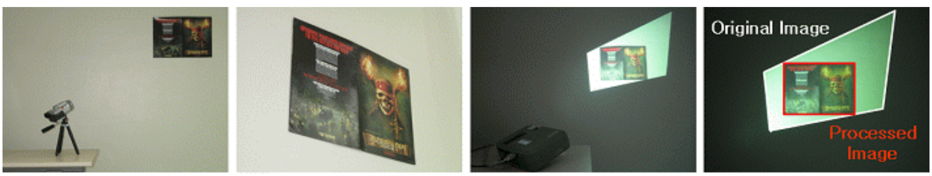
This system takes 2 steps. The second step is the Automatic Calibration using 3D virtual space. In the first step, our system receives a wireless message from user, and controls the mirror which sets on projector by remote control to every direction like left, right, up and down. And the mirror controller captures its direction coordinates and sends it to image processor by serial communication. In the other step, a virtual camera in 3D space is moved and correctly rendered image using graphics processing unit(GPU).

2.2 Image Processing

Our real-time geometric calibration system is based on simple principle. This principle is that projected image seems to be distorted in general but looks rectilinear when three stipulations are satisfied (Fig. 4).

1. The Projector's incidence and the camera's vision have the same angle.
2. The Projector and the camera are the same position.
3. They are the same direction.

In other words, this means that if projected image is rectilinear, source image is distorted when the three stipulations are satisfied. At the time, the distorted source image becomes corrected image in this case. In this way, our system makes corrected images using 3D virtual camera. The Fig. 5 certainly shows the principle of image processing of the system



(a) (b) (c) (d)

Fig. 5. The principle of image processing:(a) photography of rectilinear image, (b) photographed image,(c) projection the image, (d) corrected image

The Fig. 5(a) is a scene that offline-rectilinear image is being taken by camera. At this time, photographed image is shown in Fig. 5(b). If the image is projected by projector, you should get corrected image on the screen (Fig. 5(c,d)). The real-time geometric calibration system using this method makes processed image like in Fig. 5(b) by moving the virtual camera like real condition.

Fig. 6 shows the image processing of the system to process image from original image. First, our system captures a frame image of moving pictures by DirectShow 9.0(Fig. 6(a)). DirectShow is the Microsoft's newest and most exciting multimedia application builder. The rectangle object in 3D virtual space is covered with the captured frame image. Figure 6(b) shows camera located in front of the object. This is similar to real situation. The next step is to move the view point in 3D cyberspace

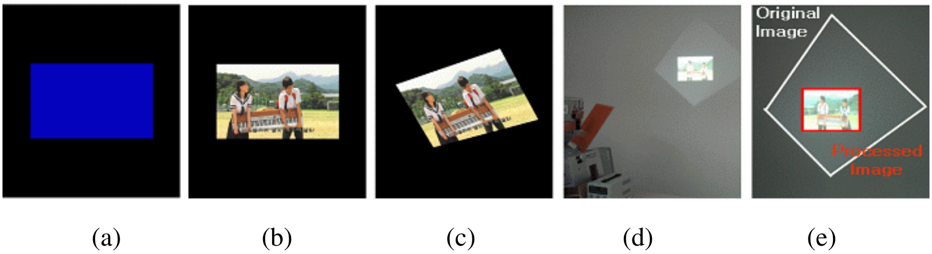


Fig. 6. Image processing of the system: (a) Rectangle object in 3D cyberspace, (b) object mapped image, (c) moving the view point, (d) projection and (e) corrected image

like a mirror which is controlled by user (Fig. 6(c)). At this point, rendered image is the same as the picture which is photographed to offline rectangle image with real camera. Finally, the rendered image is projected to the screen by the projector and finally we will get the processed image (Fig 6(d, e)). At this moment, the mirror which user controls is able to move in all directions like up, down, left, right. If the mirror shows a movement, camera in 3D virtual space moves the base to the starting point(x:0, y:0, z:0) too.

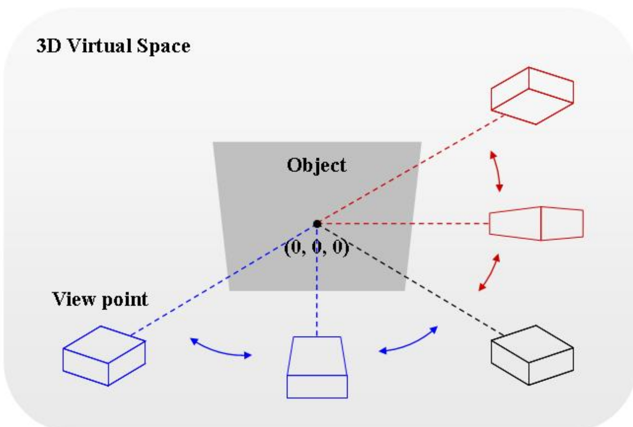


Fig. 7. The rotation of view point centered on the object(0,0,0)

2.3 Receipt of a Remote Control Message / Control of a Mirror

The real-time geometric calibration system is mounted up and fixed on a wall. User controls mirror which is in front of the projector and selects screen like wall, tabletop and ceiling. At this time, remote control is used. User can rotate the mirror as one pleases and save several directions that is used frequently. NEC Format is the most popular and is organized as three parts; first part is leader code which identify that the signal is a remote control message. Second part is customer code. This code has the information of a manufacturing company. The last part is data code that has the command of the system (Fig. 8).

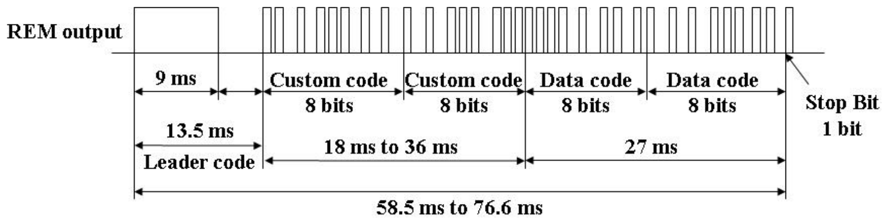


Fig. 8. NEC Format

There are three algorithms which are widely known; port-piling method, port-interrupt method and timer sampling method. The first method checks the existence and nonexistence of signal on occasion and piles data information when port changed. If the change in port outbreaks, interrupt is made and checks the signal. This is the second method. The last is a method that checks remote control message on certain period of time and compares received signal with saved value. The algorithm have several merits and demerits(Table. 2).

Table 2. Comparison of three algorithms

Algorithms	Merits / Demerits
Port-piling	Merits: Easy computing Demerits: inaccurate translation
Port-interrupt	Merits: Correct translation Demerits: Susceptibility of noises (Interrupts which are needless are producted.)
Timer sampling	Merits: Correct translation Demerits: Hard computing

The proposed system uses the method that has merits of Port-interrupt method and Timer sampling method. This is to validate the information to be correct or otherwise. The proposed method goes after Port-interrupt method until remote control message is detected, and changes algorithm to Timer sampling method. It prevents the occurrence of an interrupt needlessly. As the signal disappears, the method returns to Port-interrupt method. The proposed system is the most efficiently. Because received signal is correct and computing is easy. The real-time geometric calibration system act by checked message using the proposed method (Table. 3).

Table 3. Commands Data code for movement of mirror

Data code	Movements
0000 0000	Up
1000 0000	Down
1100 0000	Right
0100 0000	Left

3 Results

We have built a system that includes an XGV (800x600) projector, a Atmega128 to control the a mirror (200x300) and a Pentium 4 PC with SIGMACOM TV Video Capture WDM Device. Table 2 shows performance of the proposed system. Our system uses general features in Microsoft DirectShow instead of computing the warping matrix. So it is very simple and quick. Total processing time consists of to be supplied frame image at 0.0334-second intervals, and the warping image is made at 0.0031-second intervals. Therefore, the warping process is required for a frame image at 0.0365-second intervals.

Table 4. Performance of the proposed system

	Input frame image	Rendering	Total processing time
Processing Time (s)	0.0334 (29.92 fps)	0.0031	0.0365 (27.39 fps)

4 Conclusion

The existing systems can not automatically calibrate in real-time during the motion of the projector, because warping function for real-time calibration requires the special object (e.g., maker, fiducials) on a projection surface and it is determined to manual by simply projecting a special pattern. However, our system provides a real-time automatic calibration for oblique projection distortion. Our system projects image at once without the special object attached to the projection screen. This system has 3 advantages. The first advantage is to provide a correcting image during the motion of the projector. The second advantage is to process rapidly so that motion picture can be played without cutoff. The last advantage is automatically performing all process. Therefore, the proposed system is that it can be easily applied to ubiquitous computing.

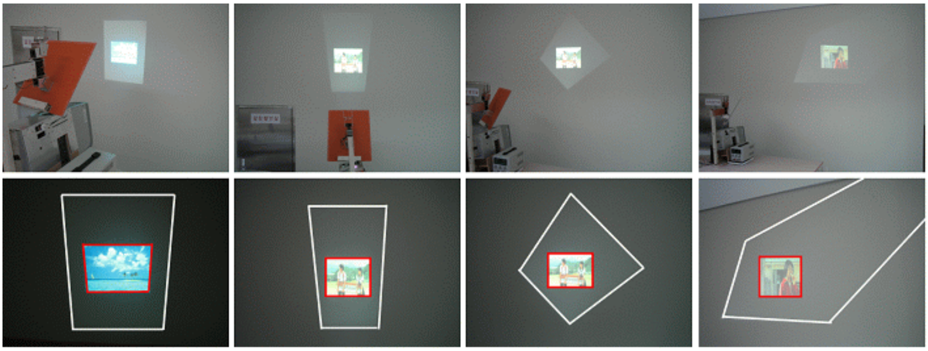


Fig. 9.

Fig. 9 shows result images of the real-time geometric calibration system. The proposed system corrects the distortion caused by oblique projection. As the projector moves, the correcting image is continuously showed on plane surface (Fig. 9).

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A User-Based Method for Speech Interface Development

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Abstract. There is a consensus on the significance and high contribution of user involvement in the process of user interfaces development. However, there is no standard way to implement user involvement in software development processes. Dealing with speech-based interfaces that involve vocal interaction of speaking and hearing, the need of user involvement is increased. In this paper, we focus on the characteristics of speech interface development and suggest a user-based method that enables continuous user evaluation. We illustrate the method implementation in two different software projects that contain speech interfaces.

Keywords: user-based development method, speech interface development.

1 Introduction

Speech is the most natural medium to interact with a computer. The main advantage in using a speech interface is that it enables a hands free control. Though there is a significant progress with speech systems, the main disadvantage is its accuracy that suffers from technological issues such as poor signal and background noise as well as language-recognition issues such as dealing with accents and homophones [3; 7; 11].

Speech as an interaction medium is slow for presenting information. It is also transient and thus difficult to review or edit. It also can easily cause cognitive overload and thus interfere with tasks that require significant cognitive resources [10]. Speech input, especially in an open or public setting can exhibit reduced privacy, making users feel less secure in the process [7]. There are also challenges concerning possible distractions and disruptions such as due to noise pollution.

Nonetheless, as indicated by Shneiderman in [10], speech interfaces are sometimes helpful for hands-busy, eyes-busy, mobility-required, or hostile environments. Moreover, speech has been shown to be useful for store-and-forward messages, alerts in busy settings, and input-output for visually-impaired, blind and physically-impaired users. According to Maguire: "speech interfaces can important offer benefits to users with visual impairments, and in a commercial study carried out by the author, a small sample of visually impaired users were very positive about the concept of a speech-based bank machine." [7]. The accuracy of dictation input has been on the increase. However, adoption outside the disabled-user community has been slow compared to visual interfaces [10].

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When developing speech interfaces one should consider the right way to include the user perspective in the process. In traditional software development approaches, when user-centric techniques are used (if at all), the design of the system is refined according to the user evaluation and mainly during the design phase. In contemporary software development methods, the design phase is merged with the coding and testing phases along the entire development process, and therefore an updated approach should be adopted for the user involvement.

In this paper, we suggest a new perspective to evaluating user interfaces and illustrate it in our plan of evaluating speech interfaces. Our main contribution is our approach to the evaluation process that basically says that this process exists as long as the product development process is, and the users as well as experts in human-computer interaction are involved with the evaluation and improved design. In what follows we describe the challenges in evaluating speech interfaces and suggest guidelines for this evaluation based on existing evaluation techniques (Section 2). In Section 3 we present the method to combine the software development approach with the user evaluation one, and illustrate it in two case studies in Section 4. In Section 5 we summarize.

2 Speech Interface Development: The User Perspective

The evaluation of user interfaces aims at improving the interfaces design and to ensure the accessibility and functionality of the system as per users' requirements [4]. Ideally, the evaluation is based on real users' experience as well as human-computer interaction experts, and performed in an iterative manner in order to ensure feedback till the design is finalized. In this part we examine evaluation techniques for speech interfaces.

We review four existing evaluation techniques for user interfaces and suggest how they can be used for speech interfaces design and evaluation. The first two techniques are performed in the absence of the user and they are the cognitive walkthrough and the heuristic analysis techniques. The second two techniques are performed by the users and they are the wizard-of-oz and the think aloud techniques. For each technique we briefly describe its principles and suggest our guidelines with respect to the evaluation of speech interfaces.

The Cognitive Walkthrough technique. Using this technique we explore what the user thinks when first using the interface without any training [9; 4]. The evaluator knows who the users are and based on a paper or working prototype of the interface selects a task to evaluate. The evaluator then should provide a well-explained reliable narrative that audits the actions the user performs in order to complete the task in addition to the motivation for each action. If the narrative is not reasonable in some sense, it indicates that a problem exists with the interface. The advantages of the cognitive walkthrough technique are that it assists in refining the requirements and that there is no need of working software to perform it. The disadvantages are that the evaluator may not represent the real users of the system, sometimes there is no enough time to go over all tasks, and there are cross-tasks situations that are not examined since each task is stand-alone examined.

With respect to speech interface evaluation, it is clear that when there is only paper prototype the cognitive walkthrough technique lacks. For such interfaces the evaluator should experience by hearing in order to provide a narrative for specific tasks. For example, without hearing, problems that relate to voice clarity as input and output for the system can be disregarded. When using the working prototype for the evaluation, the evaluator hearing skills and the noise of the inspection settings are to be considered. It is expected that the narrative that is provided by the evaluator includes utterances that are said or heard during the inspection.

The Heuristic Analysis technique. Using this technique we evaluate the user interface according to nine (that later extended to ten) defined heuristics that guide us with the design decisions [8]. A group of evaluators use the heuristics in order for each of them to identify and rank severity of problems with a paper or working prototype of the interface. Then all problems and ranks are combined by an individual or as preferred by group activity. The advantages of the technique are that by few general guidelines we can reach many interface problems and that it does not involve much effort. The disadvantages are that the evaluator may not represent the real users of the system and that there are tasks that can be disregarded by all evaluators. In what follows we provide the heuristics each followed by our suggestion for speech interface evaluation and design guidelines.

- Simple and natural dialog – natural flow of task activities without irrelevant or rarely used information. Regarding speech interface evaluation this means that the language used as input and output as well as each sequence of utterances is clear, short, simple and concise.
- Speak the user's language - use words and concepts from the user's world as opposed to system-specific engineering terms. This heuristics seems to fit speech interface evaluation as is.
- Minimize user memory load - the user does not need to remember things from one action to the next, and the information should be left on the screen until it's not needed. In speech interface evaluation this means that the interface should provide feedback by repeating the voice that was heard and using recording enables a series of past utterances [1]. Also, the system should provide the possibility to undo utterances, and to enable deletion of old audio items.
- Be consistent - similar action sequence in one part of the system should give the user the same results when applied in other places of the system. Consistency in speech interfaces refers for example to the way the speech recognizer works, which accents are accepted, and the way ambiguity is handled.
- Provide feedback – The interface provides feedback as per users' actions. For speech interface evaluation, it should be noticed that the feedback expected to be heard but if the task itself uses the audio device the feedback should be provided otherwise (by a special distinct tone or if no other choice by screen output).
- Provide clearly marked exits – Exit is correctly enabled in inner parts of the system. For speech interface evaluation, it is recommended to use a short utterance composed of one syllable in order to provide quick navigation and specifically exits.

- Provide shortcuts – an expert way-of-working is provided. For speech interface evaluation, it is expected to have a way to define by record own customized utterances in order to shorten sequences of actions.
- Good error messages – specific and clear messages are provided as error messages. For speech interface evaluation, error messages are actually voices or utterances that differ from each other in order to indicate different error.
- Prevent errors – minimize as much a possible the errors that can occur. For speech interface evaluation, more errors mean more output voices that can be referred to by the user as noise pollution, therefore should be prevented.

The Wizard of Oz technique. Using this technique we fake as if there is a system and simulate an experiment with real users who are not aware of course to the fake. A hidden person provides with the feedback the users should see. The advantages of this technique are that no need for real implementation of the system, and real users are the participants. The disadvantages are that such a setting usually needs a substantial implementation effort and it can be considered controversial because of not exposing the experiment setting to the participants. With respect to speech interface evaluation, this technique was successfully used [3; 1].

The Thinking Aloud Method. Using this technique we ask the user to tell us own thoughts while observing the user's work with the interface so we will "hear the user's thoughts". Analyzing the user actions and thoughts, the evaluator can check whether the sequences fit, and expose interface problems that cannot be revealed by examination of user actions only [4; 6]. The advantages of this technique are that it is simple and can provide new perspectives. The disadvantages are that it is subjective and relies on thoughts description that can mislead. With respect to speech interface evaluation, this technique is not simple but rather complicated. The user is asked to work with the system so speaks and listens as well as to speak about own thoughts, and the observer needs to distinguish between utterances of using the interface and these of the user's thoughts.

3 The Concept of a User-Based Development Method

The main concept that we suggest is that user evaluation should exist during the entire software development process. This concept as well as other suggestions that appear in this section was emerged in light of the principles of the agile approach and its derived methods[1].

The method of work as part of the evaluation process has few principles. The first is *user collaboration*. This principle is not new with respect to evaluation and design *with* users. The difference is that in the last decade when agile methods become more common, the design phase is no longer a phase but rather an on-going activity as part of each short iteration of few weeks of development. Therefore, as customer collaboration is accepted and fostered, the same is for the real users of the system. Given a continuous users feedback provide us with the second principle of *dealing*

[1] See the agile manifesto at http://agilemanifesto.org/

with changes in users' needs, since when design and user evaluation are on-going conducted, we can easily cope with changes in users' needs during the entire development process.

The background of the third principle is the analogy between interface evaluation and software testing. For many years software testing was neglected since it was mainly at the end of the software cycle after detailed design and implementation, when time and cost does not easily permit investing enough effort. This situation influenced the level of quality and the customer satisfaction[2]. The solution of the agile approach is to perform exhaustive automated testing from the beginning of development, and request the customer to define acceptance tests together with the team. Adopting this solution, we suggest the users to be engaged with the development process and assist in *defining usability automated tests* that enable fast feedback to developers also when users absence, e.g., [2].

While the method described can be used in any software process and interface evaluation, we illustrate in one case study (Section 4) the use of automated measurements for speech interface evaluation.

In light of the above, we suggest that the evaluation process is iterative and inductive. Meaning, in order to ensure the evaluation existence, we should iteratively *understand the users' needs, provide evaluation measures* with respect to users' needs, and *improve the interface design and implementation* in a way that each such cycle refines our product. Figure 1 presents a schematic illustration of this concept. We note that challenges in speech interface evaluation can be further detailed in future work with respect to each of the aforementioned challenges, e.g. delving into the details of users' cognition, memory, and attention.

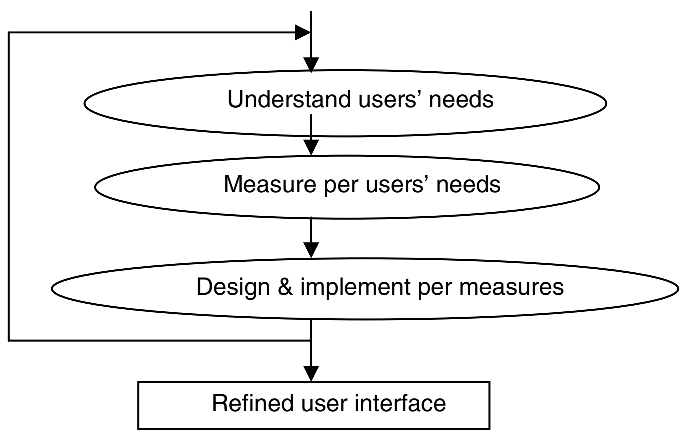


Fig. 1. A schematic illustration of the evaluation process

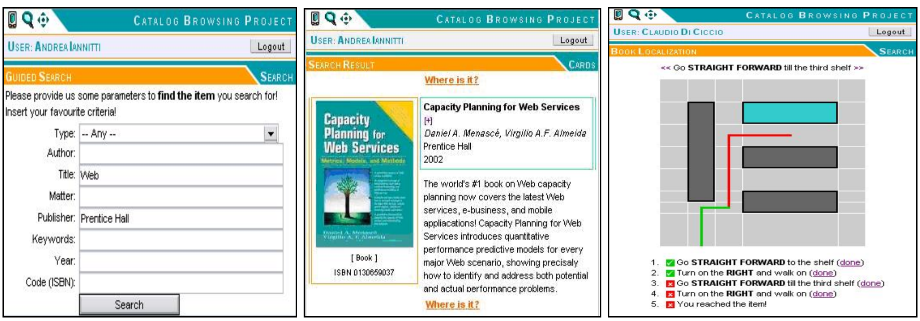
[2] See for example, Mullet, D. (July, 1999). The Software Crisis, Benchmarks Online - a monthly publication of Academic Computing Services **2**(7) – that 75% of enterprise software products are not in use or do not fit customer's requirements.

4 Case Studies

In this part we illustrate the method that is presented in Section 3 using evaluation data that was gathered in two case studies. The first data set is from the catalogue browsing project in which a speech-based mobile interface to a digital library was developed [5]. The second data set is from an entrance control project in which a speech and video interface is developed to control the entrance to a specific laboratory[3]. In this section we focus only on the speech interface development and evaluation of these projects.

4.1 Data Set 1

The interface that was developed in this project is a speech-based mobile interface to a digital library. The interface enables vocal commands for artefact searching and its localization. Speech input is enabled for navigating the application, and speech output is enabled for positioning instructions for artefact localization in a physical library. Figure 2 presents screenshots of the *Guided Search* interface (2a), *Search Result* interface (2b) and the *Book Localization* interface (2c).



(a) (b) (c)

Fig. 2. Screenshots from the catalogue browsing project

Following the user-based concept that is presented in Section 3, the evaluation process of this interface is composed of evaluation iterations that each examines the artefacts of the previous development iteration and results in design changes for the current or next development iteration. The 1st development iteration provides its artefacts. During the 2nd development iteration, the 1st evaluation iteration took place to evaluate and reflect on the artefacts produced in the 1st development iteration and further to decide upon changes that should be introduced. During the 3rd development iteration, the 2nd evaluation iteration took place to evaluate and reflect on the artefacts produced in the 2nd development iteration, and so on. Each iteration is of 3-5 weeks and as aforementioned the first release was composed of 4 such iterations.

[3] The first project was developed in the University of Rome "La Sapienza". Teh second project was developed in the Technion – Israel Institute of Technology.

We focus on a specific experiment to evaluate the speech aspect of the interface. We conducted a *within experiment* with six participants who are computer science students in different levels, 3 male and 3 female. The experiment task includes login to the system, search activities and book localization activity. The task can be performed using speech (S) or without speech (non-S). Each of the participants performed the task in both modes S and non-S, while 3 participants follow S and then non-S and 3 follow non-S and then S. Further, before starting the experiment, each participant filled an attitude questionnaire and received ten-minute training on how to use the interface. After the experiment each of the participants filled a questionnaire to reflect on his/her activities.

In what follows we present the experiment qualitative and quantitative data. Table 1 presents the answers of the participants to some initial attitude questions with respect to speech aspect, where SD means that the participant Strongly Disagrees with the statement, D means disagree, A means agree, and SA means strongly agree.

Table 1. Participants attitude to speech interfaces

Statement	*SD*	*D*	*A*	*SA*
I like interfaces with speech features	1	1	3	1
I have experience with speech interfaces	1		5	
I use speech interface when I can	1	3	2	
People whom I know do not like speech interfaces		4	1	
Speech interfaces are slow	1	2	1	1
I feel uncomfortable with speech interfaces		2	4	
Speech interfaces are fun	1		4	1
Speech interfaces are annoying		4	2	
I expect to use more speech interfaces in the future			3	3
I prefer interfaces that do not include speech		3	3	

We note that when for a specific statement the sum of answers is less than 6, it means that some participants did not answer on this one. As can be observed, the attitudes with respect to speech interfaces are mixed and do not follow a consistent approach. Though speech interfaces are fun they are also annoying, and though participants like them, they do not always prefer them.

The same questionnaire had some open questions asking the participants to provide features that they consider important to be included in speech interfaces, advantages and disadvantages of speech interfaces, and a personal scenario that happened to them when using such interfaces. Following are some of the expressions of participants answering those questions:

- "[consider important] using realistic voices"
- "…I had to provide some information to an automatic operator – it was boring waiting for its answers"
- "[disadvantage] it can take several minutes to interact with speech interfaces"
- "[advantage] they can become friendly"

Table 2. Averaged search time (in minutes)

Group	*Averaged search duration*	*Averaged Non-S search duration*	*Averaged S search duration*
Non-S → S	54.66	28	81.33
S → Non-S	26.58	14	39.16

Examining the answers, two main categories are observed which are user interaction and user friendly. One phenomenon that was found is that participants see speech interfaces as both friendly and not friendly, or as both fast and slow. For example one participant answers the following in two consecutive rows, "[advantage] faster than normal interfaces"; "[disadvantage] a user may wait too long before achieving [his/her] purpose".

After filling the questionnaire, the participants receive one-page users` guide and when completed to read with no more questions, they received the task page according to their appropriate experiment order of S and non-S. An automatic time measure, which was developed as part of the system, provides us with the time stamps of the login / logout and with the time stamps of each search start /end. Table 2 presents the averaged time in minutes that was invested on the two search activities by both experiment groups together with its division per mode.

As can be observed, the S→Non-S group performed the entire task almost twice faster than the Non-S→S group. When looking into the data of speech and non-speech per each group, we see that the participants in both groups performed the speech task slower then the non-speech task. This implies that although the speech task required more time from the participants, they learned better the system when first using it with the speech option.

After completing the task, participants were asked to fill a questionnaire to reflect on their own activities. Table 3 presents their level of agreement to some statements. As can be observed, most participants find it hard to use the interface in its current stage, though it was fun and they expect to such interfaces in the future.

Table 3. Participants reflect after using the interface

Statement	*SD*	*D*	*A*	*SA*
I like searching using speech commands		4	2	
I have experience with vocal GPS	1	2	3	
I prefer to work with the silence mode		2	4	
People will feel that the speech mode is too slow		2	4	
I feel uncomfortable with the system I use	1	1	3	1
It was fun			4	2
It was annoying	1	4	1	
I expect I will see such systems in the future			6	

The same questionnaire had some open questions asking the participants to describe what they liked with the interface, what are the problems they have encountered, their severity ranking between 1– not so important and 5– very important, and to recommend on how to deal with the specific problem. Following are some of the expressions of participants answering those questions:

- "I expect the system to vocally recognize also the value I want to search"
- "It was easy to use; Funny to use"
- "[rank 4] Instructions too fast"
- "It's been a new experience to me"
- "[rank 3] too sensitive to pronunciation"
- "[rank 5] unstable"
- "[I like] the GPS system"
- "I like activating commands by voice"
- "[rank 5] sometimes it doesn't understand what I say"
- "[rank 5] I have to repeat"
- "[recommendation] try to translate to Italian; it should be more flexible with pronunciation"
- "[I like] moving the cursor by speaking"

Examining the answers we learned that we should focus on some improvements that concerns with implementing speech for all interface features and improving the on-line usage information. This is based on our observation that when users are introduced to a speech-based interface they expect it to be fully speech-based meaning no using of keyboard at all. Further, they expect to receive vocal on-line help to assist them in the process of using the application.

4.2 Data Set 2

The following data is smaller in scope than the first data set and relates to a single first iteration of user evaluation. It is presented here in order to demonstrate *thinking aloud* evaluation data of a speech interface. The project goal is to develop an entrance control system that is based on the identification of faces from a pictures pool. The user who wants to enter activates the system by visual indication when he/she stands in front of a scanner, and by giving a vocal command that starts the process. The system warns the user not to move before taking a series of pictures, and announces the result whether the entrance is granted or denied after comparing with the pictures in its pool.

A thinking aloud experiment was conducted in the first evaluation iteration. 11 participants were asked to use the system, i.e., each of them asked the system to identify his/her face in order to grant the entrance. The participants were asked to report what they think and feel during this experience. Following is the evaluation data. 5 of the participants had the following problem: they gave the vocal command but thought that it was not accepted by the system. They start to give the vocal command again, but meanwhile the scanner took the series of pictures, the process fails, and the scanner starts again due to the second command. In 2 of these 5 trials, the process ends in success, meaning the system could announce the result. 5

participants reported that using the microphone to give the vocal command enabled them with good control over the process. One participant said that he did not know if to speak normally or in a louder tone. The conclusions of the evaluator were as follows: a) The users need a vocal or visual warning about the start and end of the scanner operation. b) The response of repeated scanning in case of a repeated vocal command should be changed. c) The time which permitted users wait should be shortened.

5 Summary

In this paper we present and illustrate the concept of a user-based method for speech interface development. We suggest an evaluation process that foster user collaboration at all stages of development and the definition of automatic tests for evaluation and research of speech interfaces.

We found that combining a user centric approach with the software development method can enhance user evaluation and we illustrate it for the case of speech interface development.

Acknowledgments. This research is supported by the DELOS Network of Excellence on Digital Libraries http://www.delos.info/.

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iTeach: Ergonomic Evaluation Using Avatars in Immersive Environments

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Abstract. This paper describes an approach to use virtual reality technology and motion capturing for the immersive teaching of virtual humans. A combination of direct and indirect interaction as well as 2D list style menus and 3D dialogs has been realized to simplify the teaching process. In contrast to existing desktop solutions the presented concept allows even inexperienced users to reasonable work with the system. The interaction principles support an iterative work flow which speeds up the ergonomic evaluation and improvement of industrial work places remarkable.

Keywords: Virtual environments, virtual humans, avatars, virtual reality, ergonomics, production planning.

1 Introduction

Virtual humans and avatars are used in many fields of applications for the evaluation and improvement of ergonomic properties of products, technical systems, etc. Especially the automotive and aeronautic industry evaluates and improves new car interiors, aircraft cockpits and systems operation with virtual humans. The advantage is that the developers can simulate in early development stages easily and fast if the product is usable for different sized and proportionate humans. These evaluations support the engineers to plan sufficient adjustment ranges, to properly arrange important operation elements or to develop different sized product variants for different markets and groups of users.

A virtual human consists of a numerical description of the body and its physical behaviour and a visual representation, the avatar. Several virtual humans, e.g. Ramsis [5] [6] [7], virtual Anthropos [4], CharAT [8], Delmia V5 Human [3], Jack [13], are commercially available. They can be purchased as stand alone packages or fully integrated into CAD-, modelling and planning systems. The usage of virtual humans in the corresponding desktop applications can be considered as standard but the

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handling is complicated and the learning effort is very high. Fully integrated virtual humans in immersive virtual reality (VR) applications offer all advantages of the 3D stereo vision and the interaction with 6 degrees of freedom. The available systems are using very similar interaction concepts for the handling of the virtual humans like the desktop applications [8].

The goal for the herein described iTeach application is to develop an easy to learn, consistent interaction concept that makes the planning and ergonomic evaluation process more efficient and easier to learn.

2 Virtual Humans in Virtual Environments

At the beginning of an evaluation a virtual human is placed in a virtual environment, e.g. a virtual car interior, at the planned working or operation position.

If the purpose of an evaluation is an analysis of a working posture a **static virtual human** is sufficient. The virtual human is placed at the correct position and with the planned posture. Visual fields and reach envelopes [Fig. 1 are switch on to evaluate if all important elements are lying inside the volumes.

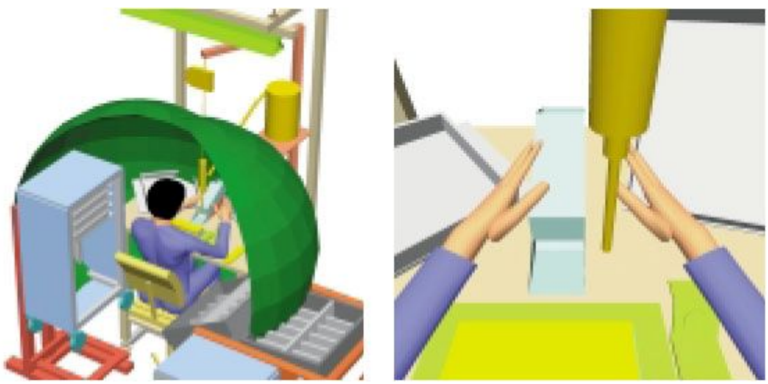

Fig. 1. Static avatar with reach envelope [2]

More complex is the analysis of movements a user must perform to operate a car, a work step, etc. In order to evaluate a sequence of movements a **dynamic virtual human** must "learn" these movements. The user picks control points, e.g. a hand, of the avatar with the interaction device and defines a sequence of key positions [Fig. 2. The positions in between are interpolated to a complete movement. A replay function allows the animation of the avatar and a control of the movements. The definition of the key positions is called "teaching" a virtual human. For complex or long movements many key positions are necessary. The exact positioning and the steady control regarding collisions make the teaching process complicated and very time consuming. The exact coordination of two movements at the same time makes the teaching even more difficult because for each key position the corresponding position of the other body part must be taken into account to end up with coordinated movements of all body parts.

Even a well trained user typically needs many mouse clicks, corrections and control steps from different view positions until an exact and natural looking movement has been defined. In a 2D desktop environment the typical effort for 1 minute simulation is 400 minutes teaching time [10].

In case of the integration of a dynamic virtual human into an immersive VR-applications the stereo vision and the interaction in 6 degrees of freedom supports the user to set the key positions in the three dimensional space and to identify collisions faster.

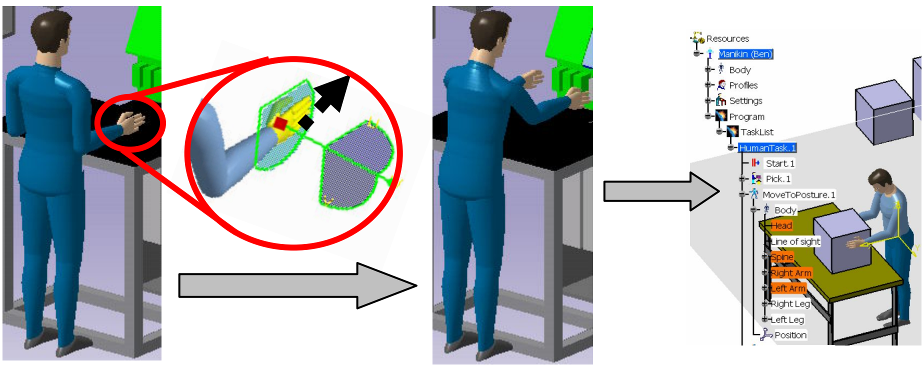

Fig. 2. Setup of a movement of a dynamic avatar (left and middle) and a sequence of movements (right) [3]

3 Application Handling in Virtual Environments

An interaction system for VR-applications consists of one or more hardware devices [Fig. 3 for interaction with 6 degrees of freedom (6 DOF), 2D and 3D user interfaces [Fig. 4 and appropriate interaction and navigation metaphors [11] [9]. Depending on the application's requirements and the user's preferences one or two handed interaction is possible. VR-installations are usually operated while users are standing in front of the projection screen. Object manipulations, navigation and 3D menu are handled with a 6 DOF device. Compared to a desktop environment with keyboard and mouse the user is forced to perform more hand and arm movements.

Complex VR-applications like the ergonomic evaluation with virtual humans need an interaction system that gives the users fast and comfortable access to the functions needed for the evaluation task. Otherwise the expected gain in efficiency due to the 3D stereo vision and the 6 DOF interaction will be lost because of slow and complicated application handling.

Fig. 3. Interaction devices “FHG-IAO Hornet” (left), ART hand target (middle) and ART finger tracking (right)

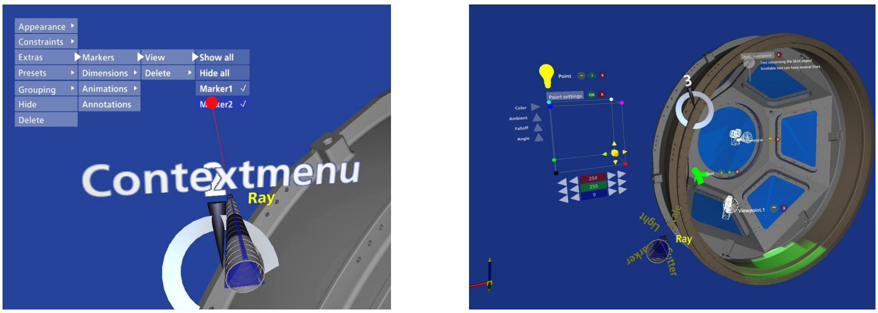

Fig. 4. Examples for list style 2D menu (left) and 3D dialogs (right)

4 Interaction Concepts

Depending on the application’s requirements, the tasks which should be performed with the application and the available interaction system different metaphors for the interaction with the avatar are possible.

- **Indirect interaction in a 2D desktop environment:** The avatar has control points for translation and rotation at the joints. The control points can be selected and moved with the mouse pointer [Fig. 2 left]. Translation and rotation are separate steps.
- **Indirect interaction in an immersive 3D environment:** As in a desktop environment the avatar has control points. The user selects and moves a control point with the 3D cursor connected to the 6 DOF interaction device. Translation and rotation can be performed in one step. Due to the stereo vision the user has a better control for collisions and the correct key positions. The 3D immersive display supports the whole evaluation process [4].
- **Direct interaction in an immersive 3D environment (motion capturing):** The user does not use an interaction device to select and move a control point. The control points of the avatar are directly coupled with the corresponding points on the user’s body. The tracking system records the user’s movements and sends the positions and orientations in real time to the control points of the avatar so that the avatar makes the same movements like the user [Fig. 5. The advantages are that the

user has the immediate and full control on the avatar and that the stereo vision helps to recognize and avoid collisions. Additionally the user gets a good feeling on how complex and stressful a certain movement is. In such a setup it is important that the size and proportions of the avatar are fitting to the user.

Fig. 5. Direct interaction with a virtual human [12]

5 Immersive Teaching

The application's name "iTeach" stands for "immersive Teaching". The purpose is the ergonomic evaluation of industrial working places. The target user groups are non VR-specialists, work place planners, physicians, constructing and design engineers and product developers, using the system for the planning and ergonomic evaluation of work places. The goal is to incorporate the relevant decision makers and discus the different economic, medical, ergonomic and functional aspects in very early planning stages. The system should be designed for its use in industrial work flows.

Accordingly the main requirement was an intuitive and easy to learn interaction concept. The system must support an iterative, communicative working style in heterogeneous working groups. Even novice users should be able to understand the relevant interaction concepts in a reasonable short time. The system must be fast ready to use so that time consuming setup procedures are not practicable.

5.1 System Setup

The target VR-installation is a 265 x 200 cm sized Powerwall. Such a wall is a good compromise between system costs and projection area. The installation is equipped with an ART optical infrared tracking system with 4 ARTrack 2 cameras. iTeach is based on the VR-runtime software Fraunhofer IAO "Lightning". For the ergonomic evaluation the virtual human and avatar Icido "CharAT" [8] has been integrated into Lightning. As hand tracking targets either two Fraunhofer IAO "Hornets" [Fig. 3 left] or two ART hand targets [Fig. 3 middle] are in use. Object manipulation, navigation and dialog and menu handling is performed with a Fraunhofer IAO Hornet.

5.2 Interaction Concepts

For the interaction with the virtual human iTeach combines direct interaction for the teaching of hand and arm movements with indirect interaction for object manipulation, navigation and the handling of 3D dialogs and menus. The direct interaction uses a simplified motion capturing, i.e. the user's head and hands are tracked only. Instead of wearing a special tracking suit [Fig. 5 equipped with many tracking targets users wear hand targets [Fig. 3 middle] at the wrists [Fig. 7. The hand targets are easy to draw and do not need a recalibration before an evaluation session can start. Due to the very high precision of the optical tracking system the user's movements are recorded and transmitted very exactly.

Object manipulation, navigation, dialog and menu handling are using indirect interaction with a virtual ray mounted at the Hornet. The user points on and selects the navigation direction or objects. If an object is selected it is connected to the Hornet and can be positioned by moving the Hornet.

The standard navigation metaphor is "point and fly". Viewpoints can be predefined and or be created during an evaluation session. The navigation to a viewpoint is either a hard "jump to" or a "fly to".

iTeach uses 2D list style menus [Fig. 6 for functions that are not often required during an evaluation session. The structure and logic of operation of these menus is very similar to desktop menus users are familiar with. The structure can be configured according to the applications needs and the user's preferences. The menu operation is completely tracking independent. The Hornet provides 3 buttons and a mini joy stick with the button function up, down, left and right which is used to scroll through and select menu items. The assignment of the Hornet buttons can be adjusted according to the user's preferences.

3D dialogs provide fast access to functions the user needs regularly during an evaluation session [Fig. 6. The dialog's buttons can be selected with the ray mounted at the Hornet. As any other 3D object the user can place a dialog freely in the virtual environment in order to find a comfortable position for interaction and to avoid disturbing occlusions of relevant parts of the displayed scenery. 3D dialogs offer "one click" access to the relevant functions of the virtual human such as record, play save and load teachings, pause, switch on and off inverse kinematics, switch on and off reach and envelopes, start and stop walking and the visual field.

Additionally iTeach can be operated from a remote console so that on demand an operator can take over the application handling and the planner can concentrate on the evaluation tasks.

A griping functionality has been built in. The user has either one Hornet or a finger tracking device [Fig. 3 in each hand. The avatar closes its hand either on a button click on the respective Hornet or by closing the thumb and index finger on the finger tracking device. If the finger tips of the avatar are touching an object while closing the hand, the object is connected to the avatar's hand and can be moved freely as long as the Hornet button is pressed or the fingers on the finger tracking device are closed.

Fig. 6. iTeach 2D menu (left) and 3D dialog (right)

5.3 The Teaching Process

For exact results the virtual human must be adjusted as exactly as possible to the gender, the proportions and the size of the user by adapting the CharAT at the gender and percentile the user belongs to. During the teaching process the user is supposed to stand at a defined point [Fig. 7 the axis of coordinates], the origin of the tracked space, in front of the screen so that the hand and arm posture of the user corresponds exactly to the posture of the avatar [Fig. 7. Each hand movement and rotation of the user is transmitted so that the avatar has the same posture like the user. The user gets

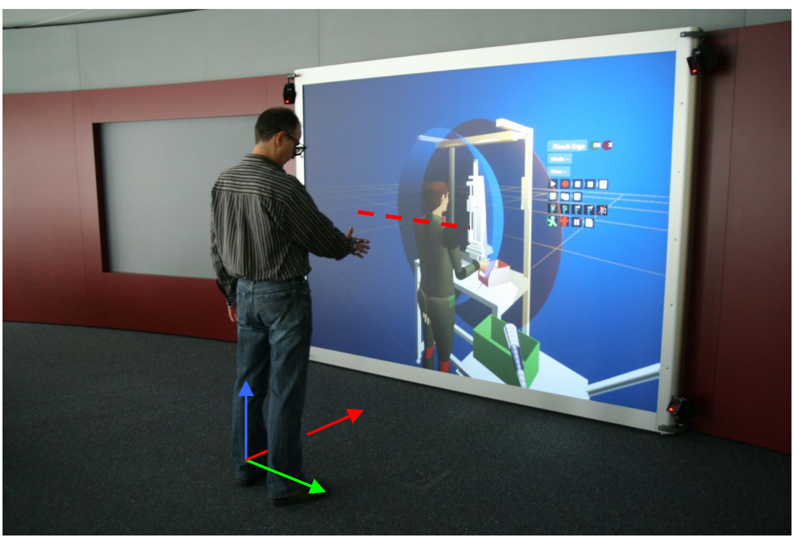

Fig. 7. Direct interaction: Coupling of the user's hand with the avatar (the red dashed line) and the origin of the tracked space (the axis of coordinates)

feedback on the stress level of a posture or movement in two ways. First he/she feels physically in the own hand and arm if a posture is comfortable or not. Second the virtual human indicates with different colours at the joints and the back how comfortable a posture is for the selected percentile of humans.

The avatar gives the necessary visual feedback on how exact the planner performs the movement and if collisions occur.

The head of the avatar can be switched of to allow a teaching position exactly at the planned worker's position. Other viewing positions are possible at any time but teaching gets harder the more the viewing position differs from the position of the avatar.

The user can iteratively reposition, add, replace or remove work place elements with the Hornet if the evaluation shows that the element's position is not optimal or an element is missing or wrong sized.

While replaying a recorded teaching the planner is allowed to navigate freely and analyze the movements and the avatar's postures from arbitrary viewing positions. Additionally the ergonomic stress values delivered by the virtual human can be saved in a file at any point in teaching time. Teachings can be saved to and loaded from files.

6 Summary

For the teaching of virtual humans the combination of direct and indirect interaction and the iterative work flow of evaluation and interactive reposition show promising results. Users are fast familiar with the system and give positive feedback. Compared to desktop solutions with a ratio of teaching time to simulated time of around 400:1 [10] the teaching process is much faster up to a ratio of 10:1.

The combination of 2D list style menus with 3D dialogs is a bridge from the well known desktop interaction to immersive interaction and application handling. Users easily understand how to operate iTeach. The biggest difficulty for untrained users is the free navigation through the virtual environment.

The herein presented approach allows the planner a realistic simulation of working situations at a planned work place. It is very easy to switch on and off and to compare different variants of a work place within one session. If the virtual workplace is scaled up or down the working situation of a smaller or larger human can be simulated in order to evaluate the resulting difficulties and stress values.

The immersive teaching and the, compared to desktop solutions, simple application handling supports the communication and the iterative planning in mixed groups.

The approach can not only be used for production planning but for evaluation of cockpits, machine operations, etc. also.

The next steps are formal user tests with productions planners to work out the user's acceptance and a benchmark between existing desktop solutions and the iTeach VR-application.

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Survey Design for Visually Impaired and Blind People

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Abstract. This paper presents guidelines for the design of self-administered surveys for visually impaired and blind people within a mixed mode approach. The different needs of the target group are fulfilled by offering different modes of participation (paper-based, braille-based, Web-based). Reading aids have in common that they enhance the focus of a specific piece of text or single word. This advantage turns into a disadvantage in terms of a clear overview and arrangement of the text elements on a page. Therefore text needs to be designed with cognitive processes and accessibility standards in mind. This is especially true for a survey questionnaire where each question and answer item has to convey its own special meaning independent from context. Design problems and their solutions are described and illustrated with experiences from pretesting and a case study.

Keywords: Accessibility, mixed mode, self administered surveys, visual design, Web, online, paper, braille, visually impaired, blind, 504c.

1 Introduction

This paper is concerned with the questionnaire design and the conduction of surveys for visually impaired and blind people. These people are challenged by the readability and usability of traditional paper-based text. Associations for visually impaired and blind people cope with the special requirements by providing various possibilities to obtain textual material. The text corpus may be printed in a bigger font, text may be converted to braille[1] paper or be read aloud to provide audio material. Additionally, text may be obtained electronically and listened to with the help of a screen reader or read by means of a braille display. Special devices can be used (enlargers) which magnify text while allowing for increase in contrast and changes in color (e.g. yellow on black instead of black on white text). All these aids have in common that they enhance the focus of a specific piece of text and sometimes just a single word. This

[1] Braille is a system of printing textual material with raised dots so that it can be read by touching them. Letters and numbers are represented by a specific combination of dots.

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advantage turns into a disadvantage in terms of a clear overview and arrangement of the text elements on a page. Therefore text needs to be designed with cognitive processes and accessibility standards in mind. This is especially true for a survey questionnaire where each question and answer item has to convey its own special meaning independent from context.

We developed several design guidelines for a large font paper-based version, a Braille version and an online version of the same questionnaire. These guidelines for the different modes support the various ways in which the target group is used to reading and responding to written material.

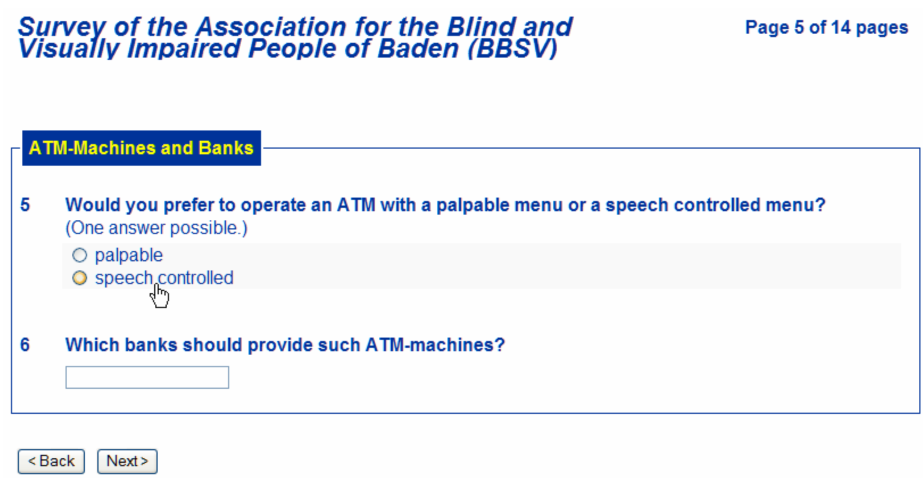

Fig. 1. Screenshot of page five of the Web Survey version. The original survey was conducted in German. Technical note: The use of label-tags in the HTML-structure make it possible to give an answer by clicking on the answer text and allow screen readers to identify the correspondent radio buttons. Usage of the field-tags results in the grouping of the two questions with a heading and a frame.

2 Mixed Mode Approach: Paper and Pencil, Braille and Web

This paper originates from a survey conducted among the members of the Association for the visually impaired and blind people of Baden in Germany. Prerequisites were a low budget which ruled out the possibility of a telephone survey, due to the fact that anonymity of respondents should also be guaranteed. This made it necessary to outsource the monitoring of data collection to the Center of Survey Research and Methodology (ZUMA) which supported the project through all stages with methodological consulting, questionnaire development, design, and implementation. To ensure that each member is able to receive information provided by the association it is a standard procedure to develop several versions of a text in different modes. The newsletter for example is provided as braille, large font, normal font and e-mail. Thus, it was a requirement to develop a braille version, a large font version and an online version of the questionnaire.

The content of the questionnaire was related to demands for supporting equipment, assistance, training, attitudes to social activities and basic demographic data. It consisted of twenty questions and was restrained to three basic question types: check one that applies, check all that apply and open question formats. Respondents were able to provide additional information for some questions with an answer item which read "Other, please specify:___ ". Figure 1 shows a design example for the Web survey implementation.

All members of the association were invited to participate in the survey (n=518). Table 1 shows the number of responses for the different survey modes. All members of the association received either a large font version or a braille version of the questionnaire identical to the mode in which they receive information material from the association. A free return envelope was enclosed. About three quarters of the members have subscribed to receive textual material. Each questionnaire informed about the possibility to take the Web survey instead of filling out the paper version.

Because approximately twenty persons receive e-mail newsletters, we were able to roughly estimate the response rates for the different survey modes, if we assumed that these twenty persons were likely to take the Web survey. The response rates for the Web and large font versions were expected to be about fifty percent, showing a high commitment of the members and giving evidence to the success of the implemented design. The braille paper version had a lower response rate of thirty percent which is still very good given the fact that answering the questionnaire with a braille typewriter is a very time-consuming task which can easily take more than an hour for only twenty questions.

Of the 235 respondents 46 percent were males and 54 percent were females, resulting in a total response rate of 45 percent. The mean age was 67 with a standard deviation of 14 years. Respondents were either blind (55.6%) or visually impaired (42.7%). Only four participants (1.8%) reported to have good eyesight.

The answers about Internet usage ("How often do you personally use the Internet at home?") reveals that the majority (81,5%) do not use the Internet or do not have Internet access. Only 15.1% are using the Internet two times per week or more often. In the large font version 70% reported that they needed help from a second person to fill in the questionnaire, whereas in the braille version only 19% and in the Web survey none requested help from others to participate. Overall, participation was perceived as rather easy (17.9%) or easy (77.7%).

Table 1. Distribution of responses according to survey mode

Mode	Response	Percent
Large font paper version	192	81.7
Braille version	32	13.6
Web survey	11	4.7
Total	235	100

3 Cognitive Aspects of Survey Design for Visually Impaired and Blind People

Modern approaches in survey research develop questionnaires based on the knowledge from cognitive psychology [1]. In recent years principles of good Gestalt were adapted to questionnaire design [2] and the usability of a questionnaire [3, 4] especially in Web surveys [5] has become an important issue. Despite these new developments, the traditional concept of burden, early defined by Bradburn [6], still plays an important role in assessing some of the problems involved in survey design. The following subsections explain how cognitive concepts shape the design specifications for surveys for visually impaired and blind people.

5. What would you prefer in an ATM?
I prefer a palpable menu .... ☐
I prefer a speech controlled menu .... ☐

Fig. 2. Traditional standard layout in a paper-based questionnaire

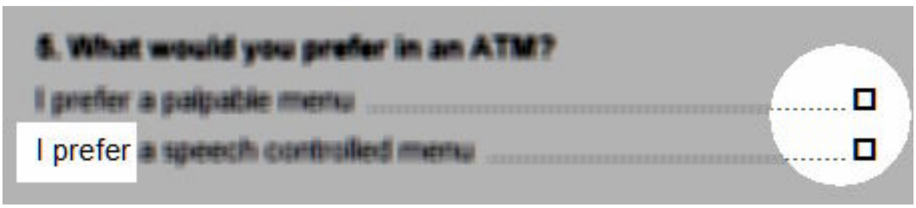

Fig. 3. Demonstration of possible restrictions of the visual field due to a magnifying device (rectangle) or tunnel vision (circle) with the question of figure 2. The background is blurred and shaded to stress the visible parts.

5. Would you prefer to operate an ATM with a palpable menu or a speech controlled menu? (One answer possible.)
a) palpable ☐
b) speech controlled ☐

Fig. 4. Redesigned survey. Copy of the top part of page three of the paper-based survey. The original survey was conducted in German and the size was 14 point. This example demonstrates the implementation of the guidelines for an enhanced overview at question level, resulting in improved navigation, orientation and easier cognitive processing.

Challenges can be categorized into three main aspects: (1) providing overview (e.g. position markers), (2) navigational aids (e.g. clear identifiers to distinguish between questions and answers on the left border), and (3) supporting the sequence of the questionnaire flow (e.g. allowing answer checks at the immediate right end of an answer option in the paper version which destroys the usual visual alignment of right checkmarks).

3.1 Provide and Support Overview

A questionnaire should provide information about the survey to foster the overview on (a) a general level and (b) at the level of specific questions. People with an impaired visual field, e.g. a tunnel view find it difficult to get an overview of a page. Several single aspects must be viewed separately and put together to actively form a whole which is not visible at one glance. Similar problems occur with enlarger devices, braille paper and screen readers. Figure 2 shows the traditional layout of a question in a paper-based questionnaire. The corresponding Figure 3 illustrates the challenges of restricted visual fields. The light rectangle exemplifies the visible part when using an enlarger, the circle can be seen as the result of tunnel vision.

The beginning of a questionnaire should therefore explicitly include information about the length of a survey in terms of number of questions and number of pages (also a footer indicating "page 1 of 6" should be added). As in traditional surveys the topic should be noted. Furthermore, instructions on how to participate need to be stated ("Please fill in the questionnaire and send all pages back to us with the enclosed envelope, which we did address and stamp for your convenience."). In the braille version we included additional instructions for the use of a braille typewriter. Respondents were asked to write the number of the question and their answer in full text: "At the end of the questionnaire you will find three sheets of paper suitable for your braille typewriter. To answer a question, please write the question number together with your preferred answer. For example to answer question 13 with 'female' you would write: 'question 13 female'. Please start each answer in a new line." The Web version implemented a textual progress indicator. In the same manner a footer was placed in the large font version.

Besides the providing of a general overview, extra information is also helpful within each question. Each question has to make clear how a response should look like, i.e. whether it is a "check one", "check all that apply" or "write your answer" question type. It is important to note that in contrast to the usual wording mentioned above the wording chosen was in such a way that the first word indicated the question type. The large font paper version used extra information as follows: "(One answer is possible)", "(Several answers are possible)".

The braille version provided additional information about the amount of possible answers and instructions to answer the questions. Examples for a set of extra information per question in the braille version are: (Several answers are possible among 5 answers), (One answer is possible among 3 answers), (Please write your age on the answer sheet). If the extra information was redundant for the question, it was not included, so that respondents did not feel fooled: For example “Are you male or female?” was not followed by “(One answer is possible among 2 answers)”.

The guidelines to improve overview are as follows:

1. Reduce the number of question and answer types to as few as possible.
2. Inform about the topic of the survey.
3. Provide instructions on how to fill in and return the questionnaire.
4. Provide information about the length of the survey. Add a footer or header with page numbers and the total amount of pages.

5. For a braille version indicate the amount of available answer options after each question.
6. Indicate the type of answer after the question. For example: "One answer is possible", "Several answers are possible".

3.2 Provide Navigation and Orientation Aids

People suffering from restrictions of their visual field find it impossible to benefit from the traditional layout of paper-based questionnaires. One may think that the two answer options in Figure 2 are easily identified. On the contrary, this is not the case for people using a magnifier or suffering from tunnel vision (figure 3). The fact that both answer options start with the same eight letters makes them harder to distinguish from each other. When moving the paper to the left under the enlarger device in order to read to the right and then turning back to the next line with one quick move, respondents might have the impression that they had accidentally positioned the paper in the same line. As a consequence they move further down and skip the second answer alternative. Pretesting revealed that with the fast and often practiced movements involved with enlargers some questions and more often answer categories were easily missed in the case of traditional survey layout. A similar consequence of such restrictions is that identical wording at the end of an answer option (in this example the word "menu") adds an additional hurdle to match the answer field with the distinctive meaning of an answer option. Thus, respondents need to be extra careful and crosscheck their paper or eye movements to avoid unintended line switching.

A restriction of the visual field makes it more difficult to orientate oneself on a sheet of paper and to focus the attention on the desired parts. Loosing orientation or the focus of attention could lead to the following outcomes:

1. A page is skipped and gets lost.
2. A question is skipped.
3. Answer categories are skipped and not considered.

An example how a page could be skipped was revealed through pretesting with a braille version of the questionnaire. The participants started by flipping through the pages, reading parts of the top and the bottom which contained the numbering. The paper sheets were turned so to also scan the backside of the papers for text. Each paper was then laid on the table or kept on the knees. By accident a paper sheet was put on the table aside from the other paper sheets. The remaining pile lead to the impression that the survey consisted of fewer pages resulting in unintentional partial nonresponse.

The derived guidelines draw from the principle that questions and each answer option should be distinguishable from each other. Figure 4 shows part of the redesigned questionnaire for the large font paper version. The following measures proved to be successful navigation and orientation aids:

7. Start each question with a consecutive number followed by a period, making each new question distinct from the very beginning.
8. Include empty lines (spacers) only before each new question but not between answer categories, nor between the question and the answers. By this question and answers are visually grouped together.

9. Start each answer category with a consecutive letter beginning with a) for each question. This helps to distinguish the answer options from each other and differentiates them from the questions which are numbered.
10. Reformulate the answer options towards a maximum of different letters in the beginning and at the end of each item, while keeping the meaning. This ensures that each item is easy to distinguish at the start of the line and in the region of the answer options.

3.3 Streamline the Answering Process

Usually, the layout of a questionnaire is based on principles of good Gestalt, like proximity and grouping [2]. As a result, check boxes are aligned on the right hand side of a page in paper-based surveys (sometimes with dotted lines to aid the eye movement) and the left hand side in Web surveys. This is only reasonable if a respondent is able to see the whole of the line and can easily connect the answer boxes with the answer categories. Obviously, respondents who only see a few words at a time (some people enlarge only one word at a time) may have difficulties reaching beyond the white gap or following the dotted line between answers and check boxes. What is worse, pretests made it clear that due to the fact that the right hand side looks like a column of similar boxes only, the correctly corresponding right box is difficult to reach and remains unclear. The intentional effect of such visual grouping does not hold in our case and the linkage between answers and answer fields is broken. As a solution, traditional grouping may be avoided. Still, the answer fields are put to the right to allow an immediate response after reading without the need for an errorprone return to the beginning of the answer option.

As a second point, processing all answer options can be time consuming when scanning the lines is not possible. Reaching a valid answer and considering the available options can easily be supported by formulating all answer options into the question. As a positive side effect such wordings do also reduce acquiescence [7]. For example instead of asking "What would you prefer in an ATM?" the question reads “Would you prefer to operate an ATM with a palpable menu or a speech controlled menu?”

The guidelines supporting the answer process are as follows:

11. In a paper-version include check boxes directly after the answer text, leaving a ragged right. Instruct respondents to mark either the checkbox at the right end or the character at the beginning of an answer option.
12. Formulate the questions to include all answer categories wherever possible, i.e. if only a few answer categories exist. Such a procedure is known to reduce burden for the respondents.

4 Conclusion

This paper puts forth twelve guidelines for the design of self-administered questionnaires for surveys with visually impaired and blind people. Several modes have to be considered to accommodate to the various channels of communication which visually impaired and blind people are used to. The discussed approach is appropriate for projects where a personal or telephone interview is out of scope. Such cases might occur when there is a need to stay within the online medium (e.g. in website evaluation forms), with missing phone numbers or simply under-funded budgets. Considering the expected difficulties with written material and the advanced age of the target group the response rate exceeded our expectations. Concepts from cognitive psychology, especially Gestalt theory, in combination with user tests have shown to be a valuable source for deriving possible solutions and developing the design guidelines for surveys with visually impaired and blind people.

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Tile Dreamer: Game Tiles Made Easy

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Abstract. The Tile Dreamer is an integrated tool for creating and managing tiles, being two dimensional recurring constituent components of commonly deployed in structuring tile-based game terrains. The application consists of four basic subsystems: (a) the main tile editor for constructing tiles; (b) the bitmap ripper, automatically computing the least number of tiles for any given bitmap; (c) the connectivity checker, to test how tiles actually fit together to form larger regions; and (d) the tile bitmap builder, to put together a final set of tiles as a single bitmap. We discuss how the design of game tiles through the Tile Dreamer tool becomes easier and more efficient.

Keywords: Game design tools, tile-based games, game development.

1 Introduction

Tiles are well known in the context of developing 2D games (Gruber, 1994) [1] as reusable, recurring, basic terrain elements, enabling the construction of large terrains which, due to size and management constraints, could not be handled through normal bitmaps. The technique was very popular in the past; however, it regains increasing interest in the context of hand-held devices. Additionally, there is an increasing trend towards the revival of 2D games, with emphasis on more populated terrains, intelligent action, powerful effects and character design deploying 3D modelling instruments with an emphasis on 2D delivery. A tile is a small bitmap, usually 16x16 or 32x32 pixels wide, that is used as a recurring element for constructing the basic game terrain. Tile-based games were very popular in the past, when machines were less powerful than today, as a way of crafting large terrains with significantly small memory and processing demands. However, besides that, tiles provide a concise and reusable graphical unit for structuring a terrain in a manageable and extensible way, offering a well-define process for terrain editing. Additionally, due to the 2D type of worlds created via tiles, the game action usually relied on side scrolling, with scenes forming a sort of an action platform. This is why tile-based games are also popular as side scrollers or platform games.

The key remark on using tiles is that a picture may be divided into smaller parts, many of which can be identical to each other, meaning one could reconstruct a bitmap from a number of sub-bitmaps possessing less storage demands than the original bitmap itself. This means less space is required in order to store the terrain bitmap,

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and as a result, faster terrain processing is achieved. Such primitive reusable sub-bitmaps are called tiles. The bitmap that contains all the different tiles (the ones that has to be stored) is called tile bitmap, and is much smaller than the initial one. For example, in figure 1, the parts that have the same number are identical, while parts 7 – 12 are used together to form a bigger part of the picture. Tiling technique suggests that we need to store only one tile for same-numbered parts, and 6 tiles for parts 7 - 12. The technique is still used today, and it offers a lot of advantages to game developers. In addition to gaining space (because only different tiles have to be stored), faster terrain processing is also feasible, because of the smaller amount of information that needs to be elaborated. Another advantage of working with tiles is that if one wishes to construct a bigger terrain, they may add a few more tiles instead of designing the whole bitmap from scratch. Games that use tiles as the basic component of their graphics are called tile-based games.

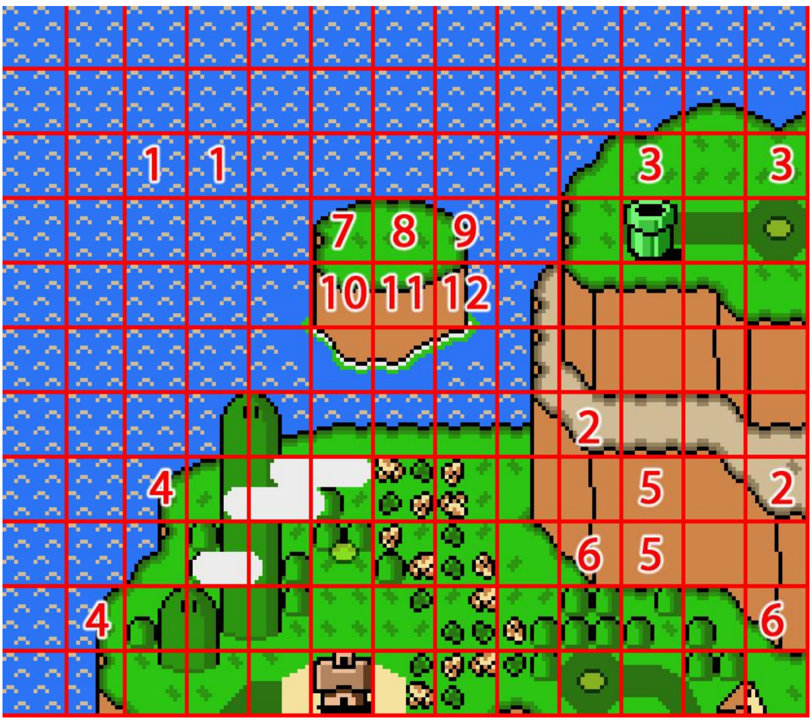

Fig. 1. Part of a tile–based terrain (Mario Bros™)

Due to the evolvement of the tile-based games, tiles are becoming more and more complex and thus, difficult for graphics designers to make them operative and efficient. Tile Dreamer is a tool for facilitating the creation of tile-based graphics. It provides a tile editor for creating both seamless tiles and tile sets (such as those in parts 7 – 12 in Figure 1) along with some powerful tools for extracting tiles from a picture, checking tile connectivity and assembling the tile bitmap. Further in this paper we will present the application along with the tools it provides and explain how graphics designers can benefit from it.

2 Related Work

Many tools for designing and managing tiles have been successfully used in the past. Besides classic widely used drawing programs such as Paint and Photoshop which are not explicitly designed for tiles, many tile editors are available to designers, together with some tools such as map builders (Mappy [2], Tile Studio [3], Game Factory [4], tUME [5], the scrolling game development kit [6]). However, these tools have a number of limitations, and some very useful functions have never been incorporated. For example, although most of the tiles are used for constructing seamless environments, no application has differentiated the editing of these tiles from universal tile editing, as no application has provided a tool for drawing a set of tiles together in order to construct tile sets. Thus, game designer needs a great deal of intuition about the seams, or plenty of time to test and correct them again and again. Regarding ripping of bitmaps, a few tools have been developed capable of slicing bitmaps into tiles, but they are not fully configurable by the user, and the output tiles have to be sieved and pasted into another application for editing. Tiles produced from Ripping and editing applications have to be put altogether into one tile bitmap. Since there is no program for doing this efficiently, the game designer has to collect all the tiles and somehow paste them into the tile bitmap. Changes inside the tile bitmap can be very painful; for example, erasing one tile involves cutting and pasting all the others in their new positions. Finally, when all tiles are ready, the designer has to determine which tiles can be put side by side seamlessly. The latter task is very difficult, as it entails straining your eyes for a long time and its result is not always optimal.

This paper discusses the development of new software that intends to assist tile graphics designers by integrating various tools into a single application. In the following pages we will present Tile Dreamer, an application targeting to help graphics designers in creating and extracting tiles efficiently, compiling them into the tile bitmap and most importantly, deciding which tiles are consistent to each other (i.e. seamless if put together).

3 Application Structure

Tile Dreamer consists of four basic components. These are: the Tile Editor (that contains Seamless or Single Tile Editor and Multiple Tile Editor), the Bitmap Ripper, the Tile Bitmap Builder and the Connectivity Checker. The user is able to transfer tiles from one component to another. More specifically, tiles from Tile Editor can go directly into Tile Bitmap and Connectivity Checker, while tiles from Bitmap Ripper and Tile Bitmap can go into the Single Tile Editor or Connectivity Checker. All tile transitions are shown in figure 2.

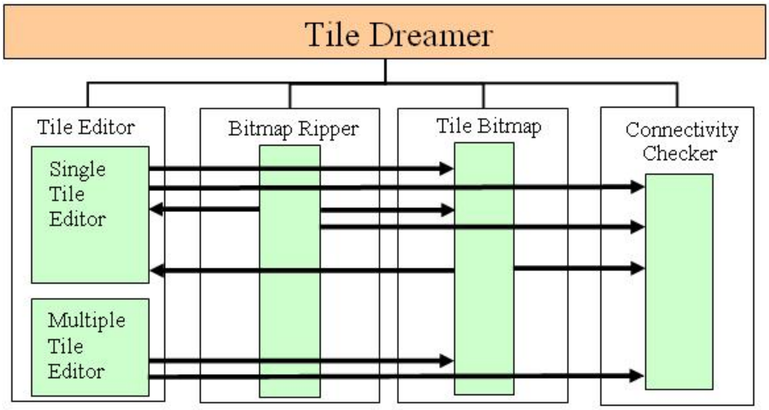

Fig. 2. Tile Dreamer structure. Arrows indicate how the tiles can be transferred among the application components

Each Tile Dreamer component is very functional, and can save a lot of time and labour to game designers. In addition to constructing the tile bitmap directly from edited and ripped tiles, the user can also check the connectivity of the tiles he chooses to keep. Tile bitmap dimensions can be easily changed, and tile editing is enhanced through the special features the two editors provide.

4 Designer's User Interface

The Graphic User Interface (GUI) is the main interface, where users are able to perform several tasks. The menu bar contains the basic components of the application, which are the following:

1. Single Tile Editor, which enables users to design seamless tiles,
2. Multiple Tile Editor, which is designed for facilitating tile patterns drawing,
3. Ripper, which is used for slicing a bitmap into tiles,
4. Bitmap, which helps the user to construct the tile bitmap, and make changes on it, and
5. Connectivity, which checks the connectivity of the tiles it contains.

In the following paragraphs, we are going to consider each of these components separately.

4.1 The Various Editors

Tile Dreamer has two different kinds of tile editors, one for designing a single tile that repeats itself seamlessly, and another for designing tile patterns; that is two or more tiles that are always used together (for example two tiles representing a single tree, see tiles 8-11 in figure 1). Each Editor has some drawing tools (pencil, ellipse, box and solid box, line, flood fill and colour picker) and some operations designed for facilitating context creation. These extra operations are:

- **Circular flood fill.** In contrast to plain flood fill, circular flood fill does not stop flooding when reaching the tile borders. For example, if the tile has four curves on its four corners which shape a circle when the tile is repeated, circular flood will fill the whole cycle instead of one quarter of it. This helps the user to think of the tile as a part of a bigger picture, and not as standalone bitmap.
- **Shift.** This function differs from Single to Multiple Tile Editor. When in Single Tile Editor, it shifts the image inside the tile borders. The parts of the image that are shifted outside the tile borders are wrapped around the tile, as shown in figure 3. When in Multiple Tile editor, one can shift either one tile alone (just as in Simple Tile Editor) or the whole image, wrapping around all tiles (as though all tiles were one). The shift operation can be very useful for designing reusable tiles. It is also very easy to use; one only has to hold down a specific key and then drag the image by using the mouse. We have found shift functionality in other tile editors (such as Tile Studio), but it was hard to use and thus, not as efficient as we hoped.

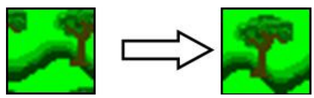

Fig. 3. Tile transformation via the *Shift* operation

- **One-button Control Zoom.** This function allows the designers to view the tiles in any zoom they wish, simply by pressing one key to zoom-in and another to zoom-out. Zoom function is also available from the Editors menu, but it is more functional when performed from the keyboard. By using it, the designer can preview their tile repeating itself inside the whole canvas in its actual dimensions, or zoom it until each pixel is displayed as a very big square. One-button zooming can be an excellent and fast-applying tool for designing details and previewing the tiles.
- **One-button Alternate Colour.** This feature enables the tile designer to alternate the current colour's R.G.B. values by pressing a single key and dragging the mouse sideward. Three keys are assigned to modifying the red, green and blue coordinates of the current colour respectively while another key is assigned to modifying all three coordinates together (resulting in brightening or dimming the current colour). The specific amount of colour that is added or subtracted from the colour values can be determined by the user via a textbox in the tools pop-up window. User can also decide if colour values will wrap around if exceeding the upper bound (usually 255) or getting below zero, simply by checking a checkbox that lies on the tools pop-up window. This functionality boosts tile drawing, as it provides the designer with the full control of his colour palette, enabling colour modifications to be performed fast and accurately.

Editors also provide facilities like show or hide grid, and one-button undo – redo. The default colour of the grid, the tile dimensions and most of the message texts used, are defined via a configuration file. Configuring tile dimensions means that tiles don't have to be square, nor their sides have to be powers of two. It is up to the game designer to specify the appropriate tile dimensions for constructing their game.

4.1.1 The Single Tile Editor

Single Tile Editor is used for drawing seamless tiles, one at the time. The working canvas is an area on which a tile repeats itself for previewing purposes. The canvas is divided into multiple tile instances that are mapped to the original tile, and drawing is allowed inside the whole canvas. Changing one tile, changes the original one in the respective area and in return, the whole canvas is updated. In this way the previewing area becomes a powerful tool for efficiently creating content in a seamless environment and thus, content creation is boosted. Users can also see their drawing in every zoom they wish, and tile border can be hidden for better previewing the tile. Tiles produced by Single Tile Editor can be sent directly to the Tile Bitmap, selected and dropped into the Connectivity Checker or they can be saved in a file. Tiles can then be loaded again into tile editor for further changes (supported formats are 24 and 32 bit-depth bitmaps in tile dimensions). Moreover, tiles can be dropped into the Single Tile Editor from other components, such as Ripper, Tile Bitmap and Connectivity Checker.

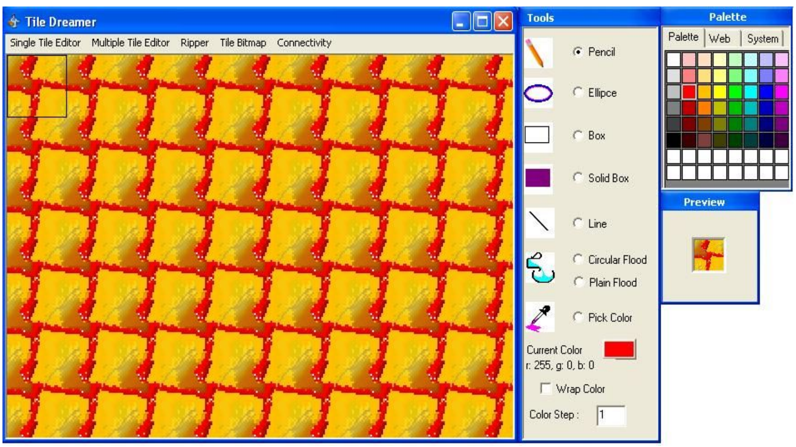

Fig. 4. An example of the Single Tile Editor

4.1.2 The Multiple Tile Editor

Multiple Tile Editor is a tool for designing a set of tiles that are used together in order to construct bigger parts of the terrain. This kind of tiles is very difficult to implement with usual editors, because one must estimate where exactly the seams will be. That's why we developed a special tool for this kind of tiles. The drawing canvas is divided into tiles, the number of which is decided by the user through the configuration file. Tile borders as though visible, do not affect the drawing, so users can draw the content of all tiles at once. This feature enhances tile pattern drawing, by making it faster and easier. The tiles can then be stored, sent to the tile bitmap or to the connectivity checker separately.

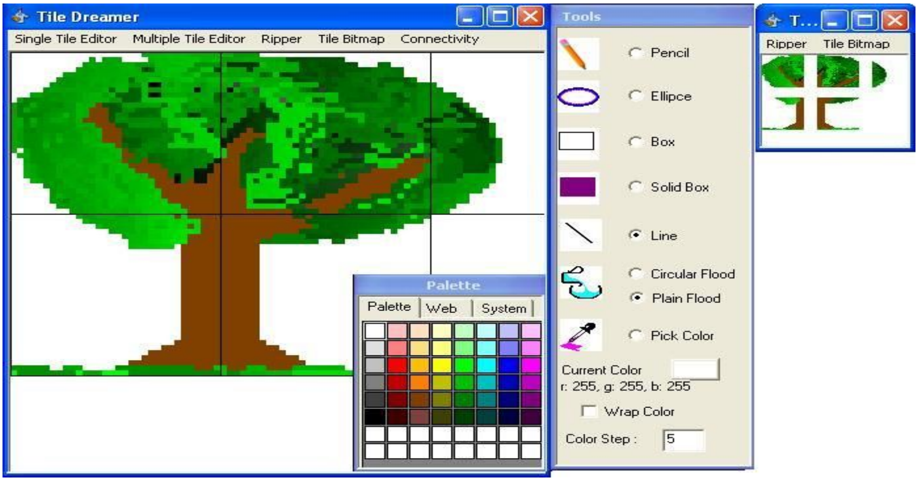

Fig. 5. An example of the Multiple Tile Editor

4.2 The 'Bitmap Ripper'

Bitmap Ripper is a tool that enables the user to extract (the different) tiles from a bitmap of his choice. It is an interactive flexible tool, compared to batch-processing tools like the 'Tile Ripper' of FastGraph™ (Gruber, 1994). The tool is fully configurable, so the user can choose among an extensive array of options. For example the user can decide whether to rip the whole bitmap or just a small part of it, from where the ripping should start (this option is very useful if the loaded picture dimensions are not multiple of the tiles dimensions) and whether small colour alterations will be taken into account in order to decide which tiles are similar. The users can select one of the output tiles to check with all the others through connectivity checker, or they can send the tiles directly to the Editor or to the Tile Bitmap.

4.3 Tile Bitmap Builder

The Tile Bitmap Builder is a tool for assisting game developers to compile a tile bitmap with the tiles produced by both editor and bitmap ripper. By being incorporated in the same application that contains both the editor and the ripper, bitmap builder can save the designers a lot of time from tile transfer among multiple applications. Besides, Bitmap Builder is designed to support common functions, such as add or delete a tile, tile swapping and sending a tile to the Connectivity Checker. The user can preview the tile bitmap, and change its dimensions any time. When tile bitmap is ready, it can be saved to a file.

4.4 The Connectivity Checker

Connectivity Checker is a tool that can determine tile consistency. The working area is divided into NxM slots for tiles (N and M are defined by the user). One can select a

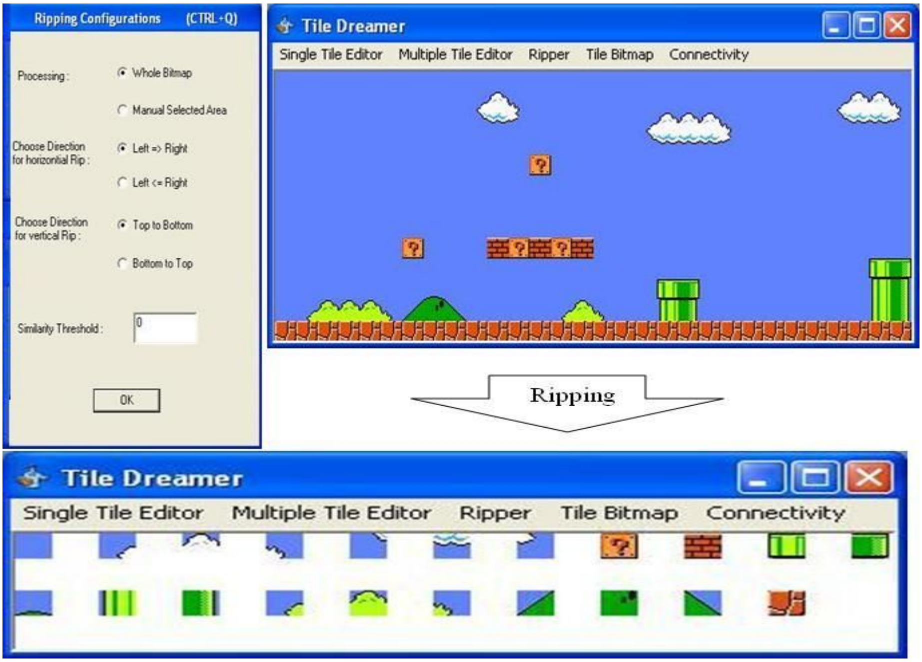

Fig. 6. An example of how a bitmap is sliced into tiles and the tiles produced

tile from the Editor, the Ripper or the Tile Bitmap and drop it into a tile slot. They can also delete and swap the tiles inside the slots. Then, a connectivity checking among all tiles can be performed. The configuration dialog box allows user to choose checking the selected tile with other tiles from above, below, left and right, and determine the similarity threshold below which the tiles are assumed consistent. The Results are then displayed in a pop-up window.

5 Preliminary Evaluation

Tile dreamer is to our knowledge a unique design tool for the creation of seamless textures that can be used in the content creation process whenever an image is repetitively used for drawing a surface. Tiles can be used in two dimensional applications, e.g. sprite based games and websites, but it is also useful in three dimensional based applications. It is a wide applied technique in any situation where memory management is important. These include real time 3D graphics for contemporary games and virtual reality, since tillable images diffuse the surface of the objects that construct the virtual world. Professional 3D animation packages also benefit from large sized tiles although offline rendering is used to achieve photorealistic images for films. An example that is relevant on both 2D and 3D usage of a tile is the creation of a terrain. It can be simulated with multiple layers of patterns

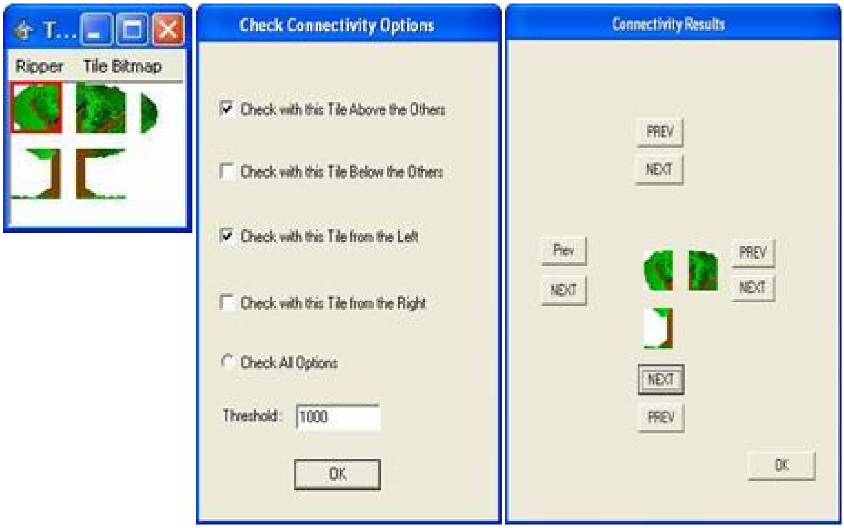

Fig. 7. An example of the Connectivity Checker

which smoothly blend between, using opacity or colour-keys, for a variety of characteristics on the terrain. In many cases a tile is applied on top of a unique image for additional detail when close up. The same principles relate for visually recreating walls, concrete surfaces, rocks and any surface where additional detail is needed.

Content creation is the most time demanding assignment for modern multimedia applications. A user friendly tool has significant impact in attaining the initial aspiration throughout the procedure. The creation of tiles is a very complex procedure since it evolves around images that are used across the board on a product and reflect the perception of the entity they represent. Tile Dreamer gives the ability to create such images, while simultaneously perceive the final visual sensation. It is simple to use and is oriented for a straightforward approach to designing or adjusting repetitive patterns. The functionality that was developed for the application is the seamless drawing and colour adjusting through simple gestures. Specific keys are used for altering R.G.B. values with mouse movement and three keys for instant zooming and wrapping the tile around the edges. The keys are close to each other so it doesn't distract the attention during the creative process and there are modifiable values for colour adjustment for enhanced accuracy or quicker adaptation. At the moment adjusting colours feels peculiar since the colour gestures work in the R.G.B. spectrum while a person normally does not think that way. In future a C.M.Y.K. and a Pigment wrapper can be included in the application to effortless generate custom colours. With that future addition, an artist will have a powerful tool to mix colours directly while crafting an image. The application was tested and utilized in numerous occasions when a tile was needed and the artist's feedback has been noted for improvements and development of a productive tool.

6 Summary/Conclusion

This paper has discussed the development of the Tile Dreamer Software that has been developed to assist graphics designers in creating tile-based graphics. The main advantage of the presented software is that it incorporates a well array of fully configurable tools designed to facilitate tile graphics designing. Tile Dreamer consists of four basic components, which are:

1. Tile Editor. It is divided into Simple tile Editor, which can be used in creating tiles in a seamless environment, and Multiple Tile Editor, which enables the design of more than one tiles simultaneously. Both editors are enhanced with some powerful functionalities that facilitates tile Drawing and offer a good perspective of the final result.
2. Bitmap Ripper, which is a fully configurable tool designed for slicing bitmaps into tiles and presenting only the different ones. Tiles can then be modified, checked for their connectivity or added to the tile bitmap.
3. Tile Bitmap, which is a tool for compiling the tile bitmap from tiles produced by both editor and ripper. The tool also enables changes inside the tile bitmap, and allows modifications to the Tile Bitmaps dimensions.
4. Connectivity Checker. This is a very powerful tool that given one tile can decide which tiles are consistent with it from each side. It intents to help developers determine which tiles can be put side by side seamlessly, relieving them from lots of headaches.

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Remote Usability Tests – An Extension of the Usability Toolbox for Online-Shops

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Abstract. Lab Usability Tests show a series of inherent shortcomings that are attributable in essence to the artificial lab situation. This article informs about the reasons for developing a specific Remote Testing approach and describes how this measure helps to avoid such deficits. Subsequently, we will introduce the approach as well as two evaluation studies that assess the result quality of a Remote and a Lab Test within the context of online shopping.

Keywords: Usability Test, Remote Test, method comparison, online shop.

1 Introduction

Testing interactive web applications assisted by the current respondents in the Usability Lab probably presents one of the most popular methods of the Usability toolbox. Tests of this sort provide valuable qualitative results based on user observation and inquiries. User interface designers, for instance, are able to translate these results smoothly into an optimisation of the application. In the meantime, User Tests have become well-accepted by all persons involved and form an increasingly steady component of developing interactive applications, especially for their high ostensible validity.

In general User Tests take place in a classical Usability Lab equipped with a lab plus observation room and comprise the production of a video tape recording. A test head observes, interviews, and instructs the participants in solving the particular type of problem. Apart from many strengths, however, this Usability method also entails some restrictions that make it seem less suitable for certain application purposes.

The artificial lab situation in particular may influence the respondents' behaviour considerably thus endangering the translation of the test results into the real context of use. Moreover, the circle of available participants often proves strongly limited with respect to their number and composition (background of use, level of experience, socio-demography). Recruitment and test conduction are characterised by tight boundaries installed by necessary expenditures, or rather, by the financing of their

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costs. For the past year SirValUse and Otto have already been trying to circumvent these limitations of Lab Tests by the joint development of a tool for asynchronous Remote Usability Tests. During an asynchronous Remote Usability Test the respondents are testing a web application from their own PC or from their workplace. They are totally independent in their moves on the test object without any time limit or content restriction. The Remote System records all mouse movements, clicks, and entries as well as screenshots of all pages visited by the participants. The respondents are requested to report any special occurrences (so-called 'critical incidents'), such as obstacles or missing functions, while they are surfing into an entry mask. The following text will describe the developed Remote Test System, the exemplary course of a Remote Test, and the results of the most recent comparison of our Lab Test and Remote Usability Test methods.

2 The Path to Gaining Insight – User Tests in the Course of the Project

During the development of an interactive application, or rather, beyond the life cycles of a product, the persons involved in the project are confronted with very distinct user- and use-related questions that are to be answered based on User Tests. The demands on User Tests are thus as diverse as their implementation and arrangement.

2.1 Rough and Fine Concepts as Subjects of Development-Oriented User Tests

Usability Tests of interactive rough concepts focus primarily on the question: "Are we on the right track?" Early conceptual ideas are examined rapidly without a drain on resources. Nonetheless, the tests ought to provide a stimulus for the project team's ability to cope with problems.

In case the development has already reached the final stages with tests of the fine concept, the pivotal question is: "Are we really finished with it?" At this point the User Test must be fit to assess the Usability of the entire application to enable the development team to decide for or against the launch without a doubt.

Development-oriented User Tests can be conducted ideally either by means of paper prototypes, by employing more or less interactive prototypes in the Usability Lab, or next door to the developers.

2.2 Status-Oriented User Tests

Proving whether an application reaches the desired business- and customer-related project goals during day operation, requires another type of User Test that asks: "Can the desired effects indeed be measured in the actual applicants?," " To which degree could the application be improved?" In sum, we have to provide convincing quantitative evidence that the aspired business-relevant effects have in fact ensued during the actual operation.

In the past we have conducted slightly modified Lab Tests, differing in certain characteristics from development-oriented Lab Tests, in order to answer the above questions as regards online shop purchases.

For this kind of User Test we have recruited respondents with actual purchase intentions of their own and asked them to conduct their planned online purchases under observation in a Usability Lab. The participants did not get tasks and remained absolutely free and uninfluenced by the test head who left the test lab after instructing them. In contrast to the classical User Test the respondents were to decide for themselves how to proceed, how much time they needed, and if they really bought anything at all. In coherence with the underlying logic they invested their own money for their purchases.

The above modifications and further adaptations were intended to equip User Tests for simulating a realistic buying situation as a means to assess the Usability status of the online shop. This approach, however, came up against limiting factors repeatedly:

- The circle of respondents for these tests is strongly limited in various respects. For financial reasons, for example, the sample is confined to about 30 participants which is too small for differentiating quantitative assessments.
- The tests are conducted in one location only.
- Purchase processes that can actually be observed in the lab are quite restricted. For instance, none of the processes can be verified after completion of the order. Neither is the delivery status being followed, nor are returned sales commissioned, nor is the customer account being checked for the correct entry of the sums. For that reason, in a Lab Test the test head can only retrace a limited selection of all destinations a customer may actually visit in an online shop.
- The lab situation remains an artificial construct: the time and duration of the shopping session, the environment, the technical equipment, and of course the presence of the test head all represent very artificial components of the shopping situation. These conditions differ significantly from those under which customers of the shop would decide about their purchases in reality.
- Despite the above mentioned recruitment efforts, actual and independent buying decisions cannot always be observed in a studio. Sometimes, further consultation with the partner may seem necessary, the respondent may not have fully decided yet, or the incentive may appear more attractive than the order itself.

These limitations, in connection with our desire to find a test method for online shops that is more valid in ecological respect, have lead to the development of the asynchronous Remote Usability Test method that will be illustrated in the following.

3 Asynchronous Remote Usability Tests

A Remote Test is a Usability Test that enables the participants to either use an application independently or solve certain problems, not in a lab, but at their home PC or from their work place. This type of test is called synchronous if a Usability expert, who may even be connected with the respondents by phone, observes the use situation simultaneously. A Remote Test is asynchronous, if the expert observation is subsequent to the actual session.

In comparison with the synchronous approach the asynchronous test has the advantage of allowing that a great number of respondents take part in the test and of providing very focused analyses. To its disadvantage it does not permit any additional, immediate questioning, for instance via a parallel phone connection. Any language channel would disturb what can be considered the greatest advantage of the asynchronous approach: the authenticity of the setting.

The system developed for the evaluation studies distinguishes itself for the following technical characteristics:

- The users' requests are first transferred to the web site via a proxy server. The server then hands the web site back to the respondent while simultaneously recording the users' screenshots, mouse movements, and entries at that moment.
- Hence, installations or interventions on the web server and the participants' PC can be avoided provided that Javascript is activated in the respondents' browser software.
- The test object must be accessible online.

3.1 A Remote Test Session Then Proceeds as Follows

- The participants are recruited online by means of a layer, a pop-up on the home page, and/or on various locations within the web site.
- After the general introductory text passage and the declaration of data privacy protection relevant screening questions (for example socio-demography, internet use, visit frequency, customer status, etc.) as well as questions for the general pre-exploration (mostly: reason for visiting) are established.
- It follows an explanation of the session's planned process: the respondents are asked to move about on the page according to their initial intentions. Moreover, they are familiarised with special occurrences ('critical incidents') and how to report them while surfing.
- A click upon a link activates the re-routing onto the Remote System. The web site is depicted in a frame that covers the biggest part of the screen. Another, smaller frame at the bottom rim of the screen offers buttons for reporting 'critical incidents.'
- The feedback questionnaire appears as a pop-up that gives room for reporting the 'critical incident,' its 'pre-history,' plus maybe a scaled evaluation. In the course of a session any number of 'critical incidents' can be reported.
- If the visit is completed, a button in the bottom frame leads to a post-inquiry about the visit's success and asks for a summarised evaluation of the web site.

Prior to the analysis the different data sources (screenshots plus mouse movements, reported 'critical incidents,' and further enquiry data) are brought together for each individual respondent and cumulatively for all participants. The analysis can be applied specifically to the following data:

- the cumulated log files,
- 'critical incidents' in connection with the corresponding screen shots, mouse movements and entries,
- the participants' click routes with negative visit success, and
- further interview data.

The analysis includes not only subjective data ('critical incidents,' enquiry data), but also observations and compilations (ex-post analysis of click routes and log files) This is of pivotal importance especially as regards the compilation of Usability problems.

4 Comparison of Lab Test and Remote Usability Test Results

The advantages of the Remote Usability Test in general and as applied to online shopping in particular seem to be perfectly obvious:

- Online recruitment permits a simple and well-controllable access to a wide spectrum of respondents.
- The observation comprises very different visit destinations, covering every phase of the shopping process. Accordingly, the scale of identifiable Usability problems is quite diversified.
- The casual testing in familiar environments without set tasks and a test head creates a high ecological validity.
- By focusing on the reported 'critical incidents' and those test sessions that have been evaluated as 'unsuccessful' the test sessions can be evaluated very efficiently.

On the other hand fundamental questions concerning the method arise:

- “Are users able to detect and report their own use problems?”
- “How efficient are Remote Usability Tests in revealing Usability problems?”

We conducted 2 evaluation studies to answer these questions. For both studies a Remote and Lab Test for an online shop were conducted simultaneously and their results compared.

The more recent, second study was conducted following the procedure described above. In this context 111 User were tested compared with 30 respondents in the lab. For the initial evaluation study 30 customers of the shop were recruited offline (by post) and asked to use the online shop through the Remote System for a period of 6 weeks. In this case the Lab Test included 15 participants.

4.1 “Are Respondents Able to Detect and Communicate Use Problems on Their Own?”

An asynchronous Remote Usability Test relies substantially on the participants' reports of high quality 'critical incidents.' The two evaluation studies produced the following results (the first number represents the results of the recent, second study, the second number the results of the initial study):

- Altogether 48 percent (91 percent) of all respondents recognised and reported ‘critical incidents’ which resulted in identifying Usability problems.
- 87 percent of these reports allowed us to comprehend which incidents were described and why. We attested them a high quality due to their comprehensible wording, their being voluntary, and the fact that they could be divided unequivocally into positive and negative reports; furthermore they withstood the inspection of a Usability expert.

The low rate of respondents who report 'critical incidents' at all increases when positive incidents are also taken into account; the participation rate then reaches 69%. By means of an adapted incentive scheme this rate could maybe further increased. It is another advantage of the Remote Test that without any incidents the participants do not cause any additional expenditures apart from the incentive.

In addition to 'critical incidents' there is another observation component that contributes valuable insights: the later analysis of the click routes that considers the reasons for visiting and the visit success (especially failure).

4.2 "Is a Remote Usability Test the More Efficient Method in Unearthing Usability Problems?"

The results show that more Usability problems are detected during a Remote Test than during a Lab Test: 61 (28) problems in the Remote Test opposite 49 (25) problems in the Lab Test. In essence this derives from the greater number of participants in the Remote Test and their more differentiated reasons for visiting.

It is remarkable that the problems revealed by the Remote Test do not concur with those of the Lab Test in many respects.

In the real and very diversified context of use the Remote Usability Test finds Usability problems which the respondents consider worthy of report. The Lab Test, by contrast, detects Usability problems that are generated mostly by the observation of participants who find themselves in a (more or less) artificial situation. These very distinct ways of proceeding obviously effect the differing result quantities of Usability problems. (See Molich[1]).

With respect to the arising expenditures as related to the identified Usability problems and the participants involved, the Remote Usability Test proves much more efficient than the Lab Test. By means of a partially automated summary and data evaluation this advantage can be consolidated further.

As regards the investigative gain the Remote Usability Test is inferior to the Lab Test. Half of the respondents do not produce any or just a minor investigative gain (for instance, the evaluation of the reason for visiting and the success thereof). In the lab, however, only 29 (52) percent of the participants are unable to contribute any essential insights. Nevertheless, this effect is compensated by the Remote Usability Test's cost-effectiveness per respondent. Overall each Euro invested in a Remote Usability Test finds more Usability problems than it would in a Lab Test.

Concerning the speed of the operation the Remote Usability Test has the potential to unearth Usability problems within a short time - faster than the Lab Test. The rapid online recruitment and the test procedure that employs several participants in parallel, shorten the period of testing significantly.

5 Prospect

Even after the conduction of 2 evaluation studies many questions still remain unanswered and need further clarification:

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[1] Molich, R.: CUE Studies Homepage, available at: http://www.dialogdesign.dk/cue.html (1998 – 2006) (05.22.2006).

- “How helpful are problems found by both methods as regards the business case, or rather, the customer's investigative interest?”
- “Which method provides better answers to which type of problem?" Current studies are indicating that especially the evaluation of web site contents becomes more valid in a Remote Test. So, "What characterises the problems that are detected primarily by a Remote, or rather, by a Lab Test?”
- “Which problems ask for a combination of both, a Remote and a Lab Test?,” “Which case number corresponds with this?”
- “Which is the optimum case number for a Remote Test?” “When will a decreased investigative gain start to kick in?”
- “How to increase the number of reported 'critical incidents' per respondent without provoking any irrelevant reports?”
- “Which role could the ex-post examination of the respondents' click routes play in relation to the reason for visiting and the visit's success?,” “Can the number of problems detected by both methods thus be increased?”

Accordingly, we are looking forward to further evaluation studies.

A Practical Inter-sensor Broadcast Authentication Scheme

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Abstract. For inter-sensor broadcast authentication in wireless sensor networks, Chen *et al.* proposed a bootstrapping scheme which enables to save only neighboring nodes' hash-chain commitments, much fewer than whole network size, before deployment [2]. However, the scheme lacks scalability and is not tolerant for node isolation. Therefore, we suggest new mechanism providing scalability and present its modified version with node-redemption which makes most of nodes participate in broadcast authentication with a little additional memory.

Keywords: security, authentication, wireless sensor network.

1 Introduction

For broadcast authentication(BA) in wireless sensor networks, μ-TESLA based on delayed disclosure of verification keys and multi-level μ-TESLA enlarging life time of system were suggested [8,11]. But these approaches were useful only in a specific model where sensors verifies packets from base station(BS). For authentication between sensors, it requires verification keys which can check mutual signs. As we consider random deployment, however, each node should pre-install $n-1$ keys nearly to n, size of entire network excluding each node itself. For dealing with this impractical situation successfully, Chen *et al* proposed a bootstrapping scheme for the first time, which enables to save only nearby nodes' hash-chain commitments, much fewer than $n-1$, before deployment [2]. This approach is very significant, for it realized inter-sensor broadcast authentication(ISBA), which overcame traditional BA in which BS becomes signer and sensor becomes verifier. Unfortunately, the scheme lacks scalability and does not suggest a solution to problems of node isolation caused by some error such as initialization failure because of packet loss which may occur after random deployment. Thus we suggest new mechanism providing scalability and node-redemption.

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1.1 Related Works

Perrig *et al.* proposed a μ-TESLA mechanism that is optimized to WSNs from original TESLA [11]. Liu *et al.* suggested enhanced version of multi level μ-TESLA which enlarges the life time of network and provides efficient updating algorithm for commitments [8]. By enlarging hash-chain level and delaying time, their scheme is weak to such DoS attack. Chen *et al.* claim that ISBA is essential in WSNs and proposed a bootstrapping scheme to achieve it based on the multi level μ-TESLA mechanism [2]. They have assumed random deployment of sensor nodes and targeted the distribution of hash-chain commitment and authentication. According to their approach, each node just needs commitments of nearby nodes after deployment without entire $n-1$ commitments. As a result, every node broadcasts their own commitments and stores commitments of the sensor nodes within a broadcast transmission range. By this optimized transmission mechanism for the distribution of hash-chain commitments, each sensor needs small storage portion as nearby density.

Contributions. Our contribution is as below.

- We proposed a first *scalable* inter-sensor broadcast authentication scheme using only symmetric primitives.
- We suggested a concept of multi-session in network lift time for enabling controlled network scalability.
- The proposed node-redemption guarantees the nodes that are isolated in bootstrapping period to participate in already organized network.
- Our schemes are *perfect resilience* under selective node capture attack in the all session.

2 Preliminary

2.1 Inter-sensor Broadcast Authentication

Traditionally in WSNs, referring to BA, many researchers have focused on verifying validity of packet which is mainly sent when BS orders specific commands to nodes or sends data. It is no wonder that forgery by malicious adversary, wrong orders, and no authentication would threaten so much usability and security of network. What is remarkable is that most of proposed methods using μ-TESLA are designed for these models. In other words, when those approaches want to broadcast to nearby nodes, not to BS, they requested that BS would broadcast through hop by hop route [8,11,13]. Intuitively, these ways lay a burden on all nodes in routes to BS due to too much communication overheads whenever nodes broadcast. Especially damage of nodes near BS participating in transmission so often is much more serious. Therefore when a node broadcasts to nearby nodes, it would be better to broadcast itself. It is ISBA that enables a certain node to authenticate itself to its nearby nodes when the node wants to broadcast to its nearby nodes. In next subsection, we consider necessity of ISBA and its application models.

2.2 Application Models

ISBA can be used conveniently and practically in *interior network process* excluding BS [2]. For example, when there is some information all the nodes within broadcast range should know, ISBA makes nearby nodes broadcast only once without unicasting as many as nearby nodes, achieving purposes they want. And when new routing is needed because of node capture or isolation, nearby nodes can inform node searching for routes or isolated node of route information rapidly. Especially ISBA is very suitable for voting mechanism researched recently. That is, existing voting approaches for logical revocation of node suspected a malicious was dependent on unicast between nodes or broadcast from BS. However, if ISBA is used, instant and local voting can be available and the length of packet will be shorter and the transmission frequency will be lower so that communication costs(very large portion of entire costs) can be reduced.

3 The Proposed Schemes

3.1 The Basic Scheme

The basic scheme consists of five phases; initialization phase, broadcasting phase, waiting phase, reveal phase, and node addition phase. All the commands of BS (e.g. START and STOP) are authenticated by BS-node μ-TESLA mechanism. In this case, storage overhead of network is very small, since every node is forced to store just only one commitment of BS to authenticate his signs on each packet. We suppose that we may say session counter s increases when it happens physical changes of network topology by system organizer. In contrast, for any changes by attacker such as node capture or isolation of some nodes in bootstrapping period, we may not call them session increasing despite of logical change of topology. In addition, we also assume that all the sensor nodes are spread randomly over a target field so that any node does not predict who will be nearby.

I. Initialization (before nodes deployment)

- For entire network size n, number all sensors by unique IDs such that $ID_1, ID_2, ..., ID_n$
- Choose GMK_m at random and then create a GMK hash-chain as following $GMK_i = hash(GMK_{i+1})$ $(i = 1, 2, ..., m-1)$ (where m is the length of session) and call GMK_1 a GMK hash-chain commitment.
- Create unique secret keys as following and store them to each sensor nodes one by one.

$$K_{ID_j} = hash(ID_j||s||GMK_s) \quad (1 \leq j \leq n)$$

where s is session counter starting from 1

II. Broadcasting Phase (after nodes deployment)

- BS broadcasts a START command to all sensor nodes.
- Each node $ID_j (j = 1, 2, ..., n)$ encrypt following value using their secret keys that already are stored at themselves and broadcast it to nearby nodes with IDs.

$$Auth = E_{K_{ID_j}}(ID_j||s||F_{ID_j})$$

(where F_{ID_j} is μ-TESLA hash-chain commitment of ID_j for general using of ISBA. Signer has this value and entire hash-chain information, and verifiers authenticate all broadcast messages from the signer using that commitment and the μ-TESLA mechanism.)

- After nodes deployment, BS broadcasts STOP command to all sensor nodes, each nodes can neither broadcast messages nor buffer received messages.

III. Waiting Phase

- Wait for time of δ.

IV. Reveal Phase

Base station

- Broadcast GMK_s to all sensor nodes.

Sensor nodes

- ID_v can construct K_{ID_j} with GMK_s, ID_j, and session counter. After that he can decrypt $Auth$ and authenticate $(Auth, ID_j)$ comparing ID_j with inside ID.
- If verification is successful, ID_v will accept F_{ID_j} as μ-TESLA hash-chain commitment of ID_j, else discard it.

V. Node Addition Phase (After session s)

- In session $s + 1$, for node addition, store following values to each sensors before nodes deployment.

$$K_{ID_j} = hash(ID_j||s + 1||GMK_{s+1})$$

- After deployment, each additional node ID_a computes following value and broadcasts $(Auth, ID_a)$ to every nearby node.

$$(Auth, ID_a) = (E_{K_{ID_a}}(ID_a||s + 1||F_{ID_a}), ID_a)$$

- Similar with phase IV, BS reveals GMK_{s+1} to all sensors, and each node computes as following

$$K_{ID_a}(ID_a||s + 1||F_{ID_a}\ D_{K_{ID_a}}(E_{K_{ID_a}}(ID_a||s + 1||F_{ID_a})))$$

If verification is successful, F_{ID_a} will be accepted as μ-TESLA hash-chain commitment of ID_a else discard it.

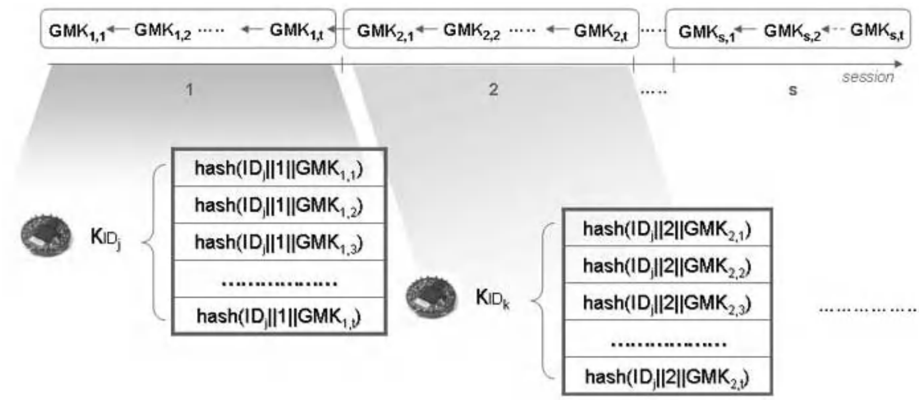

Fig. 1. Assigning GMK hash-chain key blocks for each session to provide node-redemption in deployed network

3.2 The General Scheme

The general scheme is identical to the basic scheme except that it stores hash-chain as a block unit as many as t hash-chain per every session like Fig. 1. Even if some nodes are excluded in initial authentication that uses the first key, just after deployment, the second or other keys remain secretly because they have elements of GMK that is not revealed yet. For example, after ID_j is excluded in first chance, Fig. 2 shows us authentication phases are newly started using $K_{ID_{j,1,2}}$ that includes $GMK_{1,2}$. In this way, nearby nodes can authenticate commitment of ID_j with revealed $GMK_{1,2}$. The size of t is important and we can guess practical size by following equation. It supports a node-redemption. That is, it is possible for most of nodes to be authenticated with a little additional memory unlike the basic scheme where nodes can be authenticated only within a specific time.

n: entire network size, τ: isolation rate
Φ: available authentication channel size

$$\Phi(n) = n(1-\tau)(1+\tau+\tau^2+...+\tau^{t-1})$$
$$t \longrightarrow \infty, \Phi(n) \longrightarrow n$$

If we suppose that $\tau = 0.02$ and $t = 3$, the general scheme can cover 99.9992%.

4 Analysis on Proposed Schemes

4.1 Security Analysis

Proposed schemes are secure against the following attacks.
Impersonation Attack:

– **Case 1:** All the commands to control the distributed sensor nodes are broadcasted by BS and authenticated by nodes with μ-TESLA mechanism. Since

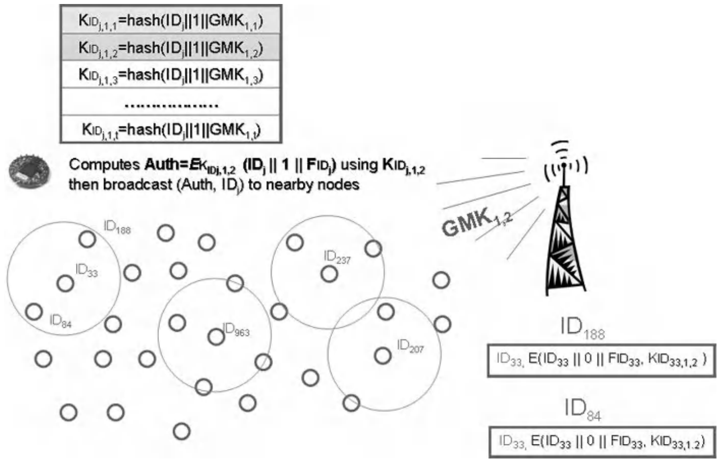

Fig. 2. An example of node-redemption

that reason, an attacker can fabricate the commands and impersonate BS with probability of forging hash values.

- **Case 2:** In many actual environments, our system may be eavesdropped by an attacker. Especially, if BS reveals the GMK in phase IV, any attacker can easily compute some node's value of Auth because of knowing his secret key used in encryption step. This result, however, dose not lead the attacker to authenticate his own hash-chain commitment successfully to nearby nodes. The reason is that any node(even malicious one) has no chance of giving his commitment to nearby nodes after the end of the broadcasting phase, except for this phase II so that one receives or accepts Auth packets.

Collusion Attack: This condition of attack can be done when one or more malicious nodes collude each other to compute another secret key using their known keys. Even if the conspirators know a number of K_{ID_j}, they can not compute any proper secret key K_{ID_m} because of unknowing GMK as pre-image part of the hash value.

Selective Node Capture: Proposed schemes construct hash-chain and its commitment independently for each sensors. So, although an adversary knows secret information of some sensors, she never knows about secrets of any other nodes.

4.2 Efficiency Analysis

Our scheme needs only one broadcast in order to send the each node' own hash-chain commitment to the neighbor nodes. And a sender stores only keys as much as the size of nearby nodes, not $n-1$. Since GMK or commitments nearby nodes are continually updated, it is needed just current one instead of whole values.

5 Conclusion

We proposed two ISBA schemes based on the initial distribution mechanism for the μ-TESLA hash-chain commitments of each neighbor nodes. Simultaneous using of the proposed two schemes provides scalability and node-redemption for isolated nodes during the initial broadcasting phase. In all the phases, we just need symmetric primitives such a hash function and block cipher algorithm. Our schemes guarantee a property *perfect resilience* under selective node capture attack for all the network sessions.

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Development of Automatic Web Accessibility Checking Modules for Advanced Quality Assurance Tools

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Abstract. Web accessibility is becoming a prominent issue in several countries, not only because of legal and compliance issues, but because of sound commercial opportunities arising in an ageing society and the Mobile Web. This paper will present recent developments under the umbrella of the BenToWeb project to create new advanced compliance modules to check automatically accessibility issues were before human intervention was necessary. These modules will be integrated in an existing Web Compliance Framework named imergo®.

1 Introduction

BenToWeb (Benchmarking Tools and Methods for the Web[1]) is a Research project co-financed by the Information Society Technologies Programme priority of the Sixth Framework Programme from the European Commission (Action Line e-Inclusion[2]). BenToWeb aims to support the European public and private sector to implement the recommendations of the eEurope 2005 Action Plan by providing new software modules and methodologies that satisfy some of the accessibility recommendations of the Web Accessibility Initiative (WAI[3]) of the World Wide Web Consortium (W3C), which are not analysed by existing tools due to their inherent complexity. Among the key objectives, we can highlight:

- Support the Web Accessibility Initiative (WAI) to develop further the Evaluation and Report Language (EARL[4] [1]) under the umbrella of the Evaluation and Repair Tools Working Group.
- Support the relevant WAI Working Groups in the development of complementary documents of the second generation of the Web Content Accessibility Guidelines, such as technology-specific techniques documents and accessibility test-suites for key W3C recommendations. In particular, XHTML and CSS Test Suites have

[1] http://bentoweb.org/
[2] http://www.cordis.lu/ist/so/einclusion/
[3] http://www.w3.org/WAI/
[4] http://www.w3.org/TR/EARL10/

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being developed for the Web Content Accessibility Guidelines 2.0 [4], and the project consortium is actively supporting the WCAG 2.0 Test Samples Development Task Force (TSD TF) for the development of WCAG 2.0 test materials [12,13].
- Investigate further the feasibility of automatic testing procedures that include issues like color-contrast, low-vision, color deficiency and consistency of navigation elements, and develop implementation modules for user testing. This development is described within this paper.

The modules developed cover the following issues:
- Automatic detection of navigation consistency on Web sites. This module implements sophisticated statistical methods to detect navigation patterns in Web sites, which are then internally compared (content-wise and with look and feel) for consistency.
- Automatic detection of low contrast problems in online markup documents and images. The implemented algorithms analyze color information in the corresponding stylesheets and markup documents, as well as of images, to alert authors of low contrast problems.
- Automatic simulation of dichromat color deficiencies. These algorithms will be used by the low contrast modules to detect contrast issues for this sector of the population.

1.1 Imergo®

The developed modules are not developed as a set of isolated modules, but to be integrated within the imergo® Web Compliance Framework [9]. imergo® comprises a set of tools that support the industry and the public sector in their online compliance efforts, not only in regard to accessibility, but in other areas like standards compliance, corporate identity, etc.[5]

This integration imposes several additional requirements to the designed framework in regard to persistence of results, reliability and performance, which cannot be underestimated.

2 Navigation Consistency Module

We consider a Web site as an interactive software system. It interacts with at least two different kinds of users:

- end users trying to achieve some goal, and
- Web developers and editors striving to keep the system functioning and improving it.

In a Web site, the consistency of presentation and controls, especially navigation, should be ensured. This includes:

[5] Imergo® is commercialized under the name of Web Compliance Manager: http://www.reddot.com/products_web_content_management_website_compliance_manager.htm

- natural organization of the information (systematic labels, clear hierarchical structure);
- contextual navigation (in each state only the possible navigation options are available);
- efficient navigation (in terms of time and effort needed to complete a task); and
- clear and meaningful labels.

All these properties related to accessibility may be further decomposed into more detailed ones that refer to specific attributes of the Web site implementation. Actually, such decomposition has to be done in order to support accessibility checking methods and to identify and fix faults.

Some of these lower-level properties refer to attributes that depend only on how the Web site has been designed/developed (e.g., textual descriptions of links embedded in images) – they are internal attributes, while others depend on the Web site and its usage (e.g., how meaningful a label is) – external attributes. This is always the case for properties referring to the content, which require some sort of interpretation that assigns meaning to symbols in order to be assessed. While for evaluating accessibility of a Web site both internal and external attributes are needed, only the former ones are directly amenable for automatic tests.

2.1 State of the Art

The task of extracting navigational elements out of documents and the automatic detection of consistency is not simple because of the lack of semantic information in the HTML markup regarding the described elements. There are a lot of efforts going on in the area of extracting of information blocks out of documents using a variety of approaches. Mostly they categorize the extracted information blocks according to specific semantic meaning. As an example Headers, Paragraphs, Forms and Navigational elements are used.

Segmentation of documents is used as a basis for such a categorization of content. The most used approach is to generate a Document Object Model (DOM) from the markup and analyze it. Embley et al. [5] developed an algorithm to extract information blocks out of tables containing data about cars (e.g., price, type, production date, etc.). They classified the elements of the document at hand according to a specified ontology, where a key role was played by the table element. By using this approach, they were very dependent on the structure of the information in the document, thus their approach is difficult to generalize. Lin & Ho [7] developed an approach to extract relevant information blocks out of Web documents by defining entropy blocks based upon occurrence of given terms. Gupta et al. [6] extracted information by removing the tags and elements that do not belong to the text content like, e.g., lists of URLs. Yu et al. [17] tried to find visual separators to divide a document into many parts. An example for such a visual separator is the HTML element <hr> (horizontal line) or a change in the background color within the page.

The above mentioned approaches are too generic as they consider only a portion of the elements of a document. They cannot be used to extract and automatically detect navigational information, because such information is hidden in a variety of elements and element structures. There are, however, other approaches, which provide a broader view on documents and consider more elements: Liu et al. [8] described an algorithm called SEW, which extracts hyperlinks out of a Web document. The core of the algorithm is the extraction of the navigation bar of a specific Web page. The execution sequence follows two steps: the first one consists of building the DOM of a Web document, where all links can be identified through <a> HTML element, to build the initial cluster. Different heuristics were developed to identify the generic properties of navigation bars which are represented in the document's DOM tree. By applying these heuristics, partitioning in clusters could be achieved. The resulting clusters possess the properties of navigation bars and build the foundation for the selection of the navigational candidates. In the second step, only numerical properties of URLs with specific content are considered. Statistical evaluations discover and deliver the right candidates with highest probability to be part of a navigation bar. This approach does not presume knowledge about the domain or its ontologies. The process might appear suitable for our purposes, however, for the second step, no algorithms or functions are provided, thus we needed to focus on the development and testing of new algorithms.

2.2 Consistency of Navigational Structures of Web Sites

To clarify some language issues, we are following the mainstream literature and we define:

- Web site: specific set of resources under a given URL or domain name.
- Web page (or resource): a single resource within the given domain.
- Navigational structure: set of navigational objects within the Web page, plus their (DOM) location and appearance. Such navigational objects are, e.g., sitemaps, search forms and navigation bars.

A consistent navigational structure means that the location and appearance of the navigational structure on all Web pages within the Web site are, to a certain degree, similar on their look and feel. This similarity does not mean a 100% exactitude, but a level such that they are identified as consistent in location and appearance by the users of the Web site. Therefore the consistency check will be specified to build similarity measures and thresholds for specific properties. The properties we will consider for consistency check are:

- Internal structure (XPath location in the DOM presentation);
- External structure (visual location within the Web page);
- Foreground color and background color of different HTML blocks; and
- Images, whenever used.

In the algorithm implementation, we considered several matching algorithms to identify and classify link patterns. Initial prototype implementations were very successful and the authors are proceeding at the moment of writing this paper to evaluate with experts and users the reliability of the results.

3 Color Contrast Module

The color contrast module was aimed to detect color contrast issues of markup documents and embedded media. The issue of color contrast has been investigated for long time in vision and design fields. Contrast is normally defined as the difference in visual properties that makes an object (or its representation in an image) distinguishable from other objects and the background. In visual perception of the real world, contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view. Ridpath & Chisholm [11] propose a measure of contrast based upon linear differences of brightness and color components of foreground and background components. We found this algorithm to provide not so reliable results, thus we used an algorithm based upon the difference in luma[6] values of foreground and background components, corrected with an exponential factor.

Our initial evaluation of the module gave promising results that will be confirmed in the forthcoming user tests.

4 Color Deficiency Modules

The color deficiency modules were targeted to implement known simulation algorithms presented in the mid-90s by the research group of Brettel and Viénot (see, e.g., [2,3,14,15,16]) for dichromats. Our work not only did implement those algorithms but provided room to test different gamma values for display systems not available at the time the above algorithms were published [10].

Fig. 1. Testing browser with the deuteranopia plug-in

[6] YCbCr is a family of colour spaces used in video systems. Y is the *luma* component, and C_b and C_r are the blue and red *chroma* components. Applied to video signals, luma represents the brightness in an image (the "black and white" or achromatic portion of the image). Luma represents the achromatic image without any colour, while the chroma components represent the colour information.

Fig. 2. Testing browser with the protanopia plug-in

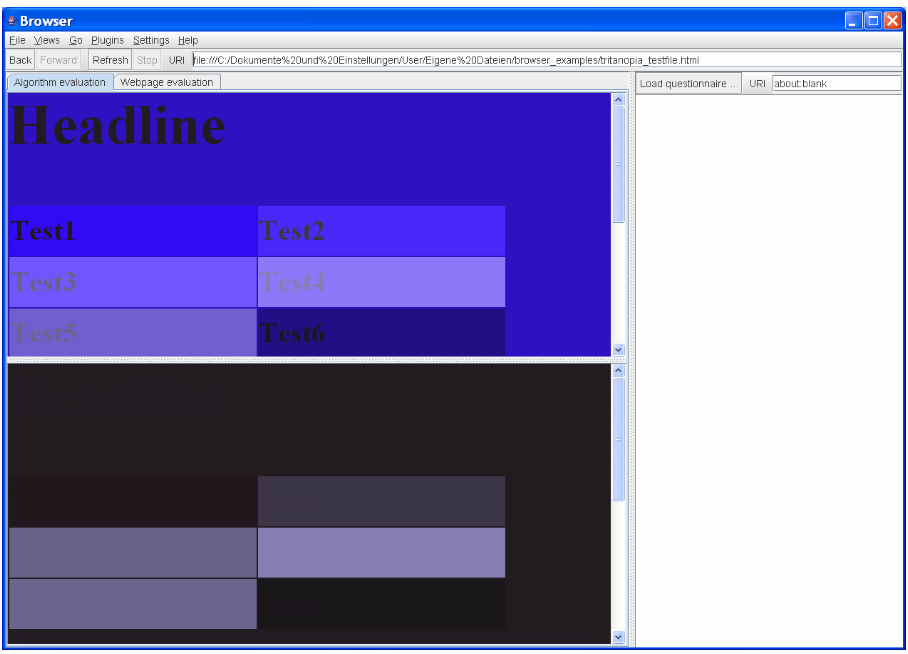

Fig. 3. Testing browser with the tritanopia plug-in

Additionally, to test the reliability of the algorithms by usability experts, a Web browser was developed on top of the JRex Java Browser Components.[7] This browser allowed via direct menu access the application of different testing plug-ins, where the expert could see the original Web document, and the modified one. For this browser, several plug-ins were developed for the three dichromacy modules (see Fig. 1, Fig. 2 and Fig. 3).

5 Conclusions and Future Work

This paper has presented our initial work to automatically test some accessibility components. Although this is work in progress, the initial prototypes present very promising results. Coming work includes expert and user testing, were the validity of our approach will be proven. Further refinement of our algorithms might occurs as a consequence of this evaluation.

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[7] http://jrex.mozdev.org/

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Knowledge-Based User Authentication Associated with Biometrics*

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Abstract. User authentication is necessary for proving and verifying the claimed identity of users in a distributed environment. Three factors such as user's knowledge, belongings, and biometric traits are usually considered for the purpose. A sort of multi-factor authentication may combine those factors in the way that a user provides the requested multi-factors separately, for improving the accuracy and security of authentication. However, such a combination of distinct factors should require each different human-computer interfaces. In this short paper, rather we introduce our on-going work to associate knowledge-based authentication with biometrics for requiring less interfaces and examine the benefits expected from it in a conceptual level.

1 Introduction

User authentication is necessary for proving and verifying the claimed identity of users in a distributed environment. It has been studied and applied for many years in today's computing environments. For authentication of human beings in those environments, three kinds of factors are usually considered, such as what we know (e.g., passwords, passphrases, or personal identification numbers), what we have (e.g., identification cards, security tokens, or software tokens), and what we are (e.g., fingerprint, retinal patterns, voice patterns, or other biometric identifier). Sometimes a combination of them is used, e.g., a bank card along with a PIN (Personal Identification Number), for producing better security in person authentication. This is called multi-factor authentication in the literature. For such a combination of distinct factors, it should be required to provide each different human-computer interfaces for users. For example, for a combination of password and smart token, the user must be provided with two different interfaces for entering the password and for inserting the smart token device. The knowledge-based authentication appeals to the human memory that may not be accessed readily by another person and may not need any external storage. A password or passphrase authentication system is deployed wide for the reasons. Since the human knowledge can also be used for making a real-time decision by the user in the real world applications, it should be a reasonable attempt to utilize the knowledge for user authentication. For example, the human interactive proofs depending on human knowledge can be applied to interactive authentication

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applications such as CAPTCHAs [1–3]. In addition, the wide-deployed interface such as a keyboard can easily be used for entering the required knowledge into the computing system. However, the knowledge-based authentication accompanies disadvantages as well. The intrinsic problem with this method is a human-memorable secret, associated with each user, has low entropy, so that it is not easy to protect the secret information when it is transmitted over an insecure channel [6]. Besides it is not easy to input the knowledge unless the keyboard-like interfacing device is provided for human users. Specifically in biometric authentication, we use another term, multi-modal authentication, for describing the enhancement to increase the accuracy of authentication systems in five different ways: multiple biometrics, multiple acquisitions of the same biometry, multiple representations for the same biometry, multiple units of the same biometry, and multiple sensors for the same biometry. The multi-modality is accordingly used for describing the multiple treatments of biometric traits associated to a person in the literature [4, 10]. However, multiple human-computer interfaces should be necessary for handling the multi-modal biometrics, while the biometric authentication is expected as a wide spread authentication technology in the future ubiquitous computing environment. Since the human-computer interactions (HCI) is the emerging field of significance in computer science, it should be necessary to study the trade-off of using both multi-factor and multi-modal authentication methods with regard to the human-computer interfacing devices. Our on-going work is to deal with this problem by exploring a method to associate human knowledge with biometrics for requiring less interfaces. In this short paper, we discuss the idea in a conceptual level but we expect more concrete results in our future study. The rest of this paper is organized as follows. In Section 2, we classify the human knowledge for authentication. In Sections 3, we discuss the knowledge-based authentication associated with biometrics in two different ways. In Section 4, we conclude this paper.

2 Human Knowledge for Authentication

In today's computing environment, it is conventional to conduct the human knowledge authentication using the human memorable password or passphrase having low entropy. When we apply Shannon's classic measure of entropy to the human knowledge for authentication, it should be ranging from 20 to 40 bits only. This is because the restricted human memory and alphanumeric characters may limit the space of interactive knowledge. For securing the transmission of such low entropy information, many studies have been done in the context of designing secure and efficient cryptographic protocols, most of which are depending on public key cryptographic technologies. From the perspectives of practical use in interactive authentication, we could classify the human knowledge as follows. In other words, we classify the human knowledge as a shared secret for authentication under the assumption that the knowledge holder, as an authentication client, registers the knowledge or its verifier to the authentication server.

– Static knowledge: The human knowledge that is held by an individual permanently (or as long as the individual's memory allows) can be used for authentication but provides lower security. The static knowledge is very similar to the biometric traits and is distinguished from the semi-static knowledge in the sense that it is very specific to the individual holder's characteristics and environments, for example, a birth place, a graduated elementary school, and some favourites.

- Semi-static knowledge: The human knowledge that is held by an individual semi-permanently (or as long as the individual does not change it) can be used for authentication. The random selection is recommended for security of the semi-static knowledge but the individual tends to choose his or her preferred one, for example, a reusable password or passphrase that is most widely used.
- Dynamic (responsive) knowledge: The human knowledge that is submitted by an individual dynamically can be used for authentication. It is not specific to the individual holder's characteristics and environments. The knowledge here means rather a key for an interactive proof of human being or an human's answer to dynamic questions, for example, a CAPTCHA.

Since the human knowledge has low entropy, an interactive proof method based on cryptographic techniques is desirable for preventing both active and passive adversaries. In the following section, our on-going work to associate the human knowledge with biometrics will be introduced from the perspectives of this classification.

3 Association of Knowledge and Biometrics

In this section, we introduce our pre-mature work to associate human knowledge with biometrics in very conceptual levels. We are studying two different approaches for requiring less human-computer interfaces. One is to associate biometrics with cryptographic protocols manipulating the low-entropy knowledge such as a password, and the other is to associate biometrics with real-time submission of human knowledge. The former associates static knowledge while the latter does semi-static and dynamic knowledge. Two approaches can be combined for more accuracy and convenience in human authentication.

It is recognized that the entropy determined in the measured sample of biometrics is not as much as required in a cryptographic society [7]. Thus, the tele-biometric authentication is not easy without encrypting the huge amount of measurement with enough randomness for secure transmission. In our first approach, we would aim to apply the well-structured cryptographic protocol for ease of secure transmission. For securing the transmission of such low entropy information, many studies have been done in the context of designing secure and efficient password-based cryptographic protocols, most of which are depending on a public key cryptographic technologies. Recently those protocols have been standardized by IEEE P1363.2 and ISO/IEC 11770-4 [6]. The merit of these protocols is that the shared secrets having extremely low entropy can be handled securely and efficiently in a distributed environment. In that sense, we could utilize these protocols for delivering the biometric information having low entropy. Here we mean by the low entropy biometric information, the reduced set of data that are abstracted and filtered from biometric samples for deterministic decision. The filtering of the biometric sample must be modeled carefully, in the way that the possible errors should be minimized within the range allowable by the numerical property of cryptographic protocols. For example, in our cryptographic protocol designed in a number field, it should be possible to replace the numerical value $y^x \cdot b \pmod{p}$ by $y^x \cdot (b + e) \pmod{p}$ in feasible computation of a small error distance e and the filtered biometric sample b. We are now studying the filter and helper functions for manipulating the biometric samples in that way. If the distinct decision can be made for biometric traits with both low entropy and extremely low errors, it is further possible to let users remember passwords by deriving it from the filtered sample, for example, pw = f(b), and input pw on a keyboard in the environment that the biometric sensor is not available. The server can then follow the rule in verification. As we have observed, the biometric traits can be associated with static knowledge within the allowable error range. While the static knowledge and the biometric traits are susceptible to replay attacks, we utilize the cryptographic protocols for resolving it in some degree. However, the stronger method can be devised.

In our second approach, we would aim to associate biometric sampling with semi-static and dynamic knowledge, for enhancing the security further against replay attacks. In other words, when the biometric sample is captured, we let the user submit additional information within the context of semi-static or dynamic knowledge. This is based on the human interactive proof of knowledge as well as the multi-modal (or simply multiple treatments of) biometrics. The merit of the knowledge-based interactive proof is the capability of detecting on-line attacks. Thus, a simple forgery of biometric traits works very hard in this approach.

As for the semi-static knowledge, we are able to devise at least two methods. (1) A user may register a sequence (or a variance) of biometric traits and in real time submit his or her biometrics within the sequence (or the variance). The most appropriate biometrics is the fingerprint for this approach. For example, a user registers a sequence of fingerprints using his or her multiple fingers, and repeats the sequence in the verification phase. (2) A user may register biometric traits with a variance (or a sequence) by the help of counter (or a similar tool). The most appropriate biometrics is the face for this approach. For example, a user registers a variance of face expressions with a specific counter value, and repeats the variance of expression when the counter meets the registered value in the verification phase.

As for the dynamic knowledge, we could apply the interactive verification method used in CAPTCHAs [2]. In other words, we could exploit the experience of passing the U.S. border control as a foreign visitor [9]. When the verification system asks us a specific request, we could response with biometrics associated with our dynamic knowledge. For example, the verification system may ask us by sending messages such as left finger, right finger, the first right finger, or smile, turn right, turn left, and something like that. We then can follow the dynamic question for submitting our biometric traits in the verification phase. If we utilize a CAPTCHA's one-time gimpy-like image that is hard to be read by a machine, we may further be able to apply the image to processing and scrambling the biometric samples in the interactive proofs [2, 5]. The methods described in this section can prevent replay attacks and on-line forgery attacks on biometrics by associating it with human knowledge.

4 Conclusion

In this short paper, we introduce our on-going work on knowledge-based authentication associated with biometrics for improving accuracy and security of user authentication with requiring less human-computer interaction devices. The goal of this study is to consider two different authentication factors without requiring multiple hardware interfaces. Specifically two different schemes are considered for the purpose, while both requiring only biometrics devices as a human-computer interface. One is to derive a low-entropy value from biometrics and apply it to cryptographic protocols using the low-entropy secrets, while the other is to apply human knowledge to the decision of biometrics. Both methods require biometrics devices only but human-knowledge can be associated with biometrics for more accuracy and security. Besides the first method can be applied to the classical computing environment having a keyboard only. Finally, such a combination can be extended more flexibly to accommodate access control features. In our future study, we will investigate more concrete details of the two proposed approaches. Our first implementation is on a PDA having a fingerprint sensor and we expect a comparable result with the related work such as [8].

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Taking Account of the Needs of Software Developers/Programmers in Universal Access Evaluations

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Abstract. Traditionally, evaluations for accessibility have been user-centered, based on guidelines and standards that are also user-centered. An argument is made for putting the needs of developers and programmers at the center of any accessibility evaluation process. Current practice in industry is briefly considered, including the roles of accessibility consultants as well as people in accessibility program offices in large companies. Their interactions with website and software application developers in the product development context is described. A project aimed at understanding developers as 'users' of universal access guidance is introduced. This project focuses on the decisions that people involved with software programming and website development make with regards to disability access issues. The rationale and methodology for the project are introduced, and a three-stage process looking at past and current events; interview studies of consultants and product developers; and observational studies of decision making with respect to universal access.

Keywords: universal access, software development, programming, website development, user-centered design.

1 Introduction

Designers and programmers typically approach problems differently than Human Computer Interaction Professionals do [1]. Cooper [2], in his anecdotal examination of the way programmers think said "If you want to change some existing code, you have to first change the programmer's mind. He will have a vested interest both in the existing code and avoiding the seemingly unnecessary effort of changing it." (p.118). In earlier research, it was reported that a common complaint from website developers was that accessibility consultants often handed them reports of website accessibility problems that were so voluminous that they did not have the capacity to tackle such a volume of site fixes [3]. It was proposed by Law et al. that, contrary to a more traditional view that the needs of end-users being at the center of the evaluation process, the programmers' needs should instead be central in the conduct of website accessibility evaluations. In other words, in order to meet the accessibility needs of a website's end users, as encapsulated by (for example) the W3C's website accessibility

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guidelines [4], the needs of the site developers who were receiving the accessibility evaluation report were paramount. Law et al. proposed a new Streamlined Evaluation and Reporting Process for Accessibility (SERPA) [3] that could be used to leverage the expertise of accessibility specialists by making reports that were tailor made for the specific team of website developers/programmers.

Guidelines and rulemaking relating to software and website accessibility have come about in part because developers do not naturally put accessibility features into their code. The W3C's original guidelines were a response to the fact that people with disabilities were having difficulty using websites in the mid 1990s. Those early guidelines were mostly technology-specific (i.e. HTML-related) but technology moved on (e.g., Flash, JAVA, XML), and so now the guidelines are in the process of being updated to meet the needs of end-users regardless of the technology employed [4]. The US Government instituted procurement standards so that accessible technologies (including websites, operating systems and application software) would be favored in purchasing decisions. The procurement standards (commonly referred to as 'Section 508' [5]) include technical details that are targeted at meeting the needs of end-users. Following the research that resulted in SERPA, it was decided to look at a number of guidelines, standards and design resources, collectively termed 'Universal Design Resources' (UDRs), for access to public-use and personal-use information technology. The examination [6] first looked at whether the needs of product designers were being met in the way the UDRs were constructed, and it was found that for seven of eight UDRs there was a mismatch between the way designers think (e.g., [7]) and what the guidance was asking them to do. The examination then moved on to look at whether the people who actually created the UDRs considered the needs of designers while they were creating them? It was found, by means of surveys and interviews, that the teams creating UDRs in the main did not ignore the needs of designers as end users of their guidance, but they did not use a systematic process to address those needs [8].

This paper describes a research project that is currently underway at RMIT University. The project is an extension emanating from the above research results and the argument for putting the needs of developers/programmers at the center of any accessibility evaluation process. The current means of addressing accessibility in large organizations is discussed, and methodological considerations of the project are described.

2 Practical Considerations

The need to comply with accessibility guidance (e.g., for software procurement or website accessibility) generates a need within business companies to start thinking about accessibility with regards to their products (**Fig. 1**).

In any given company that designs, makes and sells software, people involved in both the technical and non-technical aspects of product development will go through such a process, either formally or informally, in response to disability access demands / concerns regarding their products. Whether the demand comes from legislation, a customer request, an internal idea, or from elsewhere, people in the team have to start thinking about accessibility somewhere along the line (Step 1 on **Fig. 1**). The product may be an existing one, or a new one in the early, middle, or late stages of development, and the thinking about accessibility could start anywhere in one of the development stages. Next, accessibility options must be considered, and a design path chosen, i.e., "what do we propose to do to our product, if anything?" (Step 2 and Step 3a). As the design progresses, the approach taken may be reviewed (Step 3b). The team will eventually commit to their decision in the final design and manufacture of the product (Step 4). Based on the success or failure of the chosen approach, it again may be refined in the future (i.e., back to Step 3b, then back to Step 2).

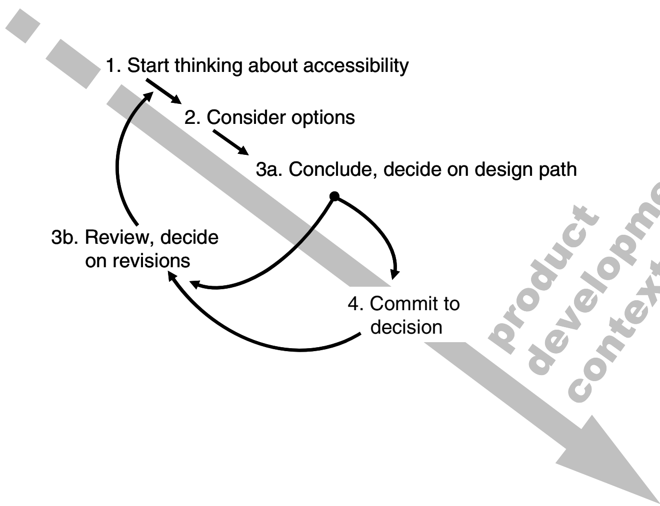

Fig. 1. Starting to think about accessibility in the product development context

People have begun to look at this process in business regarding universal access (e.g., [9]; [10]) and in particular they have looked at how to 'facilitate' such steps, and what the 'barriers' are to each step. However, there is a gap in our current understanding as to how this process actually develops, and what causes people to choose one type of direction over another, given their particular product development context. The National Council on Disability in the US found that after going through such a process of thinking about and reacting to accessibility problems, four of six companies studied had created called separate and distinct "Accessibility Program Offices" (APOs) within their company [10]. However, the people who staffed the APOs were typically not programmers, and not part of the core development team. The NCD report summed up the resulting this situation: "Unfortunately, the accessibility program office in the four companies that had program offices demonstrated very little control over design decisions that directly affected the accessibility of the final product" (p190). In research by Law and colleagues, this model was also seen in an additional two of three US companies, and four of four US government departments [6].

Developers might have difficulties in interpreting and following universal access guidelines [6, 8], and we can speculate that the emergence of the APO model of operation is possibly due to such difficulties. We know from experience that, often, members of product development teams hire accessibility consultants to help them through the process. Consultants may not be enough where larger companies are concerned, and so the company may hire people to do accessibility in-house on a permanent basis. Thus, a new industry-based department (APO) forms. As observed in the NCD report, the members of the APOs are often not integral and/or influential to the decision-making process in the development regarding accessibility.

Rather than speculate, the aim of the research project is to find out how programmers and others in the development process, who are new to and who are experienced with accessibility, actually respond to demands for solutions to accessibility problems. The important factors that determine the directions people take need to be discovered. The basis on which people in the academic community are currently producing and promoting resources for UD appears to be based for the most part on meeting the needs of end-users of products and services, and so is possibly missing some quite important information about how decisions are made in the practical contexts of product development.

3 Decision-Making and Accessibility Issues

Looking at the development of standard products, software applications, websites etc., developers get commissioned to create them and if there are accessibility demands an 'accessibility team' (or APO) often forms. This team may include an accessibility

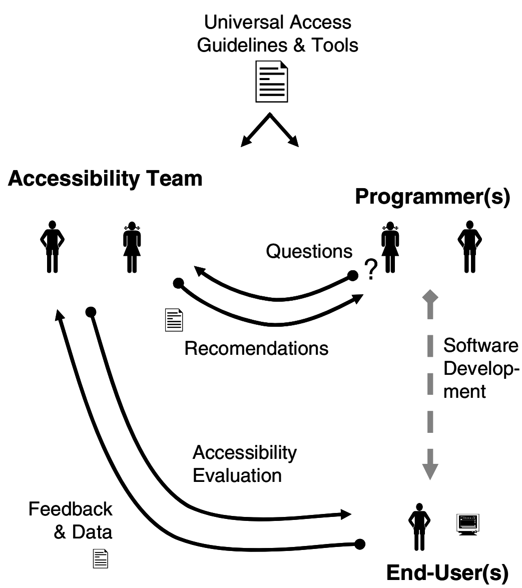

Fig. 2. A simplistic view of accessibility evaluations in practice

specialist or people from various disparate disciplines, and sometimes potential end-users. The accessibility team may evaluate the emerging application against universal access guidelines using automated and manual tools. The accessibility team may then pass their recommendations back to the programmers, who then might ask some clarification questions, and finally the programmers make the fixes to the software (Fig. 2).

We have labeled **Fig. 2** 'simplistic' because in many ways it mirrors early views of the way that people conceptualized the introduction of ergonomics / human-factors methods to influence the usability of interfaces. Such a closed-loop viewpoint of the system ignores so much of what is known about the way developers think and operate, and how different it is to that of human factors professionals (e.g., [1, 2, 7, 11]). Interface programmers at the center of the process may become convinced of the need to address access issues, and they may even be enthusiastic to, but that does not necessarily mean that the whole team is on board. They may make accessibility fixes that are later undermined by changes enforced by others in the development team. Real-world problems such as these have up to now been conveyed in the human-factors and usability fields through anecdotal accounts of the design process, the problems that consultants face, and the remedies they suggest (e.g., [2, 11]).

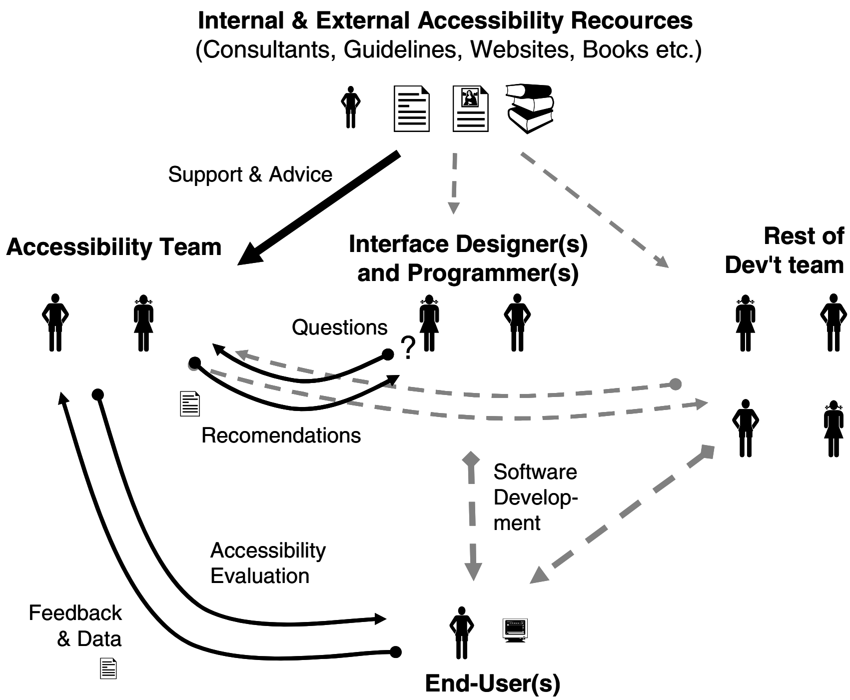

Fig. 3. Extended view of accessibility evaluations in practice (gray & dotted lines show gaps in current knowledge

We can consider an extended view of the situation. The interface programmers at the center of **Fig. 2** are only a part of a larger development team (**Fig. 3**). Although this is still a highly simplistic view of the whole system, the avenues for consideration are diverse in terms of finding out where the 'key decisions' are being made that have ultimate impact on the accessibility of the final product. A methodology is needed that can be used to locate the key points in such systems where decision-making regarding accessibility is going on, and identify the factors that have the most influence, positive or negative on the nature of those decisions.

4 Methodological Considerations

How company-wide reactions develop is of interest. For example, when looking at how the relationship between consultant(s) and people in a company's development team initially develop, it will be important to consider how the consultant's own beliefs, approaches and methods affect the interaction with their industry-based clients. It is also important to consider how the beliefs, approaches and methods of people in industry affect how they make their choices, whether they utilize or discard the advice of consultants and (later) those of their accessibility teams in APOs.

The psychology of those involved (**Fig. 3**, and others) in the development and evaluation of software applications that are universally accessible will affect the outcome of the final product(s). It is clear from current product offerings that there is still a long way to go to expect universally accessible software and products the norm rather than the exception. The study will therefore investigate people involved in the development of products and services for mainstream markets to determine what factors are involved in the decision-making processes behind those products and services.

The question of how such people respond to accessibility demands lends itself to phenomenological and interpretivistic methodologies. Given the diversity of options and the range of possibilities for people in any given company to consider, being able to find generalized cause-and-effect relationships is likely an impractical proposition. A Grounded Theory [12-14] approach is therefore proposed, to provide descriptions of the populations under study. An appropriate qualitative approach for capturing details about the factors that contribute to the decision-making process in this context is the use of case studies [15-17]. Investigations that include multiple instances of single phenomena can be useful in studies that aim to explore situations where there are few extant theories and a small body of literature [13]. The two primary research questions are (1) How do people in industry respond to demands for solutions to accessibility problems?; and (2) How do people in the industry, consultants, and external factors contribute to the decision-making process?

In order to identify the key factors in this context and build an appropriately grounded theory, a progression in the detail of the case study methodology is envisaged [13].

At first, a broad analysis will be conducted looking at past (and to some extent current) events that have had outcomes that were or were not considered 'UD' or 'ideal world'. In general, examples of the different approaches to solving the design problem will be sought. The case studies will be based on secondary data and publicly available information, such as current product offerings, reviews, journal and news articles, company and consultant websites, books, etc.

Next, a stage is required to actually describe what goes on in the spheres of business and consulting. The overlap of these two spheres is of interest. The approach will basically be etiological, utilizing qualitative interviews to investigate the origins of decisions for development of ICT accessibility solutions.

It is anticipated that an outline or preliminary theory will be formulated based on outcomes of the above stages. A record will be obtained of what people say they think and do. However, what people say they does not necessarily encapsulate what they actually do in practice. A final stage of case studies is planned to observe decision making in the field. At the present time the candidate methods envisaged are structured observation and/or participant observation [18, 19].

5 Conclusion

This RMIT University based research project as described is in its early stages. The current dearth of universally accessible IT products and services requires that we understand what is actually happening in industry-based practice with the information that academics are producing and the policies that governments are promoting / enforcing. Past research by the lead author and colleagues as part of the Universal Design in Practice (UDiP) project[1] at the Georgia Institute of Technology has been described briefly in this paper. In that research a programmer-focused website was proposed. Such an approach is partly based on the broad assumption that user needs are already captured in the relevant guidelines. As human factors professionals, we make that statement knowing full well that the user needs relating to any given product are not really going to be encapsulated by generic guidelines alone. In many companies and APOs however, practical constraints restrict the ability to conduct usability evaluations with end-users, let alone accessibility evaluations with end-users. Often then the only resources are published information and guidance on website accessibility.

Given the scale of the problem, with the enormous numbers of developers making software applications, and the relatively tiny number of people interested in inclusive or universal access, generating the knowledge through such studies such as that proposed in this paper will fill a gap in the current literature. To find an appropriate leverage point for making universal access widespread or pervasive may still take some years. The authors hope that by sharing their approach, others may be interested in fully examining the merits of placing developers at the center of any given universal access / accessibility evaluation process. We believe that through such work there will be eventual improvements to the tools available to those involved in making products more accessible. There is a hope that this will then improve software applications and websites. This in turn may provide accessibility and universal design benefits to end-users.

Acknowledgments. This work is supported by an Australian Postgraduate Award and a State of Victoria ICT scholarship through the School of Business Information

[1] http://cise.bme.gatech.edu/udip/

Technology at RMIT University, Melbourne, Australia. More information on the project can be found at http://udprojects.org/.

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Biometric Digital Key Mechanisms for Telebiometric Authentication Based on Biometric Certificate*

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Abstract. Existing biometric authentication systems use probabilistic method to decide the claimed identity of a user. But, these are weak on the privacy protection perspective as anyone can access someone's biometric template without restrictions. Therefore, we propose a scheme that can improve the biometric authentication accuracy with the concept of digital signature with biometric digital key. By using these biometric digital key pairs, each entity(sender) can mutually authenticate the others based on the biometric certificate on open network.

1 Introduction

The creation and use of biometric templates has previously been addressed in several documents such as X9.84, BioAPI, and CBEFF. In particular, X9.84 (and CBEFF) addresses the role of data encryption and digital signatures to provide template privacy and template integrity, respectively.

What has not been covered to date in these previous works is a description of deriving a keying material from biometric templates. Therefore, it is desirable to propose new mechanism by deriving a biometric digital key (or a semantically equivalent value) from biometric templates for user authentication and a secure communication mechanism on open network.

A user's biometric template stored in Biometric Certificate(BC) can be used for identification and it also can be used to generate private secret data such as biometric digital key. Therefore, it is required to suggest a common digital key generation framework using biometric template that incorporates with cryptographic authentication framework called the digital signature technology. Additionally, security requirements must be considered on biometric digital key generation and digital signature framework with both Certificate Authority(CA) and Biometric Certificate Authority(BCA).

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A *digital signature* is a term used to describe a data string which associates a digital message with an assigned person only. It has many applications in information security such as authentication, data integrity, and non-repudiation. One of the most significant advances in digital signature technologies is the development of the first practical cryptographic scheme called RSA[1], while it still remains as one of the most practical and versatile digital signature techniques available today[2].

It is often desirable to generate a digital signature by deriving a signature key (or a semantically equivalent value) from human source(biometrics) in today's communications environment rather than keeping the key in an external hardware device. Therefore, *biometrics* is the science of using digital technologies to identify a human being based on the individual's unique measurable biological characteristics[4,5,8]. In detail, it means by biological characteristics and some physiological or behavioral characteristics such as fingerprint, voice pattern, iris pattern, face, retina, hand writing, thermal image and hand print, etc.

This paper proposes a digital key (both private key and public key pairs) generation and extraction mechanism using biometrics data for biometric-digital signature on telecommunication environment. To propose key generation mechanism using biometric data, it should be considered to assure that only the authenticated user can make digital key pairs.

This work also can be applicable into authentication frameworks for protection of biometric systems as related to their operational procedures, roles and responsibilities of the personnel involved in system design. It is expected that the proposed countermeasures will ensure security and reliability on the flow of biometric information in the telecommunication environment.

Chapter 2 overviews on the basic concept and background on digital signature key generation module and biometric certificate on existing telebiometric environments. And we reviewed on the existing signature mechanism and fuzzy vault[4] scheme related with key generation and hiding procedure in Chapter 3. And the new mechanism on both digital key generation and protection/extraction steps are shown in Chapter 4 and 5 respectively. Chapter 6 shows the experimental result with security considerations.

2 Background

2.1 Biometric Digital Key on Open Network

Fig. 1 depicts the common component or modules on telebiometric system with proposed key generation module, which commonly includes a step to extract features through signal processing after acquiring biometric data from a biometric device such as a sensor. The features are then compared or matched against the biometric data, which were already obtained through the same processes and saved in a database, and the result is decided on decision step. After signal processing the key generation step is used to generate digital signature key from biometric data. It is possible to combine existing public key infrastructure such as RSA[1] or ElGamal[3] to generate digital signature key on biometric data.

In order to guarantee the security of the information and service on open networks, identity authentication is an important component of network security system. Now, PKI authentication framework based on cryptographic keys is the most widely used authentication mechanism. Existing framework requires the user to remember preserve their cryptographic key securely.

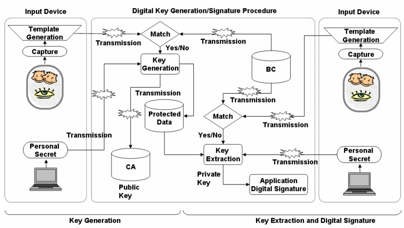

Fig. 1. Biometric Digital Key Model

For telebiometric authentication, the PKI authentication system should issues the user's private key depends on the biometric identification result. However, biometric authentication uses probabilistic method to decide about the claimed identity of a user, the biometric authentication result may not accurate. Therefore, we proposes a scheme that can improve the biometric authentication accuracy with the concept of digital signature with biometric-digital key. By using these biometric digital key pairs, entity at sender(client) can securely communicate with receiver(server) based on the biometric certificate and also can mutually authenticate each other on open network.

2.2 Public Key Infrastructure and Biometric Certificate

For an authorized assertion about a public key, we commonly use digital certificates issued by a trusted entity called the certificate authority (CA) in the existing public key infrastructure (PKI).

Biometric identification process is combined with digital certificates for electronic authentication as biometric certificates. The *biometric certificates* are managed through the use of a biometric certificate management system. Biometric certificates may be used in any electronic transaction requiring authentication of the participants.

The electronic transaction is authenticated by comparison of hash values in the digital signature with re-created hash values. The user is authenticated by comparison against the pre-stored biometric certificates of the physical characteristics of users in the biometric database.

3 Overview on Existing Schemes

3.1 Problems on Existing Biometric Digital Key Mechanisms

Recently several methods have been proposed to use biometrics for generating a digital signature. In 2001, P. Janbandhu and M. Siyal studied a method for generating biometric digital signatures for Internet based applications [17]. Their scheme was actually focused on using a 512-byte iris code invented by J. Daugman [9,10], and deriving a singature key from the iris code.

In 2002, R. Nagpal and S. Nagpal proposed a similar method except that they used a multi modal technique combining iris pattern, retina, and fingerprint in order to derive RSA parameters [15]. In 2002, P. Orvos proposed a method for deriving a signature key from a biometric sample and a master secret kept securely in a smart card [14]. In the commercial fields, several products that generate a digital signature only by accessing the server or smart card through biometric authentication, are being announced [8].

We could observe that the first two schemes are far from practice due to their inadequate assumption on acquiring deterministic biometrics [15,17], while the remaining results eventually use biometrics as only a means to access the signature key stored in some hardware devices [8,14].

More recently in 2004, Y. Dodis, L. Reyzin, and A. Smith showed a method of using biometric data to securely derive cryptographic keys which could be used for authentication by introducing a secure sketch which allows recovery of a shared secret and a fuzzy extractor which extracts a uniformly distributed string from the shared secret in an error-tolerant way [13].

In 2005, X. Boyen, Y. Dodis, J. Katz, R. Ostrovsky, and A. Smith improved this result in a way that resists an active adversary and provides mutual authentication and authenticated key exchange [20]. There is an approach of template-protecting biometric authentication proposed by P. Tuyls and J. Goseling in 2004 [7], but it does not provide a method for deriving a cryptographic key.

3.2 Secret Hiding Function: Fuzzy Vault Scheme

Fuzzy vault is a simple and novel cryptographic construction. A player Alice may place a secret value $\boldsymbol{k}$ in a fuzzy vault and 'lock' it using a set A of elements from some public universe U. If Bob tries to 'unlock' the vault using a set B of similar length, he obtains $\boldsymbol{k}$ only if B is close to A, i.e., only if A and B overlap substantially.

Thus, a fuzzy vault may be thought of as a form of error tolerant encryption operation where keys consist of sets. Fuzzy vault like error-tolerant cryptographic algorithms are useful in many circumstances such as privacy protected matching and enhancement, authentication with biometrics and in which security depends on human factors like fingerprint, etc[4].

4 Proposed Telebiometric Digital Key Mechanism

4.1 Biometric Digital Key Generation Mechanism

The proposed key generation framework is described in detail. In the key generation model(Fig. 2), the identity of the user is verified by comparing the captured biometric data with biometric certificate that is stored in BCA. Therefore, no one can act for the original user in key generation mechanism. Only the user who has registered his/her own biometric template on BCA can make public and private key pairs.

To propose key generation mechanism using biometric data, it should be considered to assure that only the user who has his/her own biometric data can make digital keys. To satisfy this requirement, we use the user's biometric template stored in BCA. After key generation, the public key is sent to the CA for key and key owner's registration. Therefore, the proposed model can be applied to authentication and digital signature application.

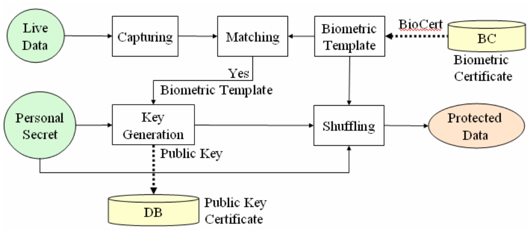

Fig. 2. Biometric Digital Key Generation Model

1) Capturing Function

This function makes the biometric template from the biometric raw data. The noise on the captured image is reduced through image processing. Then the set of minutiae are extracted from the enhanced image. Finally, the biometric template is made from location and angle values of minutiae set.

2) Biometric Digital Key Generation Function

The private key is generated by hashing a user's personal secret and a biometric template. Key generating module generates a private key with the biometric template and stores it as a protected data. And public key is also stored at the trusted CA. Key extracting module extracts a private key from the protected data.

- Process

Step 1: Prepare a user's biometric template and personal secret information for hashing.

Step 2: The private key is generated by using hash function such as MD5 or SHA-1.

3) Shuffling Function

Shuffling module conceals the private key by using biometric template and personal secret value. Shuffling module is a secret locking function used to hide the private key to enforce the security on the generated secret data(biometric digital key).

- Process

Step 1: Generate fake minutiae set and insert them to the user's biometric template for protection of the template.

Step 2: For hiding private key, polynomial for real minutiae set and polynomial for fake minutiae set are constructed. Then, we project private key into each polynomial and get results.

Step 3: The protected template is made by combining results from step1 and step 2. It consists of minutiae's (location, angle, result) value set.

4.2 Biometric Digital Key Protection and Extraction by Biometrics

1) Biometric Digital Key Protection
Private secret data is stored as a protected form on protected storage. The confidentiality of biometric private key can be assured by this mechanism. For biometric private key as well as biometric template is a kind of individual private data, the certificate user have right and must delete their biometric private key from certificate database when the biometric certificate is revoked.

For example, we can implement 'Shuffling' module by using fuzzy-vault scheme as follows. Firstly, we generate fake minutiae set and insert them to the user's biometric template. Secondly, for hiding private key, polynomial for real minutiae set(original biometric template) and polynomial for fake minutiae set are constructed. Then, the private key is projected to each polynomial. Finally, the protected data(template) is made by combining these results. It consists of minutiae's (location, angle, result) value set.

2) Biometric Digital Key Extraction
User authentication is performed at first as same as in key generation mechanism. The user cannot disguise himself(herself) as a other for extracting the private key stored by a protected data. This requirement should be considered in key extraction mechanism based on biometric data. The private key is extracted from protected data by using 'Key Extracting' function with biometric template and personal secret value. Cryptographic function such as fuzzy vault can be applicable into this mechanism.

The private key is extracted from protected data by using 'Key Extracting' function with biometric template and personal secret value. Cryptographic function such as fuzzy vault can be applicable into this mechanism.

This work uses ElGamal signature scheme to simulate the digital signature generation in our framework. The private key a is generated by previous function and the public key y is computed as follows.

Entity A generates a large random prime p and a generator g of the multiplicative group Z_p. And then A selects a random secret a , $1 \le a \le p-2$. A also computes $y = g^a \bmod p$. A's public key is $(p; g; y)$ and private key is a . It is computationally infeasible to solve discrete logarithms over GF(p). Generated public key $(p; g; y)$ is stored on DB and certified by CA

5 Telebiometric Authentication Using Biometric Digital Key

5.1 Biometric Digital Signature

Fig. 3 shows the digital signature generation mechanism. At first, user authentication is performed by comparing the signer's captured biometric image with his(her) own biometric template in BCA. Due to the property of the proposed key extraction mechanism, the signer can not make other signers do signing a message. The signer gets the private key which is extracted from the key extraction mechanism. Then, the signer generates his(her) own digital signature on the message with the private key and sends it to the verifier.

The verifier gets the signer's public key from CA(Certificate Authority) and verifies the signature on the message with the public key. Signature verification mechanism is as same as that of ordinary digital signature verification scheme. Entity at the receiver(server) can verify the digital signature by using the signer's public key and biometric certificate.

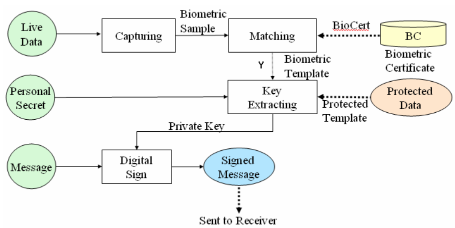

Fig. 3. Biometric Digital Signature Model

The private key extracted from the previous module is used to sign the message. The message and the signature on it are sent to the verifier.

For example, we can generate digital signature ***(r, s)*** on the message ***m*** from the input private key.

Step 1: The signer A selects a random secret integer k, $1 \le k \le p-2$ with gcd(k, p-1) = 1.

Step 2: The signer A computes $r = g^k \bmod p$ and $k^{-1} \bmod (p-1)$. Also entity A can generates $s = k^{-1}\{h(m) - ar\} \bmod (p-1)$.

Step 3: The signer sends ***(r, s)*** to the verifier.

The verifier receives the digital signature ***(r, s)*** with public key. And then the receiver can verify the signature as follows.

Step 1: To verify A's signature ***(r, s)*** on ***m***, B obtains A's authentic public key $(p;\alpha;y)$ and verifies that $1 \le r \le p-1$; if not, then reject the signature.

Step 2: If satisfied, B computes $v1 = y^r r^s \bmod p$ and $v2 = g^{h(m)} \bmod p$.

Step 3: B accepts the signature if and only if *v1* = *v2*. Otherwise, reject the signature.

5.2 Telebiometric Authentication with Digital Signature

A digital signature of a message is a number dependent on some secret known only to the signer, and, additionally, on the content of the message being signed. Signatures must be verifiable. Digital signatures have many applications in biometric security on telecommunication, including authentication, integrity and non-repudiation. Therefore, common telebiometric user authentication framework by digital signature is also possible.

Additionally, biometric encryption is also possible. The objective of biometric encryption is to provide privacy and confidentiality using biometric digital key(a private and a public key pairs). In biometric encryption systems each client receives public key from DB. Any entity wishing to securely send a message to the receiver obtains an authentic copy of public key and then uses the encryption transformation. To decrypt, the receiver applies decryption transformation to obtain the original message after biometric authentication process. Common biometric encryption mechanism with digital key is also possible as follow Fig. 4.

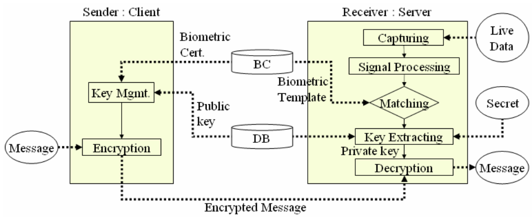

Fig. 4. Biometric encryption with digital key

6 Security Considerations and Implementation Results

6.1 Security Considerations

1) Security Requirements on Biometric Digital Key Generation
Biometric data, as a potential source of high-entropy, have been suggested as a way to enable strong, cryptographically-secure authentication of human users. The protected data stored in the database must provide the least possible information about the original biometrics. Additionally, to derive the private key (i.e., the signature key) securely, two critical requirements must be given.

1. to randomize the biometric digital key derived from biometric template.
2. to keep the biometric template secure from Hill-Climbing attackers.

To make digital key based on biometric data, we should consider making the seed data which is used to pseudo random number generator based on DATE, TIME, serial number information and biometric data. The seed data is used in hash function of 'Key Generation' module of the proposed digital key generation mechanism.

We also should consider following items for selecting the seed data, randomness property and uniqueness property.

1. Length of the seed data: The length of the seed data should be selected considering the length of the digital key.
2. Randomness: The seed data also should have randomness property that any one cannot fake it.
3. Uniqueness: A user's biometric data is used to make seed data so that the uniqueness property holds.

2) Security Requirements on Biometric Digital Key Protection/Extraction
We use biometric certificate to authenticate user's identity. The biometric certificate is a biometric data registered by BCA. So we consider privacy protection mechanism on the biometric certificate. The mechanism for providing confidentiality of the private key is essential. In the proposed key generation and extraction mechanism, we

use digital key hiding technique such as fuzzy-vault scheme. The security of the key hiding function also should be analyzed. 'Reproducibility of extracted key data' and 'Capacity of protection key length' are also important factors to be considered in digital key extraction mechanism

6.2 Implementation and Evaluation Results

This work proposes an evaluation results. First step is a fingerprint enhancement module (By Transformation (1)) for extracting set of fingerprint minutiae. After this fingerprint enhancement function, the set of minutiae is generated and it is used for generating private key with personal secret from template registration and key generation step. Generated private key is commonly 256 bit in this experiment. But it is possible for us to generate diverse key length from 256 bit to 1024 bit from input biometric data.

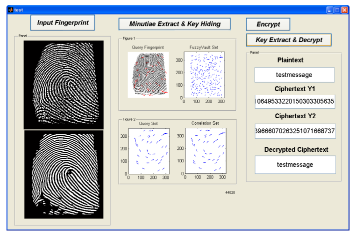

Fig. 5. Implementation of Biometric Encryption using Fuzzy Fingerprint Vault

Follow Fig. 5 show the implementation software based on fuzzy vault scheme after locking someone's secret within his/her own biometric template. Developed module provides and generates protected template from input fingerprint template.

It is possible for us to evaluate the average time of digital signature key generation from input fingerprint. As for the practical performance, this work examines proposed mechanism in a modular calculation. The total running time can be measured by $T_{total} = T_{bio} + T_{key} + T_{FV} + T_{sig} + \varrho$ in both key generation and signature framework where each subscript means its corresponding operation and ϱ is a negligible factor.

7 Conclusion

We proposed biometric digital key generation/extraction mechanisms, which are essential for authentication and digital signature protocols on open network environments. The proposed model uses biometric template in Biometric Certificate for user authentication in key generation/extraction mechanisms. By using biometric template in user authentication step, the user can't legally generate or extract other person's biometric digital key pairs. Only the authenticated user himself(herself) can participate in key generation/extraction mechanisms. And this work also proposed evaluation result based on fuzzy vault with ElGamal signature scheme.

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I See Your Voice: The Development of Image Caption Generating Software and On-Line User Community for the Auditory Disabled

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Abstract. This study is on developing methodology of accessibility and usability for the auditory disabled by producing the interface of converting auditory elements into visual elements that are extracted from elements of the artistic representational method of contemporary media art, and by building on-line community for the auditory disabled to enhance and to reflect the accessibility and the usability through the group's own development and design. At the first stage, analyses on current web animations and their accessibility of auditory disabled persons. At the second stage, analyses on contemporary media artworks are followed to extract usable elements from the artwork. At this stage, actual image captions are created. At the third stage, the image caption generating software is developed, and adjusted image captions are produced as the content. At the last stage, the linkage of web and on-line user community is set up. The development can improve accessibility of the auditory disabled using a various digital content, and it magnifies the territory for the application and the production of creative interfaces. It can also expand the area of content technology.

Keywords: auditory disabled, digital content, accessibility, usability.

1 Introduction

Recently the importance of the digital video content is growing with acceleration of broadcasting and communication fusion. Because of such aspect, the digital video content is having the use value which is infinite from the industrial side. While the digital content evolves more and it come to be abundant with technical evolution, digital divide of the disabled person is getting wider.

In the instance such gap solution, the caption working group of New Zealand. Also the auditory disabled person will be able to see the movies from the theater, inserts the appropriate caption. This group shows a movie to the auditory disabled person with the caption which is converted a site sound, a sound effects and a musical sound to a bracket and italic letters. So they help the auditory disabled person to understand a movie well. Like this effort will evaluate highly because they contribute to satisfy partially cultural desire of the auditory disabled person.

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But the actual condition in Korea, the accessibility of the disabled person about the digital video content is restricted considerably. That is because the originative contents and interface development for the auditory disabled person are not become accomplished well. Thus it is necessary for the auditory disabled person that new technology which is able to deliver not only the information but the emotion. In order to deliver the various auditory elements which are included in the digital video content well, necessary to convert the auditory element which is included in video with visual element such as an icon or image.

Especially the animation which has the unique development method is not limited in only communication process of information transmission and language understanding. Delivering the effective emotion about movement, presentation and reaction of the character is a cardinal point of seeing, feeling and enjoying the animation. The authors, therefore, devised an image caption production for the visual effective conversion of auditory element with the method of delivering an emotion.

2 Development Methodology

It finds the problem point as the analysis of accessibility and usability of the auditory disabled person about digital video content. In order to find a solution, extracts a fluid element of contemporary media art works or web animation. It produces the image content with the extracted element and it develops the interface for applying that content, namely image caption generating software.

At last, sets up the on-line community, opens to the community, and it is able to share the diversity user created image caption and video content. Consequently, it improves the digital video content accessibility and usability of the auditory disabled.

2.1 Analyses That Usability of the Auditory Disabled About Digital Video Content

The auditory disabled is divided into the person who are impossible of hearing entirely and able to know meaning as hearing partially. At the side of linguistic and emotional understanding, usability of digital video content gets better at the case of hearing is improved using the hearing aid, but emotional understanding has a problem still. However, in spite of nothing hear, usability and understanding of digital video content about a story and contents improves more when the content provide with visual information about a sound.

2.2 Creating Image Caption Content

Analyses on contemporary media artworks are followed to extract usable elements from the artwork. Based on the inter-sensibility of those elements in experimental artworks, cognitive elements from traditionally representational methods and organic elements from new and experimental artistic methods for representation are integrated.

2.3 Development of the Image Caption Generating Software and Adjusting Image Captions Are Produced as the Content

To develop the image caption generating software, the interface for converting auditory elements to visual elements consists of those extracted elements from the artwork.

This software is developed in the environment of Microsoft Visual C++ and is attached class library MFC(Microsoft Foundation Class) in integrated development environment of Windows applications. The image caption generating software has the execution file which name of *CaptionPlayer* (CaptionPlayer.exe).

The software plays digital video content, and inserts letters and image captions saving and exporting the moving image. That is, the user watches the digital video content at the player, and edits the digital video at the caption generating interface by inserting image captions at the same time. After editing the digital video with the image caption, the final edited digital video content is saved as the same video file name without the rendering process. Also simple user-made image captions can be uploaded to the software. After the production of the software, the application test is followed to review the established animation.

2.4 The Linkage of Web and Setting Up On-Line User Community

The user can use the image caption generating software, and produce new digital video content by thrusting image captions on the screen. Anybody can use the tool and remake animation easily on the web, and build the on-line user community for designing and producing new image captions, based on the suggested artistic diverse experiment.

3 Image Caption Content

3.1 Analyses on Contemporary Media Artworks and Extracting Usable Elements from the Artwork.

The art work of the artist who does a work activity with the name is *AWNN*, "Energy Flash" does to move six people to harmonize with music by selection of the user at six *Quicktime Player*. Tempo of music comes to be quick from this work, shows the person whom it moves quickly and the user will see and feel a rhythm from the movement. See the Figure 1.

Fig. 1. AWNN, Energy Flash, 2000

Fig. 2. Seungho Cho, 67/97, 2001 (video capture)

Seungho Cho's artwork *67/97*(2001), attaches the bar code in things and shows the scene of scanning that thing with finger. It sounds the 'ppi~' when the spectator scan with finger simultaneously, and the red color flash to be emphasized at visual process, it shows the same effect with listening to sound. See the figure 2.

Jinyo Mok and Kichul Lee's artwork *Drawing on Music Box*, when the spectator inputs the shape of picture from the terminal, the music box rolls and the music is played and the light comes out like with the shape of picture in the music box. This artwork is converted visual element into synesthesia of visual and auditory element. See the figure 3.

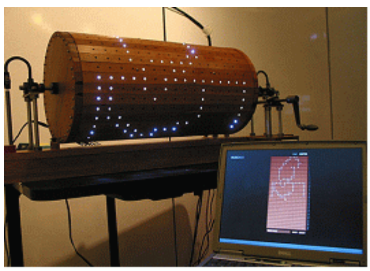

Fig. 3. Jinyo Mok and Kichul Lee, Drawing on Music Box, 2004

3.2 Analysis of Existing Caption and Classification of Using Case

Analyses the caption of existing video content that it will be converted auditory information into visual effect, and classifies the caption according to the use case. At the result of analyzing the existing content, the semiotic meaning of letter and the iconographical meaning of diagram, icon, image, etc., it was represented sound information included in letter as image, it will be able to complement to the lack of auditory information with visual. For example, see the figure 4, it is able to deliver a little suspense and horror as offering the visual information about inserted sound information in order to maximize suspense and horror.

Also it will be able to apply kinetic typographical element in order to represent the rhythm and perspective of sound. It is able to convert the sound into the representation of visual as method of resizing, transforming, controlling the weightiness on typo

Fig. 4. Example of Adjusting Image Caption to Digital Video Content

about an intonation of massage from the change on pronunciation when the pronouncing units of a syllable, a word, a phrase, etc. segments. The image captions are classified according to site-specific sounds(room, kitchen, living room, street, road and forest, etc.), sound of musical presentation, voice of men and women of all ages, mechanical noise and sound of situation.

3.3 Creating the Image Caption Content Set

The result which it tries to apply in the animation it completed a basic image caption set. See the figure 5.

Fig. 5. Image Caption Set

The image set is a bundle of icon. Each icon is 24 bit windows bitmap image and size of icon is 32X32 pixels. If the icon is in a lump form of image caption set, it is difficult to satisfy the synesthesia of visual and auditory element primarily to be seen in digital video content. Thus it needs to develop and to make continuously that it is able to maintain the universality and to customize a diversity representative form of specific digital video content.

4 The Development of Image Caption Generating Software

4.1 Basic Interface

Many digital video file formats, for example, avi, mpeg-2, mpeg-4, wmv, asf, etc.,are used in the environment of personal computer. The interface needs to have the basic function with playing many file formats. Thus, it is developed the basic interface that

Fig. 6. Basic interface

the basic functions of open, play, pause, stop, fwd, rwd, etc. and the added functions of scroll bar to control status of play, volume control, view to full screen. See the figure 6.

4.2 Integrated Interface

It completed the entire interface which is the image caption generating software as integrate all interface that the basic interface for playing digital video content, the caption interface for applying caption content and supplement function for managing the image caption as to add or delete the caption. See the figure 7.

In the caption interface, it is to insert not only the image caption but also the caption based letter. In the case of inserting the caption based letter, different point with old caption is able to insert any position in the boundary of screen not to fix the position of caption under screen.

Fig. 7. Integrated interface

4.3 Remaking of Digital Video Content Using Image Caption Generating Software

The image caption generating software is simple excutable file and need not to install. After the excutable file(CaptionPlayer.exe) enter, it will be able to see the video and to edit easily at real time. See the figure 8.

After the edit is over then the video content is saved without rendering. And file name of the edited video content is saved at the same name of original file on same directory. As original video file is kept intact and extra file is saved about added caption information, encoding and decoding of the video content is not necessary.

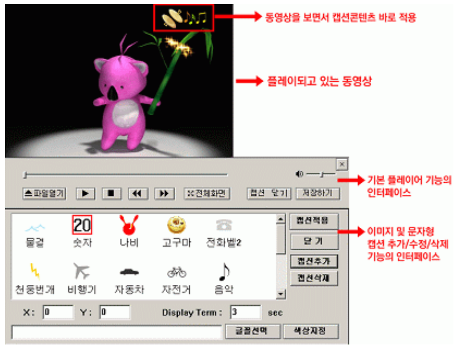

Fig. 8. Edit using the image caption generating software

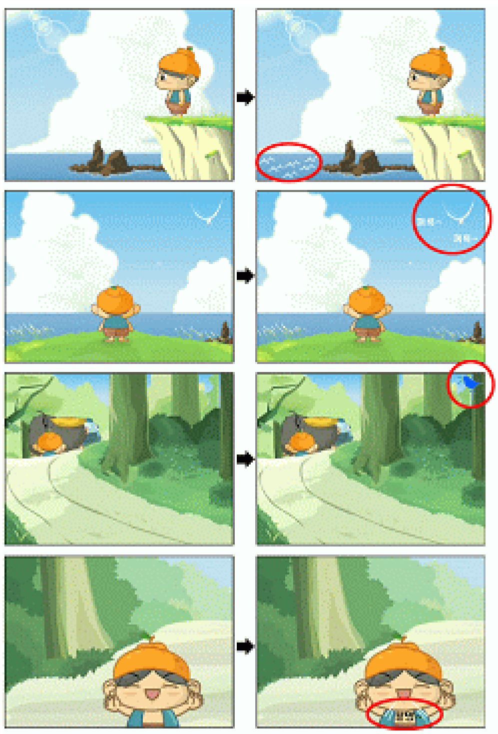

Fig. 9. Remade animation

Consequently, it is playing of the layer which has newly added caption information on the screen of original video content simultaneously. As a result of applying a specific animation for the auditory disabled using the image caption generating software, we knew that it is as follows. See the figure 9.

- Visual expression of auditory information as an image complement
- Visual expression of the sound of sea gull as an imitative words
- Visual expression of the sound of birds using icon
- Adding the speech using text and image

5 The Linkage of Web and Setting Up On-Line User Community

The image caption generating software which is developed in order to be used from local PC, it will not be able to use on the web site. Thus this software should distribute with shareware from the web site and many users who are the content provider offering diversity image caption should be got from the on-line community. Ultimately accessibility and usability of the auditory disabled will improve owing to the remade video content which is shared from on-line community.

In the future, if it is developed in order for use this software directly and remake the video content from the web site as linkage of web, to get more good usability and accessibility. The image caption generating software is used limited boundary for the auditory disabled, in that video content is remade by user participation, it will be able to understood similarly with UCC(User Created Content) which coming into the spotlight.

6 Conclusion

In this study, we developed the image caption content that auditory element converted into visual effect in accordance with each digital video content which have the diverse representational form and element. And we completed a set of the image caption content and the image caption generating software with applying to a specific animation, but it is some excessiveness that the image caption is applied in common all digital video content such as the movie or animation.

We have primary purpose that the image caption content and the image caption generating software provide diverse content to the auditory disabled user. It will not be able to advance all process at on-line until now. But it will be able to remake easily digital video content of existing as form of the file using the image caption generating software in local PC, and if it will be linked the web site and on-line community, and it will be developed continuously so as to be able to edit, save and export on-line, then the application value will be more higher according to that it is not simple way for complement of auditory difficulty but the useful and interesting content for the ordinary person beyond the initial improvement of usability about content for the auditory disabled as the case of UCC.

On the other hand, it will be find the possibility that this study is expanded development of content for another disabled person. Now, it will be able to induce the extension of the five senses about content service which is advanced from the level of simple solution for the auditory disabled person, accordingly, it is possible to develop of versatile content. In other words, this is not to cease content service for the auditory disabled, but to induce the development of such content of itself.

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Economic and Social Condition of the Software Quality Assessment

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Abstract. Issue of the computer software quality has an interdisciplinary nature and it is a subject of research in numerous scientific disciplines, including the software engineering, economics, psychology and ergonomics. Considerations concerning the integration of the subjective factors with the technical parameters in respect of the computer software quality testing are not present in the literature[1]. Therefore, this Article comprised the results of research on the software quality assessments made by users. This Article includes four parts, which represent: the research methods, the economic conditions connected with the computer software quality assessment, the social conditions and the Summary. The first part of the Article discusses the method of correspondence as well as the typology of the economic and social working conditions that were used to create the correlation model for the computer software assessment. In the second part of the Article the authors discussed the economic conditions for computer software assessment that were qualified to one of the three groups: variables that describe: organizational and technical situation, self assessment of the employee's position in the company and the evaluation of the employment security. Further part of this Article is dedicated to correlation between the social issues and the computer software quality assessment. The four variables: sight affections, monotony of work, work intensiveness as well as the psychophysical affections were classified under a single group titled Employee Health Hazards. This Article is concluded with Summary, where the authors indicated the essentiality of economic and social issues in the computer software quality assessment.

Keywords: software quality assessment.

1 Research Method

Review of the literature indicated the proposed typology of the economic and social working conditions that was used to create the correlation model for the computer

[1] B. Krawczyń-Bryłka, Psychologiczne aspekty jakości oprogramowania, Informatyka, vol. 11-12, 2000, p. 37.

C. Stephanidis (Ed.): Universal Access in HCI, Part I, HCII 2007, LNCS 4554, pp. 447–452, 2007.

software assessment (evaluation of characteristics described in ISO 9126)[2]. This model may be used by software developers and company management to find out the reasons of the employees' specific attitude toward implemented software.

With a view to conduct an empirical research, the research methods, including the representative method, sample selection and the method of correspondence analysis were characterized. The method of correspondence analysis was used to examine quality-quantifiable features that constituted both economic and social working conditions and the qualities of the computer software. Additionally, due to non-measurable character of qualities pertaining to the software being assessed by the users, the universal unitary scale of relative conditions used to determine the software quality was presented. Characterization of the persons examined according to demographic and social characteristics was required to perform the computer software assessment.

The results of evaluation of economic and social working conditions in concerned companies that were used to determine the employees' attitude and motivation for work are presented here. Six characteristics from the international standard ISO 9126 were adopted to assess the quality of the computer software. These characteristics are: functionality, reliability, usability, performance, modifiability and transferability. Such selection of features allows the computer software users to indicate which properties are essential for the users. For the 162 researched companies the improvement of the software performance would effect in increased financial benefits.

Improvement of transferability and reliability of the computer software would significantly affect the organization of work and the same the acceptance of computerization by the users, who work in the concerned companies.

Determination of how the assessment of computer software is correlated with the economic and social working conditions was demonstrated by means of the model presented in Tabele 1. Relations between particular variables were presented by value of inertias in two-dimensional perception maps that were contained in the matrix. For better visualization of the results the hypsometric scale was used for inertia values of the coordinates configuration. From calculated average inertia values the importance level of relation between the computer software quality assessment and the economic and social working conditions were determined.

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[2] D. Galin, Software Quality Assurance, Pearson Education Limited, Addison Wesley, London 2004, p. 38.

Table 1. Relations between the computer software quality assessment and the economic and social working conditions

			Computer Software Qualities						Importance of quality
			Functionality	Reliability	Usability	Performance	Modifiability	Transferability	
Economic and social working conditions	Assessment of organizational and economic condition of the company by respondents	Company computerization	100,00	100,00	100,00	100,00	100,00	100,00	**1**
		Company's economic benefits	94,65	96,07	90,05	80,85	92,38	94,82	**7**
		Organization of labour	90,83	79,14	91,00	88,53	90,65	74,40	**10**
	Self-assessment of the employee's situation in the company	Satisfaction of pay	97,20	97,70	98,78	97,44	95,42	98,94	**2**
		Cooperation between respondents and computer staff	99,68	92,87	97,22	82,88	99,79	99,44	**3**
		Training quality	89,65	97,73	87,63	87,99	94,58	99,48	**5**
		Satisfaction of work	89,78	86,88	94,49	90,79	85,52	93,58	**6**
		Attitude to computerization	79,26	68,58	79,93	83,67	80,14	87,42	**11**
	Evaluation of the employment security	Risk of the job loss	100,00	100,00	100,00	100,00	100,00	100,00	**1**
	Evaluation of health hazard by respondents	Sight affections	94,90	94,90	94,76	98,44	91,72	92,68	**4**
		Monotony of work	93,38	92,74	92,36	84,99	95,59	82,25	**7**
		Intensiveness of work	91,50	90,83	96,51	88,30	81,08	85,56	**8**
		Psychophysical affections	96,99	82,19	93,79	84,89	95,60	79,36	**9**

coordinates configuration. From calculated average inertia values the importance level of relation between the computer software quality assessment and the economic and social working conditions were determined.

2 Economic Conditions of the Computer Software Quality Assessment

Economic conditions of the computer software quality assessment were classified into the three groups: variables that determine: organizational and technical situation, self assessment of the employee's situation in the company and evaluation of the employment security.

The first place, where inertia value is 100%, is taken by the relation between the computer software quality assessment and the importance of computerization for the company (group of the organizational and economic factors) and the evaluation of the job loss risk (employment security). The employees who evaluate the software quality very well are convinced that computerization has a great importance for their company. Computerization in its general meaning stands for development and upgrading of the information system. It contributes to the raise of the company's competitiveness. The company that does not want or is not able to adapt to the market and the conditions related with the economy transformation stops to develop, and in time it loses its ability to satisfy the needs of the environment and its employees, and the same it must be unsuccessful in its operation[3]. That is why the management should take actions to enable satisfying of the needs connected with personal development of the employees. Then, the employees who reach their own development goals would positively associate them with the company's development and computerization.

In the circumstances of the job loss risk due to computerization the employees assess the software quality as bad, while if they are not afraid of losing their jobs their assessment of the software quality would increase. Such correlation may be due to current situation in the labour market. Absence of the job loss risk is for the Polish employees one of the two, next to the pay, most important factors in their careers[4].

Subsequent second, third, fifth and sixth place belong to conditions for the computer software quality assessment that are included in the group of the self assessment of the employee's situation in the company.

In the second place it is relation between the software quality assessment and the satisfaction of pay. Average inertia in this place is 97.6%. Third place with average inertia 95.3% is taken by the relation between the computer software quality assessment and the evaluation of the respondents' cooperation with computer staff, which is expressed by the relationship between the superiors and the subordinates, who are the respondents, i.e. subordinates and other employees. Attitude of superiors to all employees should be based on the rule of equality according to the principle of social justice. Average inertia value 92.8% assigned fifth place for the relation between the computer software quality assessment and the quality of computer training. Rise of qualifications by employees training is helpful in breaking the fear of and reluctance for adaptation to new working conditions and the fear of being moved

[3] R. Borowiecki, M. Romanowska, Strategic Information Systems, Centrum Doradztwa i Informacji Delfin sp. z o.o., Warsaw 2001, p. 73.

[4] The same, p. 257.

to another job. Rising of qualifications would affect the employee's sense of his or her own value.

Sixth place with average inertia 91.5% constitutes the relation between the computer software quality assessment and the evaluation of the satisfaction of work. It may be concluded from the made analysis that this relation is directly proportional. Seventh place with inertia value 90.2% was reached by the relations between the computer software quality assessment and evaluation of the company's economic profits (variable classified to this group under the title Evaluation of the Organizational and Technical Situation). The same group includes the relation between the computer software quality assessment and the organization of work that took tenth position with the average inertia value of 85.8%. The made analysis indicates that very good quality of the software is identified with improved efficiency of work, and good and rather good quality with fastness and correctness of retrieved data. Average inertia value of 79.8% gave the last eleventh position to the relation between the computer software quality assessment and the respondents' attitude toward computerization (the group of self assessment of the employee's situation in the company) that is traditionally regarded in the literature as a collection of bad assessment of the software quality and the reason of resistance to the changes in the company.

3 Social Conditions of the Computer Software Quality Assessment

Social conditions of the computer software quality assessment were classified to single group – employee's health hazards. This group contains the four variables: sight affections, monotony of work, intensiveness of work and psychophysical affections.

The highest value among the social factors – fourth place in general hierarchy of the average inertia value – 94.6% - was taken by the relation between the computer software quality assessment and the evaluation of sight affections. Eye fatigue is an essential factor that affects human well-being and psychophysical condition. As it is indicated by the analysis, affections connected with the perception of information by the sight organ affects the computer software quality assessment. The seventh place with the average inertia value of 90.2% was taken by the relation between the computer software quality assessment and the evaluated monotony of work. The seventh place in the classification went to the variable titled Monotony of Work. Average inertia value of 89.0% assigned the eighth place to the relation between the computer software quality assessment and the intensiveness of work that is number of tasks performed by the software user. The analysis indicates that the computer software quality is well assessed by the users whose tasks number is adequate and does not exceed their capacities. Average inertia of 88.8% assigned the ninth place to the relation between the computer software quality assessment and the evaluation of the psychophysical affections that are hazardous for the employee's health. The made analysis indicates that the persons who are anxious and nervous as well as exhausted and weakened have worse assessment of the software quality than the persons with such affections like: painfulness of joints, stiffness and painfulness of wrists.

4 Summary

The developed model demonstrates that the analysis of users may not be based only on their experience and skills, but it must extend over details concerning their economic and social working conditions. The research confirmed that the relation between the computer software quality assessment and the economic and social working conditions existed in the concerned companies. The research allowed developing of the model of correlation between the computer software quality assessment and the economic and social working conditions. This model represents both cognitive and practical value as it allows the companies that implement information systems to recognize possible risks connected with the absence of acceptance for the software by the users.

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Agile Methods and Visual Specification in Software Development: A Chance to Ensure Universal Access

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Abstract. Within the eEurope2010 initiative "An Information Society for All", development methods which enable the inclusion of the end-user become essential in order to ensure the paradigm of Universal Access. It is important to understand the end-users, their behavior, their knowledge of technology and their abilities and the context in which the applications will be used. In this paper, we combine our experiences in both Agile Methods and Usability Engineering and show that the resulting agile usability methods – however these maybe designated – are ideally suited to design and develop applications which follow the idea of Universal Access and where the end-user is having great influence on systems design.

Keywords: Human-Computer Interaction, Usability Engineering, Extreme Programming, Agile Methods, Universal Access.

1 Introduction

To achieve maximum benefits by making both useful and usable applications, it is strongly recommended to apply an usability engineering (UE) approach [1]. Some key principles of UE methods include understanding the users and analyzing their tasks, setting measurable goals and involving the end-users from the very beginning.

Based on experiences in the recent MoCoMed project and on previous work [2, 3, 4, 5], we consistently assess the role of UE in the realization of both usable and useful applications, especially in the difficult environment of an outpatient clinic.

Facing melting budgets and shorter time to markets, engineering processes in general have to come up with design approaches that can still guarantee quality in terms of functionality, reliability, user performance and user experience etc. Ensuring user interface (UI) usability with ordinary methods is then a demanding, if not an impossible undertaking. This leads to challenges for project managers but moreover to an eminent change in software engineering (SE).

With this article we want to emphasize that simple, cheap and easy-to-use development models can be a step closer to the information society for all, where people are assisted by Information Technology [6].

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2 Agile Approaches to Software Development

The challenges and conflicts with development times and changing requirements are partly addressed by agile approaches to SE. Pressure of time is accommodated with less documentation, pair programming or coding from the very beginning etc., while uncertain requirements are addressed by incremental and iterative development.

However, agile software lifecycles, e.g. most popular eXtreme Programming (XP) [7] and Agile Modelling (AM) [8], lack end-user involvement and do not explicitly take care of User Interface Design (UID) issues [9]. Reasons for this exclusion are the belief that good UI quality is an effortless by-product of stakeholder feedback and the bad reputation of UE as a heavy-weight, time-consuming and expensive activity. Nevertheless, many professionals know by experience that typical agile properties, such as incremental design or refactoring, contradict UID due to problems with learnability, UI consistency etc. [9, 10]. When UE becomes part of agile SE, this helps to reduce the risk of running into wrong design decisions by asking real end-users about their needs and activities. Ultimately and contrary to its reputation, UE can decrease project costs and help to increase the acceptance of software products.

Consequently, interdisciplinary scientists came up with ideas about integrating (agile) SE and UE [3, 9, 10]. They all agree that the design of usable software demands (agile) UE methods embedded throughout the lifecycle, e.g. in terms of prototyping and evaluation. Likewise, all approaches share a limiting shortcoming of usual UE practice: none starts visual design and coding before the Requirements Engineering (RE) phase is finished. However, agile methods cannot afford waiting longer to start coding (AM: Software Is Your Primary Goal). Approaches which employ role and task models [10] during RE, can make typical UID less trial-and-error driven and more task-oriented. But models still need to be transferred into code and their abstract representation fails to show UID vision and UI behaviour, which is essential for good usability. It therefore needs to be defined and assessed, together with stakeholders, as soon as possible (UE: Participatory Design).

Also, typical set phrases of usability goals, e.g. “easy to learn” or “easy to use”, do not state anything about UI behaviour. In UE, the assessment of user performance and user experience goals, as well as the analysis of impacts of UID on the system architecture, is usually postponed to later stages of the lifecycle. When initial designs do not match expectations of stakeholders and require iteration and enhancement, these iterations slow down the progress of the overall development, which contradicts time-critical agile processes.

3 How to Build Better Software with Agile Usability Methods

Our development method is, on the one hand, based on research about prototyping [11, 12] as a bridging technique for UE and SE. On the other hand, we tie up with our previous findings about the extension of XP by principles and practice of AM and UE [9]. We also integrate our experience within the MoCoMed project (see Chapter 5).

For merging UE with XP (see Figure 1), we encourage an earlier externalization of design vision in order to make the development of usable software more effective: Interactive prototypes of specific fidelity, enable a better understanding of end-users

(AM: Active Stakeholder Participation) and their tasks, lead to a better collaboration (AM: Model With Others) and make it possible to produce better software faster. All stakeholders should be able to collaboratively discuss the look and feel of the UI from the very beginning (AM: Model To Communicate, Model To Understand) and cross-check the outcome with their requirements (AM: Prove It With Code). In order to make this course of action effective and efficient, all stakeholders need to be able to visually express and share their ideas and talk the same language [11, 13, 14, 15].

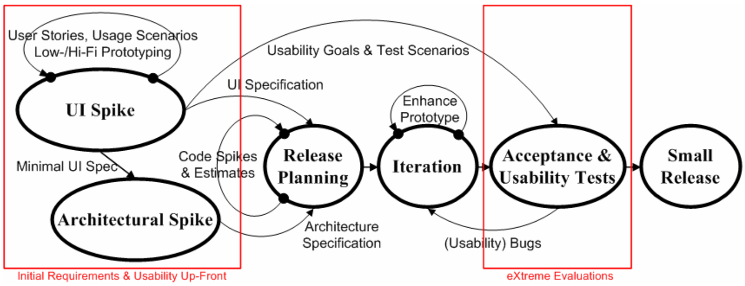

Fig. 1. The XP lifecycle extended by UE methods during up-front and test phase

Interaction and functional issues can be addressed sooner and the usability requirements realized during early stages of design by using expressive prototypes [5]. Prototypes act as discussion pieces and all stakeholders are invited to change them. Although this is very much in alignment with UE's practice of Participatory Design (PD), on the contrary we do not build throw away prototypes just in order to discover the requirements and document them. We employ the prototypes themselves as living requirements repositories. In usual UE practice, style guides are developed in order to have a reference document for designers, to share knowledge, to ensure consistency with UID standards and to save experience for future projects. A running simulation can also imply and express much of this knowledge and is less ambiguous. When expressive prototypes transport design reference along the development process, they can decrease the necessity for using abstract and extensive documents. Writing a style guide for a complex product can take up to hundreds of hours of effort. Instead of produce documents that require permanent updating (XP: Software Is Your Primary Goal), one should rather change the prototype (AM: Model With Purpose), and enhance it to a visual specification that guides development.

As illustrated in figure 1, XP's up-front is extended by adding UI prototyping. This increases time and effort, but also adds important value to the engineering process. As many UI elements as possible are gathered up-front in order to agree upon a minimalist UI specification [10] to be forwarded to system developers. It decreases the probability of later changes of core parts of the UI, which could harm UI consistency and have a delicate impact on the system architecture [9, 10]. It reduces leaping between (re-)design and evaluation. Later on, back-end system development can take place in parallel (AM: Create Several Models In Parallel) to the further enhancement of the UID prototype towards a visual specification.

4 Participatory Prototyping for Visual Specification

Prototypes for visual specification are required to have characteristics of both experimental and exploratory prototypes (see Table 1), as e.g. incorporated by functional prototypes (see Table 2). We neither build throw away prototypes, nor do we need pilot systems as the outcome of the requirements up-front.

Table 1. Approaches of prototyping, based on [2, 4, 13, 16]

Goal	Description
Evolutionary prototyping	Continually adapt a system to a rapidly changing environment; ongoing effort to improve an application
Experimental prototyping	Used to test hypotheses; try out solutions to meet requirements; communicate on technical and usability issues; gather experience
Exploratory prototyping	Used when problem at hand is unclear; express how something should work and look; design exploration understand requirements; elicit ideas and promote cooperation

Table 2. Classification of UI prototypes, based on [4, 13]

Type	Description
Presentation prototype	Supports the initiation of a project; present important aspects of the UI; illustrate how an application solves given requirements
Functional prototype	Temporary, executable system; implements specific, strategically important aspects of the UI and functionality; share experiences, opinions and arguments; discuss design rationale and trade-offs
Breadboard	Investigate technical aspects such as system architecture or functionality; study alternate designs to foster creativity
Pilot system	Very mature prototypes which can be practically applied

The low fidelity versus high fidelity debate (see Table 3) has a long history. For early stage prototyping during RE, the degree to which the prototype accurately represents the UID and – even more important – the interaction behavior, is the determining factor guiding the development process.

Abstract or low fidelity prototypes are generally limited in function but only need limited prototyping effort. They usually do not require programming skills and coding. They are constructed to facilitate discussion of UI concepts and design alternatives, rather than to model the user interaction with a system.

Therefore, low fidelity prototypes mainly demonstrate the look and rarely demonstrate the feel of an UI. They will show design direction but will not provide details about how navigation is going to work or what interaction behaviour is like [15].

Table 3. Main (dis-)advantages of low- and high-fidelity prototyping, based on [15]

Type	Advantages	Disadvantages
Low-Fidelity	less time & lower cost evaluate multiple UID concepts address screen layout issues proof-of-concept	poor detailed specification to code navigational and flow limitations facilitator-driven limited error checking
High-Fidelity	complete functionality fully interactive defines navigational scheme look & feel of final product serves as a “living” specification	time-consuming to create more expensive to develop blinds users to major representational flaws management may think it is real

Among widely known low-fidelity prototyping methods (see Table 4), paper prototyping is one of the cheapest and fastest visual techniques one can employ in a design process. It is also popular as a method for rapid prototyping [16].

Table 4. Overview on popular low-fidelity prototyping methods

Method	Description
Content inventories	Simple lists inventorying the information of controls to be collected within a given interaction context
Sticky notes	Visual content inventories, incorporate position and spatial relationship among UI contents
Wire-frames	Schematics outline the areas occupied by interface contents
Paper prototypes, paper mockups	Rough sketches of the UID; for usability studies or quick reviews; rated as fastest method of rapid prototyping
Storyboarding	Sequence of paper prototypes, e.g. arranged with users

Realistic prototypes help resolve detailed design decisions in layout, visual presentation, and component selection, as well as finding points in interaction design and interface behaviour [17]. If a developer has to present his design visions to less experienced users, executives, or a more technical audience, “a more robust and aesthetically invested prototype might be appropriate” [2].

High fidelity prototypes range from detailed drawings to fully interactive simulations (see Table 5), which show real system behaviour rather than just presenting static screens. They address issues such as navigation and work flow, as well as the matching of design with user models [15].

High fidelity prototypes should not be used for exploring design alternatives. More simple designs (AM: Use The Simplest Tools, Depict Models Simply) can externalize initial design problems better and cheaper. They provide the starting point for discussion and requirements engineering. But after they helped to narrow the design space to the most promising solution(s), they are then too sketchy and vague to give guidance for developers (AM: Iterate To Another Artifact).

Table 5. Overview on high-fidelity prototyping methods, partly based on [13]

Method	**Description**
Graphical Mockups	Images of a the UI, e.g. created with Adobe Photoshop, Microsoft Powerpoint, HyperCards
HTML prototypes	(Partly-)Functional simulations implemented in HTML. Popular tool: Adobe Dreamweaver
Interface builders	Complete development environment for graphical design

Especially when elderly end-users are involved from the very beginning, high-fidelity prototyping (see Chapter 5) adds important value to the design process. Because they are fully functional, they can provide a better basis for thorough evaluation with end-users. Although the application of low fidelity and high fidelity prototyping is comparatively effective at detecting usability issues [12, 18, 19], users are likely to prefer working with more detailed prototypes. They get a better feeling for how the product will behave and can therefore make more valuable recommendations about functionality and usability (AM: Apply The Right Artifacts).

As we want to utilize prototypes collaboratively, together with various kinds of stakeholders, the necessity of coding should be avoided, for which GUI-based UI builders are required (see Table 5). With mockups, simulation of UI behaviour (reaching from simple *mouse over* effects to animations or *zoom operations*), is impossible, for this more sophisticated tools need to be used (see Table 6).

Table 6. High-fidelity prototyping tools for visual specification

Tool	**Description**
Adobe Flash	Flash can be used for abstract sequences of static screens or fore full functional applications with complex interaction behavior. By adding Action Script code, any prototype can be enhanced to a full system.
iRise Studio	iRise Studio allows the creation of screens and their stringing together to storyboards. Besides standard UI components, the designer can use templates and master components to build the UI.

With appropriate tools, changes can be done quickly and stakeholders can see the impact of their suggestions immediately (AM: Rapid Feedback). If there is no lag between decision and testing, stakeholders become fully integrated and contributing members of the design task force (AM: Model With Others).

5 Sample Application

We were able to gain experience with our development model during research for the automotive industry and in several projects at Graz University Hospital. One of these projects was the MoCoMed-Graz project, first described in [20]. As a part project of the Melanoma Pre-care/Prevention Documentation, which is an important step toward fighting skin cancer, the project MoCoMed-Graz dealt with the design, development and implementation of a fully functional mobile solution to assist patient data surveys. The problem was that the paper based questionnaires had several disadvantages; including the necessity of retyping them manually into the database, most of all, they were awkward to fill out by elderly and partially sighted patients, or for example by patients with tremors. The idea of using mobile computers was to ensure that the data acquisition within the clinical department runs smoothly and also that the cancer researcher is allowed to collect data away from the clinic, for example during a survey study in an outdoor swimming pool.

The workflow: The patient reports to the central administration desk of the outpatient clinic of the dermatology department. There, they are registered via the MEdical DOCumentation System (MEDOCS) administration program into the pigmented lesion outpatient clinic. At the clinical workplace, an overview of the waiting patients, who have been already registered in the system, but not yet released by a medical doctor, can be seen. In the corresponding column on the clinical workplace, there is an indication of whether or not they have already filled out a questionnaire. Now the medical doctor or the nursing staff of the clinic can decide whether this patient is to fill out a questionnaire and/or which questionnaire to provide to the patient. After the decision to ask the patient to fill out a questionnaire, an empty questionnaire is created in MEDOCS, by pushing a button. The questionnaire in MEDOCS is registered with a definite user and a unique identification code, so that it is clearly evident that it corresponds to a version from the patient and not the medical doctor. At the terminal, the patient is equipped with a touch based Tablet PC and a code, with which he/she can login to MoCoMed and complete the questionnaire following the instructions from the touch based application. After the questions have been answered and the questionnaire is completed, MoCoMed transfers the data into MEDOCS. Further technical background of MoCoMed can be found in [20]. Further issues on touch based interface desing can be found in [21].

6 Requirements Engineering: Flexibility Is Essential

The first step was to determine both requirements and clinical context. It is necessary to differentiate between the primary end-users, the secondary end-users and the stakeholders. However, the stakeholders influence, or are influenced by, the system but are not the actual users. A precise specification of end-users is necessary (unlike to XP), which includes the typical end-user characteristics, e.g. age range, computer literacy or physical limitations (disabilities). Within clinical development it is necessary to adapt the usability of the system to the abilities of the anticipated patients, in order to enable universal access. One objective included to capture as much as possible information about the workplace and physical conditions. Actually, the work atmosphere within an outpatient clinic is difficult, hectic and chaotic. For example, the noise level made several ideas of providing audio feedback inappropriate. Also, both low and high levels of lighting have an impact on end-users (office versus outdoor swimming pool, where sunlight is always a problem and causes glare on the screen). However, we also considered room and furniture because the characteristics of the place of installation must be studied in order to operate the system safely and comfortably. It is also important to consider user posture; in our case it is possible to use the mobile device within a total mobile setting or on an adjustable wheel table (e.g. sitting versus standing and looking down at a display). The social and organizational context is most often neglected, however this is essential for the success and is also a crucial factor to enable universal access.

6.1 Level 1: Lo-Fi Prototyping

Following our previous experience [22], we employed paper prototypes for exploring the design space. With standard office supplies, each interface element (see figure 3) has been sketched. This led to an easy creation of design alternatives, since it encouraged more suggestions due to the ease of alteration.

The intensive study of end-users by the application of paper mockups resulted in a great advantage and clear benefit. Some advantages were that the first sketches allowed immediate usability feedback (AM: Rapid Feedback). At the beginning of our project, we were able to concentrate on abstract interface concepts rather than on technological details (AM: Create Simple Content).

Fig. 2. One of our elderly patients is operating the paper mock-up

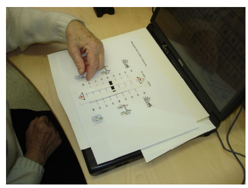

Fig. 1. Various input possibilities have been tested on paper

During the interaction, we were confronted by many problems, particularly with the navigational model and the sequence of the screens. However, as expected, it was relatively difficult to simulate real interface behavior, for example, how the interface components react upon touch or how the system converts screen states.

6.2 Level 2: Hi-Fi Prototyping

The hi-fi prototyping had the advantage that end-users both participated and were studied in a realistic setting (users could work with it directly). We found out why end-users preferred certain styles of interaction and could specify our design rationale accordingly. With more sophisticated UI representations, we were able to assess problems with screen content, i.e. form structure or their understanding of the questions. This procedure helped to trace the source of and anticipate many problems in the early stage of RE and before the programming started. Consequently, we avoided later misconceptions as well as more iterations in systems design.

Concerning the design and the content of the questionnaire, we found that there were iterative improvements possible until the final experiments, including words, phrases and familiar - in the sense of intuition - concepts. However, we followed an aesthetic and minimalist design: none of the dialogues contained irrelevant information (AM: Create Simple Content).

7 Lessons Learned: Designing for Universal Access

By using prototypes for the visual specification of interactive systems, we entered a very interesting field of research. High-fidelity prototyping can be a partial substitute for any textual UI specification. When the described UI properties are available both visually and by code, such a prototype becomes a living design guideline and programming basis. “Whenever the programmer needs UID guidance, the prototype is fired up and the function in question is executed to determine its design” [15]. This allows an efficient and agile reuse of such prototypes [23] for further development (AM: Model With Purpose, Software Is Your Primary Goal).

Our future work will concentrate on the question to which extent functional and non-functional requirements and design knowledge can be transported in executable simulations. We will try to find out whether additional properties are required to completely replace textual documents with prototypes.

During MoCoMed, we also realized that testing methods such as Thinking Aloud were experienced as strenuous and, apart from its application with more typical end-users, took more time and preparation. Consequently, our further research will also focus on “eXtreme evaluation” [24] methods (see Figure 1) for agile development.

Altogether, we encourage developers to use a cost-efficient design of usable software systems for Universal Access based on XP, AM plus UE, in order to enable access for people who are non expert end-users.

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Biometric Person Authentication for Access Control Scenario Based on Face Recognition

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Abstract. There are tremendous need increase for personal verification and identification in internet security, electronic commerce and access control in recent years. Also, as the demands for security in many applications such as data protection and financial transaction become an increasingly relevant issues, the importance of biometric technology is rapidly increasing. In this paper, we explored face recognition system for person authentication. We explicitly state the design decisions by introducing a generic modular PCA face recognition system. We designed implementations of each module, and evaluate the performance variations based on virtual galleries and probe sets. We perform experiments and report results using equal error rates (EER) based on verification scenario for access control applications.

1 Introduction

As the demands for security in many applications become an increasingly relevant issues, the importance of biometric authentication is rapidly increasing. In addition to research based on improving the performance of personal authentication and evaluation technologies, standardizations are emerging to provide a common interface and to permit an effective comparison and evaluation of different biometric technologies. We explored core technologies for uni-modal biometric based on face recognition system and provide performance evaluation technology for higher reliability of core biometric algorithms.

In this paper, we present a modular projection-based face recognition system [6] for access control applications. Our face recognition system consists of normalization, PCA [5] projection, and recognition modules [1,10]. Based on the modular design for projection-based algorithms, we evaluate different implementations [8,9]. Because we use a generic model, we can change the implementation in an orderly manner and assess the impact on performance of each modification [4]. We report verification performance score for each category of probes using equal error rate (EER) which is critical factor for access control applications.

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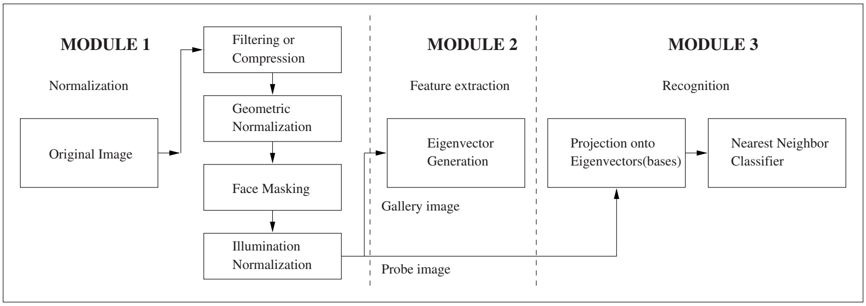


Fig. 1. Block Diagram of Projection-based Face Recognition System

In biometric person authentication, two critical questions are often ignored [7]. First, how does performance vary with different galleries and probe sets. Second, when is a difference in performance between two algorithms statistically significant. We systematically designed the modular based face recognition system and explored this question by analyzing randomly generated 100 galleries of the same size. We then calculate performance on each of the galleries against **fb** and duplicate probes. Because we have 100 scores for each probe category, we can examine the range of scores, and the overlap in scores among different implementations of the PCA-based face recognition system.

1.1 System Modules

Our face recognition system consists of three modules and each module is composed of a sequence of steps (see Figure 1).

The first module normalizes the input image. The goal of normalization is to transform facial images into a standard format that removes variations that can affect recognition performance. This module consists of four steps. The first step filters or compresses the original image. The image is filtered to remove high frequency noise in the image. An image is compressed to save storage space and reduce transmission time. The second step places the face in a standard geometric position by rotating, scaling, and translating the center of eyes to standard locations. The goal of this step is to remove variations in size, orientation, and location of the face. The third step masks out background pixels, hair, and clothes to remove unnecessary variations which can interfere verification process. The fourth module removes some of the variations in illumination between images. Changes in illumination are critical factors in algorithm performance.

The second module performs the PCA decomposition on the training set. This produces the eigenvectors (eigenfaces) and eigenvalues. We use the training set which was used for FERET program for the generation of eigenvectors.

The third module identifies the face from a normalized image, and consists of two steps. The first step projects the image onto the eigen representation. The

Table 1. Size of galleries and probe sets for different probe categories

Probe category	duplicate I	duplicate II	**FB**	**fc**
Gallery size	1196	864	1196	1196
Probe set size	722	234	1195	194

critical parameter in this step is the subset of eigenvectors that represent the face. The second step recognizes faces using a nearest neighbor classifier. The critical design decision in this step is the similarity measure in the classifier. We presented performance results using L1 distance, L2 distance, angle between feature vectors, Mahalanobis distance. Additionally, Mahalanobis distance was incorporated with L1, L2, and angle between feature vectors mentioned above.

2 Test Design

2.1 Database

The FERET database provides a common database of facial images for both development and testing of face recognition algorithms and has become the de facto standard for face recognition of still images. There were variations in scale, pose, expression, and illumination of the face. The size of the galleries and probe sets for the four probe categories are presented in Table 1.

2.2 Verification Model

In our verification model, a person in image p claims to be the person in image g. The system either accepts or rejects the claim. (If p and g are images of the same person then we write $p \sim g$, otherwise, $p \not\sim g$.) Performance of the system is characterized by two performance statistics. The first is the probability of accepting a correct identity; formally, the probability of the algorithm reporting $p \sim g$ when $p \sim g$ is correct. This is referred to as the verification probability, denoted by P_V (also referred to as the hit rate in the signal detection literature). The second is the probability of incorrectly verifying a claim formally, the probability of the algorithm reporting $p \sim g$ when $p \not\sim g$. This is called the false-alarm rate and is denoted by P_F.

Verifying the identity of a single person is equivalent to a detection problem where the gallery $G = \{g\}$. The detection problem consists of finding the probes in $p \in P$ such that $p \sim g$.

For a given gallery image g_i and probe p_k, the decision of whether an identity was confirmed or denied was generated from $s_i(k)$. The decisions were made by a *Neyman-Pearson* observer. A Neyman-Pearson observer confirms a claim if $s_i(k) \leq c$ and rejects it if $s_i(k) > c$. By the Neyman-Pearson theorem [3], this decision rule maximized the verification rate for a given false alarm rate α. Changing c generated a new P_V and P_F. By varying c from it's minimum to maximum value, we obtained all combinations of P_V and P_F. A plot of all combinations of P_V and P_F is a receiver operating characteristic (ROC) (also known as the relative operating characteristic) [2,3]. The input to the scoring algorithm was $s_i(k)$; thresholding similarity scores, and computing P_V, P_F, and the ROCs was performed by the scoring algorithm.

The above method computed a ROC for an individual. However, we need performance over a population of people. To calculate a ROC over a population, we performed a round robin evaluation procedure for a gallery G. The gallery contained one image per person.

The first step generated a set of partitions of the probe set. For a given $g_i \in G$, the probe set P is divided into two disjoint sets D_i and F_i. The set D_i consisted of all probes p such that $p \sim g_i$ and F_i consisted of all probes such that $p \not\sim g_i$.

The second step computed the verification and false alarm rates for each gallery image g_i for a given cut-off value c, denoted by $P_V^{c,i}$ and $P_F^{c,i}$, respectively. The verification rate was computed by

$$P_V^{c,i} = \begin{cases} 0 & \text{if } |D_i| = 0 \\ \frac{|s_i(k) \leq c \text{ given } p_k \in D_i|}{|D_i|} & \text{otherwise,} \end{cases}$$

where $|s_i(k) \leq c \text{ given } p \in D_i|$ was the number of probes in D_i such that $s_i(k) \leq c$. The false alarm rate is computed by

$$P_F^{c,i} = \begin{cases} 0 & \text{if } |F_i| = 0 \\ \frac{|s_i(k) \leq c \text{ given } p_k \in F_i|}{|F_i|} & \text{otherwise.} \end{cases}$$

The third step computed the overall verification and false alarm rates, which was a weighted average of $P_V^{c,i}$ and $P_F^{c,i}$. The overall verification and false-alarm rates are denoted by P_V^c and P_F^c, and was computed by

$$P_V^c = \frac{1}{|G|} \sum_{i=1}^{|G|} \frac{|D_i|}{\frac{1}{|G|}\sum_i |D_i|} P_V^{c,i} = \frac{1}{\sum_i |D_i|} \sum_{i=1}^{|G|} |s_i(k) \leq c \text{ given } p_k \in D_i| \cdot P_V^{c,i}$$

and

$$P_F^c = \frac{1}{|G|} \sum_{i=1}^{|G|} \frac{|F_i|}{\frac{1}{|G|}\sum_i |F_i|} P_F^{c,i} = \frac{1}{\sum_i |F_i|} \sum_{i=1}^{|G|} |s_i(k) \leq c \text{ given } p_k \in F_i| \cdot P_F^{c,i}.$$

The verification ROC was computed by varying c from $-\infty$ to $+\infty$.

In reporting verification scores, we state the size of the gallery G which was the number of images in the gallery set G and the number of images in the probe set P. All galleries contained one image per person, and probe sets could contain more than one image per person. Probe sets did not necessarily contain an image of everyone in the associated gallery. For each probe p, there existed a gallery image g such that $p \sim g$.

For a given algorithm, the choice of a suitable hit and false alarm rate pair depends on a particular application. However, for performance evaluation and comparison among algorithms, the *equal error rate* (EER) is often quoted. The equal error rate occurs at the threshold c where the incorrect rejection and false alarm rates are equal; that is $1 - P_V^c = P_F^c$ (incorrect rejection rate is one minus the verification rate.) In verification scenario, the lower EER value means better performance result.

3 Experiment

The training set for the PCA consists of 501 images (one image per person), which produces 500 eigenvectors. The training set is not varied in this experiments. In the recognition module, faces are represented by their projection onto the first 200 eigenvectors.

For the baseline algorithm, the non-masked facial pixels were transformed so that the mean was equal to 0.0 and standard deviation was equal to 1.0 followed by a histogram equalization algorithm.

First variation,the non-masked pixels were not normalized (original image). Second variation, the non-masked facial pixels were normalized with a histogram equalization algorithm. Third variation, the non-masked facial pixels were transformed so that the mean was equal to 0.0 and variance equal to 1.0. The original images were compressed and then uncompress prior to being feed into the geometric normalization step of the normalization module. For both compression methods, the images were compressed approximately 16:1 (0.5 bits per pixel).

In the normalization module, we varied the illumination normalization and compression steps. The results show that performing an illumination normalization step improves verification performance but which implementation that is selected is not critical. Based on our experiments, compression or filtering the images does not significantly effect performance.

In the recognition module, we experimented with three classes of variations. First, we varied the number of low order eigenvectors in the representation from 50 to 500 by steps of 50. Based on our experiments, the recognition performance increases until approximately 150–200 eigenvectors in the representation and then performance decreases slightly. Representing faces by the first 30–40% of the eigenvectors is consistent with results on other facial image sets that the authors have seen.

Second, the similarity measure in the nearest neighbor classifier was changed. This variation showed the largest range of verification performance. The range of performance variation shows that selecting the similarity measure for the classifier is the critical decision in designing a PCA-based face recognition system.

3.1 Variations in the Normalization Module

Our experiment includes three variations to the illumination normalization step. For the baseline algorithm, the non-masked facial pixels were transformed so that the mean was equal to 0.0 and standard deviation was equal to 1.0 followed by a histogram equalization algorithm. First variation,the non-masked pixels were not normalized (original image). Second variation, the non-masked facial pixels were normalized with a histogram equalization algorithm. Third variation, the non-masked facial pixels were transformed so that the mean was equal to 0.0 and variance equal to 1.0.

3.2 Variations in the Recognition Module

Nearest Neighbor Classifier. Our experiment includes seven similarity measures for the classifier [6] and its verification performance results are listed in Tables 2. The performance score for **fc** probes shows most variation among different category of probes. In Figure 2, we reported detailed verification performance results for **fc** probes.

Table 2. Verification performance scores based on different nearest neighbor classifier. Performance scores are equal error rate (EER).

	Probe category			
Nearest neighbor classifier	duplicate I	duplicate II	**FB** probe	**fc** probe
Baseline (L_1)	0.24	0.30	0.07	0.13
Euclidean (L_2)	0.21	0.26	0.05	0.22
Angle	0.19	0.22	0.05	0.22
Mahalanobis	0.11	0.12	0.04	0.11
L_1 + Mahalanobis	0.34	0.39	0.12	0.13
L_2 + Mahalanobis	0.25	0.30	0.07	0.12
Angle + Mahalanobis	0.11	0.12	0.03	0.10

3.3 Variations in Galleries and Probe Set

The comparison among algorithms are based on algorithm performance on four probe sets. The performance among the different probe sets cannot be directly compared since the number of probes in each category of probes are different. The natural question is, when is the difference in performance between two classifiers significant?

To address this question, we randomly generated 100 galleries of 200 individuals, with one frontal image per person. The galleries were generated without replacement from the **FB** gallery of 1196 individuals. Then we scored each of the galleries against the **FB** and duplicate I probes for each of the seven classifiers. (There were not enough **fc** and duplicate II probes to compute performances for these categories.) For each randomly generated gallery, the corresponding **FB** probe set consisted of the second frontal image for all images in that gallery; the duplicate I probe set consisted of all duplicate images in the database for each image in the gallery.

For an initial look at the range in performance, we examine the baseline algorithm (L_1 similarity measure). There are similar variations for the six remaining distances. For each classifier and probe category, we had 100 different scores.

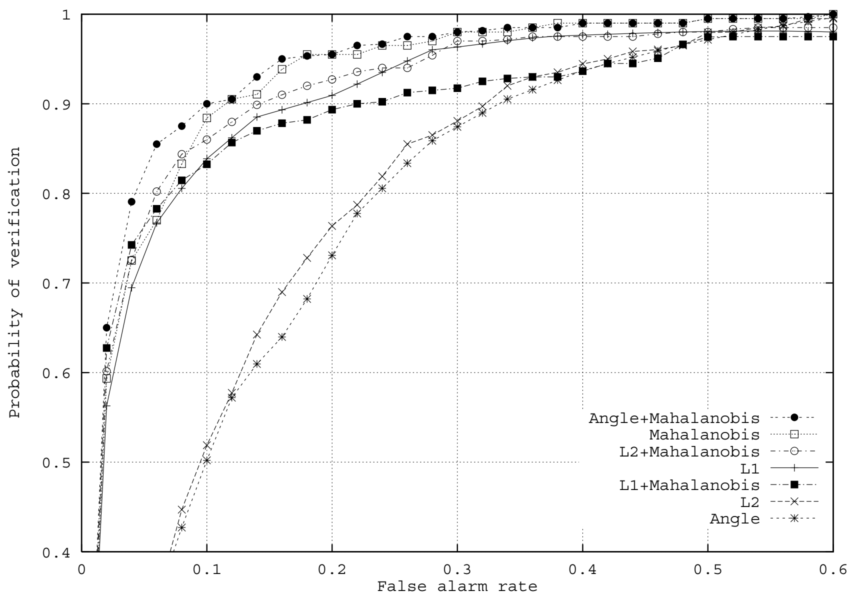


Fig. 2. Effects of nearest neighbor classifier on performances for **fc** probes

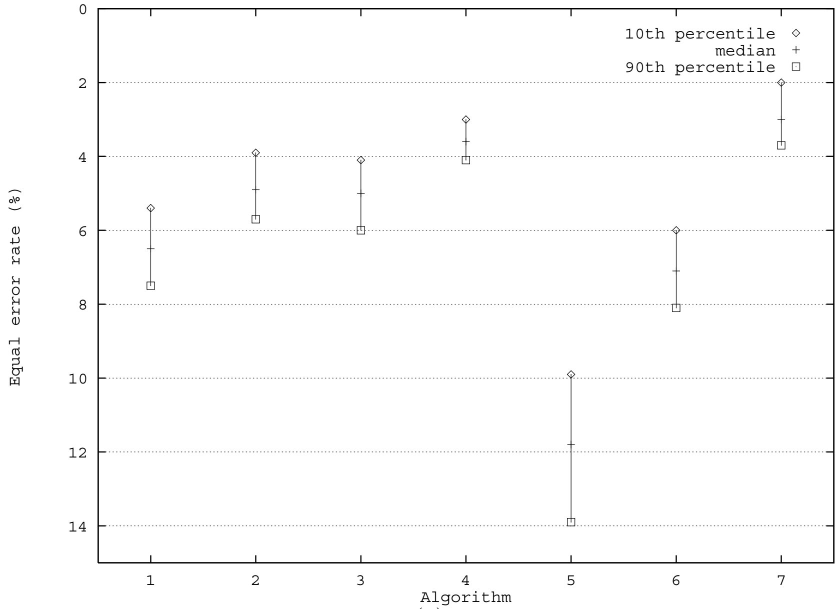
Performance ranges from 18.8 to 33.2 for equal error rate. This clearly shows a large range in performance of the 100 galleries.

In Figure 3, we reported a truncated range of equal error rates (%) for the seven different nearest neighbor classifiers for both **FB** and duplicate I probe sets. For each classifier, score is marked with; the median by $\times$, the 10th percentile by $+$, and 90th percentile by $*$. We plotted these values because they are robust statistics. We selected the 10th and 90th percentile because they mark a robust range of scores and outliers are ignored. From these results, we get a robust estimate of the overall performance of each classifier.

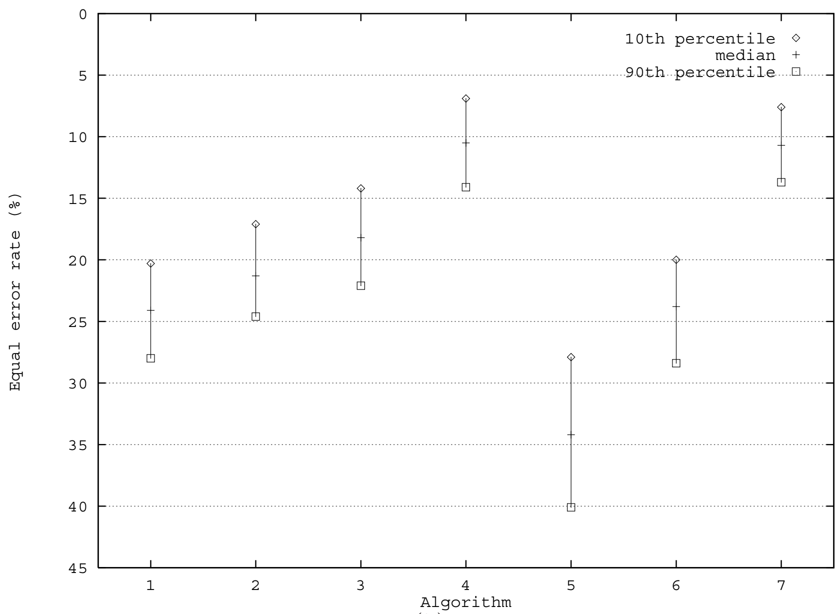
3.4 Discussion

The main goal of our experiment was to get a rough estimate of when the difference in performance is significant. From Figures 3, the range in verification score is approximately ± 0.06 about the median. This suggests a reasonable threshold for measuring significant difference in performance for the classifiers is ~ 0.12.

The top performing nearest neighbor classifiers were the Mahalanobis and angle+Mahalanobis. These two classifiers produces better performance than the other methods as shown in Figure 3. In this experiments, the L_1+Mahalanobis received the lowest verification performance scores. This suggest that for duplicate I scores that the angle+Mahalanobis or Mahalanobis distance should be used. Based on the results of this experiment, performance of smaller galleries can predict relative performance on larger galleries.



(a)



(b)

Fig. 3. The range of equal error rates (%) using seven different nearest neighbor classifiers. Note that the value of y-axis is in reverse order. The nearest neighbor classifiers presented are: (1) L_1, (2) L_2, (3) Angle, (4) Mahalanobis, (5) L_1+Mahalanobis, (6) L_2+Mahalanobis, and (7) Angle+Mahalanobis. (a) **FB** probes and (b) duplicate I probes.

Table 3. Comparison of verification performance scores for Baseline, Proposed I ($\mu = 0.0$ and $\sigma = 1.0$, LPF, first low order eigenvector removed, angle+Mahalanobis distance), and Proposed II ($\mu = 0.0$ and $\sigma = 1.0$, Wavelet [0.5bpp], first low order eigenvector removed, L1+Mahalanobis distance) algorithm. Performance scores are equal error rate (EER).

	Probe category			
Algorithm	duplicate I	duplicate II	**FB** probe	**fc** probe
Baseline	0.24	0.30	0.07	0.13
Proposed I	0.11	0.21	0.07	0.15
Proposed II	0.20	0.22	0.07	0.10

4 Conclusion

We proposed a biometrics person authentification system based on face recognition and evaluation procedure. In our experiment, we performed a detailed analysis of biometrics person authentification scenario based on face recognition system. The main goal of our experiment is to point out the directions for optimal configuration of PCA-based face recognition system. We introduced a modular design for PCA-based face recognition systems and systematically vary the core algorithms and measure the impact of these variations on performance. From the results throughout the series of experiments, we present two models for PCA-based face recognition system. In proposed models, our design decision includes processing steps with better performance in each module.

The choice of steps used in Proposed I system includes: (1) illumination normalization ($\mu = 0.0$ and $\sigma = 1.0$), (2) Low-pass filtering (LPF), (3) remove first low order eigenvector, and (4) angle+Mahalanobis distance. The choice of steps used in Proposed II system includes: (1) illumination normalization ($\mu = 0.0$ and $\sigma = 1.0$), (2) wavelet compression [0.5 bpp], (3) remove first low order eigenvector, and (4) L_1+Mahalanobis distance. Proposed I system addresses the effects of LPF with angle+Mahalanobis distance while Proposed II system represents wavelet compression with L_1+Mahalanobis distance.

In Table 3, the verification performance for duplicate I probe is improved from 0.24 to 0.11 for Proposed I method, and duplicate II probe improved from 0.30 to 0.21 for Proposed I method (equal error rate). The verification performance score for **FB** probe shows same results for all three methods, and **fc** probe improved from 0.13 to 0.10 for Proposed II method (equal error rate).

Based on these results, the proposed algorithms show reasonably better performance for duplicate I, duplicate II (for Proposed I method) and **fc** probes (for Proposed II method) than the baseline algorithm in verification scenario. For **FB** probes, verification results show almost identical performance scores for each method used.

From the series of experiments with optimal configuration of PCA-based face recognition system, we have come to three major conclusions.

First, image preprocessing and normalization (applying LPF, JPEG or wavelet compression) module do not degrade performance. This is important because it indicates that compressing images to save transmission time and storage costs will not reduce algorithm performance.

Second, selection of the nearest neighbor classifier is the critical design decision in designing a PCA-based algorithm. The proper selection of nearest neighbor classifier is essential to improve performance scores. Furthermore, our experiments shows similarity measures that achieve the best performance are not generally considered in the literature.

Third, the performance scores vary among the probe categories, and that the design of an algorithm need to consider the type of images that the algorithm will process. The **FB** and duplicate I probes are least sensitive to system design decisions, while **fc** and duplicate II probes are the most sensitive.

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Biometric Driver Authentication Based on 3D Face Recognition for Telematics Applications

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Abstract. In this paper we developed driver authentication system based on face recognition. Since 2D based face recognition has been shown its structural limitation, 3D model based approach for face recognition has been spotlighted as a robust solution under variant conditions of pose and illumination. Since a generative 3D face model consists of a large number of vertices, a 3D model based face recognition system is generally inefficient in computation time. In this paper, we propose a novel 3D face representation algorithm to reduce the number of vertices and optimize its computation time. Finally, we evaluate the performance of proposed algorithm with the Korean face database collected using a stereo-camera based 3D face capturing device. In addition, various decision making similarity measures were explored for final results. Our experimental results indicated that the algorithm is robust for driver authentication inside the vehicle and is also reasonably fast for real-time processing.

Keywords: biometrics, 3D face recognition, 3D Model, driver authentication, driver identification, telematics application.

1 Introduction

Biometrics is a rapidly evolving technology which has been widely used in variety of applications such as criminal identification and car theft, etc. In addition, it can make an important role in telematics applications. Especially biometric authentication methods based on face recognition can be a valuable tool to prevent unauthorized access to the vehicles, to detect drowsiness of the driver, and to do automatic adjustment of driver's settings for in-vehicle devices such as back mirrors, driver seat, and other telematics devices etc.

Traditional face recognition systems have primarily relied on 2D images. However, they tend to give a higher degree of recognition performance only when images are of good quality and the acquisition process can be tightly controlled. Recently, many literatures on 3D based face recognition have been published with various methods and experiments. It has several advantages over traditional 2D face recognition: First, 3D data provides absolute geometrical shape and size information of a face.

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Additionally, face recognition using 3D data is more robust to pose and posture changes since the model can be rotated to any arbitrary position. Also, 3D face recognition can be less sensitive to illumination since it does not solely depend on pixel intensity for calculating facial similarity. Finally, it provides face segmentation information since the background is typically not synthesized in the reconstruction process [1].

Image captured by in-vehicle camera is very sensitive to pose and illumination variation which makes this application differentiated from the other 2D based approaches. In this paper we propose a novel 3D face representation. Proposed algorithm has flexibility to reduce the vertex number of each 3D face remarkably and all the 3D faces can be aligned with correspondence information based on the vertex number of a reference face simultaneously.

This paper is organized as follows. The next section presents the proposed driver authentication process for face recognition. Section 3 describes the procedure of the 3D face recognition process. Experimental results are presented in Section 4 based on a Korean database. Finally, conclusions and future work are discussed in Section 5.

2 Driver Authentication Process

We assume several constraints for this study.

- Car is used by limited number of drivers
- Medium size and quality of video/digital camera is utilized for realistic experi ments.
- Camera is fixed at upfront of driver seat and centered to the forehead of driver.
- Maximum 100 drivers are to be identified per vehicle.

Figure 1 shows the block diagram to explain the driver authentication process.

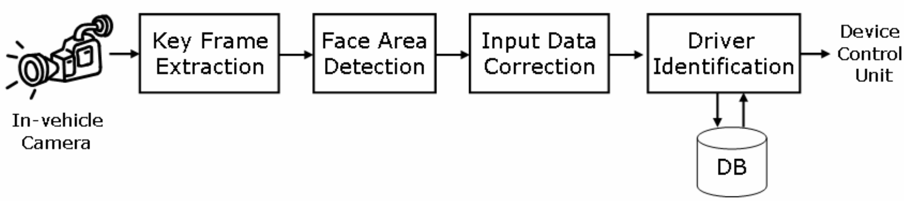

Fig. 1. Block diagram of the driver authentication system

When driver sits in the vehicle, video frames are acquired by in-vehicle camera. Since face recognition algorithm is sensitive to shooting conditions in the vehicle such as amount of lights, angle of camera to the face, etc, each frame is investigated to choose multiple key frames which have good image quality and good position of the face(i.e. fore front of the face). Then normalization techniques are applied to improve the quality of the images for further processes.

We assumed that the face detection algorithm is applied to produce normalized face images. Then the 3D based face recognition system process the 2D face image and look up the driver database to identity or verify the specific person. Authenticated driver is informed to the device control unit for user-dependent customization of telematics services.

2.1 Key Frame Selection

Key frame extraction technique has been widely used for video abstraction which can summarize a video clip with the limited number of major frames that contains significantly important information of the clip. Most of the algorithms observe variation of information in the video frame among adjacent frames, such as motion and object properties, etc [2].

In this study, however, change in adjacent frames is not important. Because of the variation of environment inside car, we observed that many different conditions of face images had acquired even within the same video clip. Since the face recognition algorithms is very sensitive to light conditions such as intensity, contrast, etc, we developed key frame extraction method which can adequately reflect those properties.

In addition, the algorithm focused on the quality of the foreground object (i.e. driver) by eliminating background scene to improve the reliability of the algorithm. We used object segmentation algorithm in [3] to extract object area. The algorithm is suitable for real time process and performs well especially for the object with stationary background. We present the pseudo-codes for key frame extraction method as below.

```
 for (each_frame) {
  Do_object_extration();
  if (extraction_is_failed()) continue;
  get_histogram_luminance_contrast();
  score_frame();
}
Select_best_scored_frames();
```

2.2 Face Area Detection and Input Data Correction

The extracted object contains driver's face and upper body. In order to segment the face we applied filtering followed by masking procedure. If the segmented face is tilted, geometrical transform is applied to correct the position of face. Histogram equalization and histogram specification [4] was also performed for improve the contrast of the face.

2.3 Driver Identification

Driver identification module is divided into feature extraction and similarity measure. Principal component analysis (PCA) a based algorithm [5] has been widely used for many face recognition applications. The algorithm, however, it has drawback for pose and illumination variation. Since in-vehicle environment in this study is highly affected by the driver's pose and light from outside, we used 3D based face recognition algorithm which is more robust to the pose and illumination variation. For similarity measure, we explored L1 + Mahalanobis distance, L2 + Angle was performed for the test [6].

3 3D Based Face Recognition

In general, a 3D face scan consists of texture intensity in 2D frame and geometrical shape in 3D. Especially, the shape information is represented by close connections of many vertices and polygons. Since the vertex number of each of 3D face scans is different from each other, it is necessary to manipulate them to have the same number of vertices for consistent mathematical expression. We propose a novel 3D face representation algorithm as shown in Figure 2.

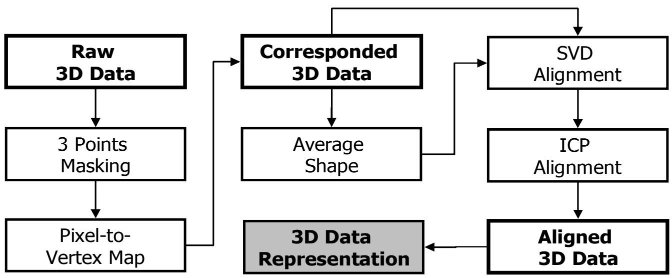

Fig. 2. 3D face representation process

3.1 Face Alignment and Model Generation

It is possible that all 3D face scans in our database are expressed with the same number of vertex points. To construct a more accurate model, it is necessary to utilize some techniques for face alignment, which is transforming the geometrical factors (scale, rotation angles and displacements) of a target face based on a reference face. Face alignment in our research is achieved by adopting singular value decomposition (SVD) [7] and Iterative Closest Points (ICP) [8][9] sequentially.

We constructed separate models from shapes and textures of 100 Korean people by applying PCA [10] independently. The separate models are generated by linear combination of the shapes and textures as given by equation below.

$$\mathbf{S} = \mathbf{S}_0 + \sum_{j=1}^{N_S} \alpha_j \mathbf{S}_j , \qquad \mathbf{T} = \mathbf{T}_0 + \sum_{j=1}^{N_T} \beta_j \mathbf{T}_j . \tag{1}$$

where $\boldsymbol{\alpha} = [\alpha_1\, \alpha_2 \cdots \alpha_{N_S}]$ and $\boldsymbol{\beta} = [\beta_1\, \beta_2 \cdots \beta_{N_T}]$ are the shape and texture coefficient vectors (should be estimated by a fitting procedure). Also, $\mathbf{S}_0$ and $\mathbf{S}_j$ are the shape average model and the eigenvector associated with the j^{th} largest eigenvalue of the shape covariance matrix, $\mathbf{T}_0$ and $\mathbf{T}_j$ in textures likewise.

Fig. 3. A generative 3D model. These are rotated versions of the 3D model in Y-axis direction. Each version from the first is ranged from -45 degrees to 45 degrees at 15 degrees interval.

3.2 Fitting the 3D Model to a 2D Image

Shape and texture coefficients of the generative 3D model are estimated by fitting it to a given 2D input face image. This is performed iteratively as close as possible to the input face. Fitting algorithms, called stochastic Newton optimization (SNO) and inverse compositional image alignment (ICIA) were utilized in [11] and [12], respectively. It is generally accepted that SNO is more accurate but computationally expensive and ICIA is less accurate but more efficient in computation time [12].

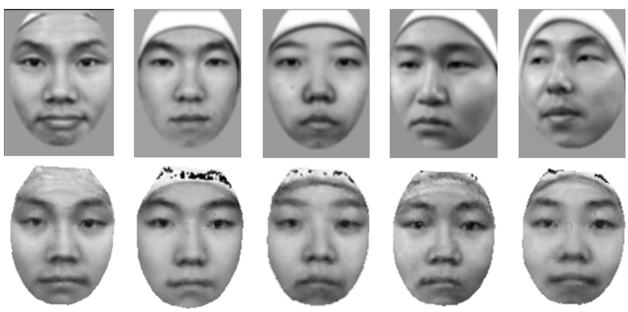

Fig. 4. Fitting results. The images in top row are input images and those in bottom row are the fitted versions of our 3D model. Especially, the inputs to the third column are frontal and the others are rotated 30 degrees approximately.

We also explore the ICIA algorithm as a fitting method to guarantee the computational efficiency. Given an input image, initial coefficients of shape and texture and projection parameters for the model are selected appropriately. Initial coefficients of shape and texture usually have zero values but projection parameters are manually decided by the registration of some important features. Then, fitting steps are iterated until convergence to a given threshold value, minimizing the texture difference between the projected model image and the input image. During the fitting process, texture coefficients are updated without an additive algorithm at each iteration. But in case of shape coefficients, their updated values are not acquired with ease because of the nonlinear problem of structure from motion (SFM) [13]. To solve it, we recover the shape coefficients using SVD based global approach [14] after the convergence.

4 Experimental Results

We evaluate our face recognition system based on a 3D model generated using proposed representation algorithm. As mentioned in previous sections, 3D Korean faces are collected using a Geometrix Facevision 200 [15], which is a stereo-camera based capturing device offering a 3D face scan including approximately 30,000 ~ 40,000 vertices and corresponding 2D texture image. There are 218 3D face scans collected from 110 people during 3 sessions, which are limited with frontal views and neutral expressions, in our database. We used 100 scans in session 1 for 3D model generation and 52 scans in other sessions for the performance evaluation. Also, 7 sided face images with range from 15 to 40 degrees are acquired separately using the same device for variant pose test. Some example scans are showed in Figure 5.

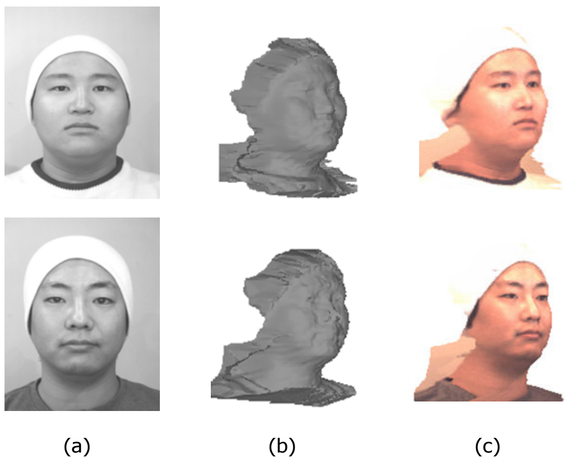

Fig. 5. 3D face examples : (a) texture images (b) shaded shapes (c) rendered 3D views

The experimental results to frontal and sided faces are shown in Table 1. In both experiments, we utilized the L2 norm and angle combined with Mahalanobis distance as a distance metric, denoted by L2+ Mahalanobis and Angle+ Mahalanobis respectively [16]. Also, we performed additional experiments on two cases, one is to use only texture coefficients and the other is to combine texture and shape coefficients. Recognition accuracy with rank 1 in both tests was 90.4% (47 out of 52 subjects) and 85.7% (6 out of 7 subjects) respectively. The average fitting time taken without the shape recovery was 3.7s on 1.73GHz Pentium-M and 1GB RAM, but when the recovery process is included, it required 11.2s on the same machine. A remarkable result is that utilizing the shape coefficients doesn't improve the performance meaningfully in spite of increased computation time.

Table 1. Recognition accuracy with rank 1 to frontal faces and pose variant faces

	Only Texture		Texture + Shape	
	L2+Mah	L2+Angle	L2+Mah	L2+Angle
Frontal faces	90.4%	86.5%	90.4%	88.5%
Pose variant faces	71.4%	85.7%	71.4%	85.7%
Computation time	3.7s		11.2s	

5 Conclusion

In this paper we developed driver identification system based on face recognition. Since the algorithm is video-based, key frame extraction was performed followed by face area detection and input data correction. For pose and illumination-invariant properties, we presented a novel 3D face representation algorithm for 3D model based face recognition system. On the basis of the presented method, an original 3D face scan including 30,000 ~ 40,000 vertices could be represented with about 5,000 vertices. We have generated 3D model using 100 3D face images (each 3D face image composed of 4822 vertices). Then, shape and texture coefficients of the model were estimated by fitting into an input face using the ICIA algorithm. For 3D model generation and performance evaluation, we have made the Korean 3D face database from a stereo-camera based device. Experimental results show that face recognition system using the proposed representation method is more efficient in computation time. Romdhani et. al. [12] presented that the fitting time takes about 30 seconds with almost same condition as our proposed algorithm, though it is less accurate in terms of recognition performance. Our preliminary results indicated that the algorithm is robust for in-vehicle face video and is also reasonably fast for real-time processing. Our future works will focus on automatic initialization in the fitting procedure and real-time processing.

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A Graphics Adaptation Framework and Video Streaming Technique for 3D Scene Representation and Interaction on Mobile Devices

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Abstract. In this paper, we propose a graphics adaptation framework with a mechanism of video streaming to overcome the shortcoming of real-time representation and interaction experiences of 3D graphics application running on mobile devices. We therefore develop an interactive 3D visualization system based on the proposed framework for rapidly representing a complex 3D scene on mobile devices without having to download it from the server. Our system scenario is composed of a client viewer and an adaptive media streaming server. The client viewer offers the user to navigate the 3D scene and interact with objects of interests for studying about them through the responded text descriptions. The server adaptively provides media contents to the client according to the user preferences, interactions, and the condition of wireless network.

Keywords: Video streaming, interactive 3D visualization, adaptive media content, MPEG-4/H.264 standard, color vision deficiency.

1 Introduction

In recent years, real-time representation and interaction for a highly complex 3D scene is one of fundamental problems in 3D graphics application for mobile devices. It is because the performance of 3D graphics requires a powerful computational capability, and large storage memory. In addition, a very huge data size of 3D scenes will also cause problems for storing, transferring and rendering the contents not only on mobile devices but also on PCs.

A number of individual approaches are proposed to overcome these difficulties. Teler [1], [6] presented a method of streaming 3D scene for remote walkthrough by selecting a portion of the 3D scene and reducing quality representation for objects. This method only sends the visible 3D contents at the observer viewpoints. These contents are then kept in the client sides for reusing so these contents will not be sent again. Schneider [2] and Hesina [3] introduced a network graphics framework that includes various transmission methods to provide a constant quality of 3D-contents downloaded with different conditions of environment. AlRegib [7] developed a special network layer called 3D model transport protocol for streaming 3D models over the network. A single-level compression method is used to reduce the transmitted bits.

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Some other methods attempt to reduce bandwidth requirements by developing compression algorithms [14], [15], [16], [17]. Using arbitrary triangular mesh with an irregular connectivity, a 3D model is compressed by two channels of data (geometry data and connectivity data) before it is streamed to the client. To deal with the scene complexity, Hoppe [4] and Funkhouser [5] proposed approach of level of detail (LOD) models and object progressive rendering. Users can see the objects with different levels of detail depending on transferring intervals of time or distance from the observer viewpoint to the objects.

Similar to our research, many researches invested accelerated rendering algorithms in taking advantages of displaying 2D rendered images for easily visualizing a 3D scene in the client sides. Image-based rendering techniques [8], [9], [10], [11], [12], [13] do not use 3D geometry information of the 3D scenes such as object attributes, vertex points and their connectivity. Thus, the client alternatively receives and displays rendered images in a very short time. To archive high performance, the rendered images usually are compressed using JPEG compression standard [9]. However, the data size of compressed images is still big compared to the bandwidth of wireless links of mobile devices.

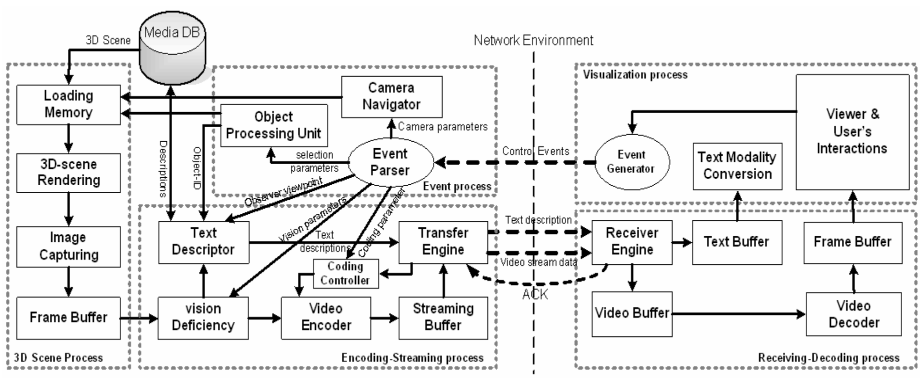

Fig. 1. A graphics adaptation framework for the Inter3DV system, the client can navigate for a large and complex 3D scene without having to download it from the server

The above solutions all, however, require a powerful computational capability, large memory for storing, 3D graphics hardware, and programming capabilities from the client sides. Meanwhile, every mobile device can not embed required hardware for rapidly displaying and memory capacity for storing the large and complex 3D scene. Moreover, the mobile devices are still limited in bandwidth of wireless links so that transferring data of a 3D scene over the network is a big challenge. Whereas, today mobile devices usually support natively video, audio, and text, they offer direct optimization for playing back of such media contents. Consequently, in this paper, a graphics adaptation framework for an interactive 3D visualization (Inter3DV) system is proposed. The Inter3DV system offers the client viewer on mobile devices to rapidly represent a large and complex 3D scene resided in the server without having to download it. The user can remotely navigate the 3D scene and select an object of interests for studying according to the text description introducing about it.

The graphics adaptation framework is providing a representation, interaction and adaptive media content experiences with no additional processing cost on the client side. Our solution is developing an adaptive media streaming (AMS) server for streaming the video stream generated from a remote interaction. The AMS server frequently renders a sequence of images and then encodes them into a video stream. The video stream is then received by the client, which decodes the video stream into video-frames and displays. Video codec processes is based on MPEG-4/H.264 standard. The AMS server provides the client with adaptive video stream in term of color vision deficiency, quality representation according to the user preferences and the variation of network bandwidth and also provides suitable text descriptions depended on the user interactions.

2 A Graphics Adaptation Framework

Figure 1 illustrates a graphics adaptation framework of the Inter3DV system that takes the advantages of video streaming technique for reducing the data transmission rate and accelerated rendering on the client sides. The client viewer offering real-time representing and navigating a complex 3D scene is specially developed for HP iPAQ Pocket PCs. The client viewer provides a user-interface for representing the responded media contents and for controlling visualization. The server, AMS server, plays important roles of transforming the 3D scene into suitable media contents due to the user interactions and streaming these media contents to the client viewer.

2.1 Adaptive Media Streaming Server

Before the media contents are sent to the client, the server has a lot of works to do that can be performed in three processes.

Event Process. This process manages the interactions derived the user on the client. Event process includes *event-parser, camera-navigator,* and *object-processing-unit* modules. On the client side, whenever the user interacts with the 3D scene such as walking through the scene or selecting an interested object, the event-generator creates a control event and sends it to the server. On the server side, the event-parser converts the control event into control parameters (camera, selection, coding parameters, etc.) that will be conveyed to one of the following processes: text-descriptor, camera-navigator, object-processing-unit, vision-deficiency and coding-controller. The observer viewpoint of the 3D scene is updated following the movement and orientation of the virtual camera. The camera-navigator uses the camera parameters to adjust the virtual camera by changing camera coordinates in position (x, y, z) and changing camera orientation in pose (h, p, r), h is rotated by z-axis, p is rotated by x-axis and r is rotated by y-axis. The object-processing-unit uses the selection parameters to obtain the selected object in the 3D scene. The process of object identification is doing as follows. Because the size of image rendered in the server side (called *rendered image*) might be different to the size of image displayed on the client side (called *displayed image*). Therefore, the position of mouse event should be mapped into the rendered image at the current observer viewpoint to archive correct coordinates. Assume that, x_n and y_n are coordinates projected on the rendered image,

x and y are coordinates projected on the displayed image. x_n and y_n are calculated as the following: $x_n = x*r_w$ and $y_n = y*r_h$, where r_w and r_h are ratio by width and ratio by height between the rendered image and displayed image. The x_n, y_n coordinates are then projected into the 3D space of the 3D scene to obtains the object-ID of the selected object. The selected object is marked by adding its triangle mesh. The object-ID is also sent to the text-descriptor for querying its text description in the Media DB.

3D-scene Process. 3D-scene process is designed for rendering and grabbing images from the 3D scene at the observer viewpoints. This process is broken into four processing layers: loading-memory, 3D-scene-rendering, image-capturing, and frame-buffer. When a client sends a request to access a 3D scene in the AMS server, the 3D scene is loaded to the loading-memory and then a virtual camera is mapped to the 3D scene. Responding to the observer viewpoints, the 3D-scene-rendering constantly renders raster images. This method uses a special function that is available in OpenGL called *feedback* function [21], [22]. When using feedback mode the 3D scene is not rasterized like the usual way, the transformed data (rendered/raster image) is stored in a feedback buffer. After that, the 3D-scene-rendering signs the image-capturing to read back the rendered image from the feedback buffer using *glReadPixels* function and store it into the frame-buffer preparing for the video encoding process.

Encoding-Streaming Process. The main tasks of encoding-streaming process are adaptively providing and streaming media contents (video stream data and text descriptions) in accordance to the control parameters received from the event-parser to the client. This process is performed as follows.

(1) The images in the frame-buffer first are passed to the vision-deficiency module for pre-processing color vision. If the vision parameters indicate the degree of color vision deficiency then the images will be converted by the visual content adaptation algorithm [19] to suit the visual perception characteristics of the user.
(2) The video-encoder compresses the converted images into a video stream based on MPEG/H.264 standard [18]. The video stream is finally stored in the streaming-buffer. During encoding process, the quality of video compression is always adjusted in order to satisfy the user preferences. *Channel rate* (a), *minimizing distortion* (b), and *quantizer* (c) are three encoding options for the user on the client. The channel rate option requires that, the system should always keep a stable frame rate. The minimizing distortion option requires that, the system provides result with a minimal video distortion for video segment in the streaming-buffer. If the user chooses option (c), the quality of video compression will not be changed. If the user sets up option (a) or (b), the system requires the coding-controller to find an optimal quantizer [20]. The coding-controller receives control parameters from the event-parser or a signal from the transfer-engine it finds an optimal quantizer and sends to the video-encoder for adjusting quality of video compression. The value of quantizer is varied from 1 to 31 in steps of 1. The increment of quantizer value is in inverse ratio to the quality of video compression.
(3) The transfer-engine receives the video stream from the video-buffer and receives text descriptions from the text-descriptor. It creates two data transmission channels,

one is for transferring the text descriptions and one is for transferring video stream data. If the text-descriptor receives an object-ID from the object-processing-unit or the vision-deficiency it tries to obtain the text description of the object-ID and sends to the transfer-engine. Whenever the transfer-engine receives ACK message from the receiver-engine, it indicates the coding-controller to find a new optimal quantizer for the video-encoder due to the rules of the coding options.

2.2 A Client Viewer

A client viewer, a real-time client application offering adaptively representing and navigating a complex 3D scene, is specially developed for mobile devices (HP iPAQ Pocket PCs). In previous works [1], [2], [3], [7], the clients need time-delay for downloading the 3D scene, a large memory space for storing data and required graphics hardware for accelerated 3D rendering. In our method, a video streaming technique is employed instead of streaming 3D scene for solving the above limitations and for accelerated representing a complex 3D scene. Therefore, a complex 3D scene resided in the AMS server is rapidly represented by the client viewer without having to download and store it as well. In this study, we are taking advantages of the video streaming technique due to not only the low computing capacity of the clients and the potential low bandwidth of wireless links, but also security concerns. The user on the client can not access the original data from the server because only generated video stream data is transferred to the client.

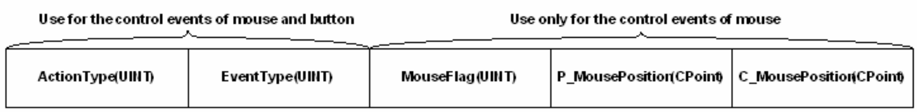

Fig. 2. The *Event_Action* structure of a control event

The media content, received by the receiver-engine, is temporarily stored into the video-buffer if it is a video stream data and stored into the text-buffer if it is a text description data. The video-decoder decompresses the video stream data into frames and stores into the frame-buffer. After that, the visualization process displays the frames and represents the text description through the *viewer & user's interaction* and *text-modality-conversion*.

The client viewer supports the user with walking through the 3D scene, turning view orientation, and selecting objects for studying about them according to their text descriptions. The user interactions are generated to as control events and transferred to the server by the event-generator (see figure 1). Each control event is formed by the Event_Action structure as shown in figure 2. *ActionType* defines type of the interactions (e.g. ACT_WALK or ACT_SELECT). *EventType* defines interface-button or mouse events (e.g. mouse move, mouse click, etc.) *MouseFlag* records statuses of mouse click (e.g. left or right). *C_MousePosition* and *P_MousePosition* record the current and previous position of mouse events based on the size of displayed image.

2.3 Streaming Protocol

Data transmission between the client and the server are conveyed through sockets. User diagram protocol (UDP) is often the favoured transport protocol for delivery of media data over the network [23]. However, as UDP, the sender can continuously send data to the receiver without guarantee the delivery of transmitted data [7]. Therefore, the media streaming system needs to be supported extra information to manage the delivery of lost, delayed, and unordered packets. A real-time media streaming system usually uses UDP with supplementation of framing and feedback information that provided by real-time transport protocol (RTP) [24].

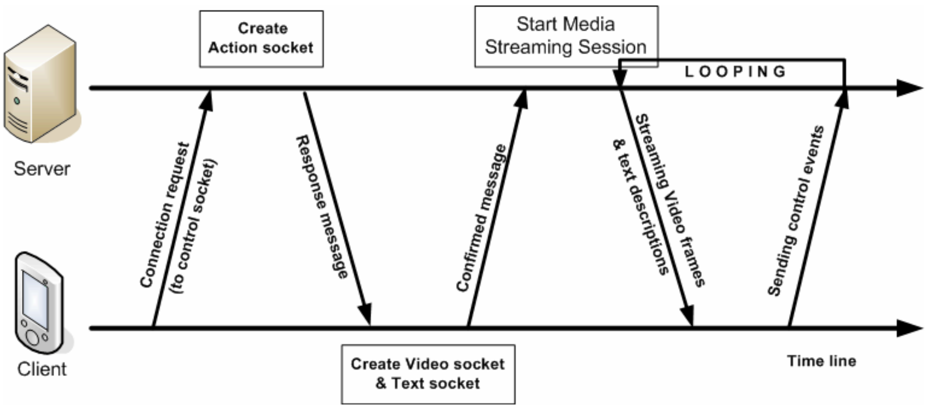

Fig. 3. A mechanism for establishing sockets of the interaction and streaming sessions

In this paper, the socket connections include *control socket*, *action socket*, *video socket,* and *text socket.* The control socket is used to establish and manage all communications between the client and the server. The control socket always listens request messages from the client. User interactions from the client are sent to the server over the action socket. The video socket is created for transferring video stream data. Text socket is created for transferring text descriptions. Figure 3 depicts a mechanism of establishing socket connections for interaction and media streaming sessions. To access and visualize the 3D scene, the client first sends a request message to the server over the control socket. The server creates an action socket and sends a response message to the client. The client then sends the user preferences and device information to the server for starting interaction session and also creates from the server and it again sends a confirmed message to the server. After that, the server opens media streaming session for transferring the media contents to the client.

3 Implementation and Results

To verify the graphics adaptation framework, an interactive 3D visualization (inter3DV) system is developed. We implemented an adaptive media streaming (AMS) server and client viewer. An implementation based on a central workstation is configured in which the AMS server is running on. The central workstation is equipped with a single Pentium IV, 1.8 GHz, 1 GB of RAM and running on WindowXP platform. Client nodes are HP iPAQ PocketPCs working on WinCE 2005 platform. PocketPC devices currently have a small screen resolution - 240x320 pixels and 16/32 bit color depth. In this experiment, MPEG-4/H.264 standard is used to encode the input images into video stream and UDP/RTP is used to packetize and stream generated video data to the client over the network. The size of video compression is Quarter Common Intermediate Format (QCIF – 176x144).

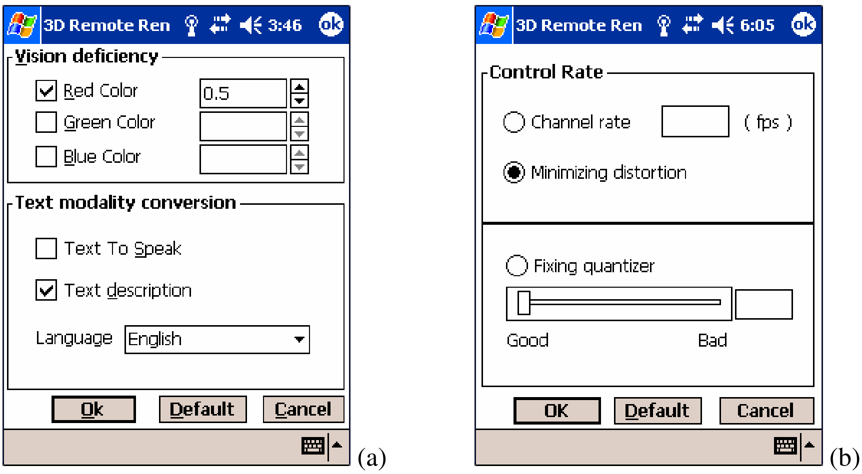

Fig. 4. The user preferences on the client viewer, with (a) vision deficiency and text modality conversion options, (b) control rate option

Figure 4 is two screenshots of the user preferences. In figure 4.a, the user can setup the vision deficiency characteristics based on three primitive colors (Red, Green, and Blue) and text modality conversion such as text-to-speak (TTS), text description, and language for presenting text modality conversion. In figure 4.b, the user can select one of three control rate options. The channel rate allows the system to fix the frame rate and tries to adjust the quality of video compression by finding an optimal quantizer. Similar to the minimizing distortion option, the system adjusts the quality of video compression by finding an optimal quantizer in order to obtain a minimum distortion for decoded video data in the client side. The quantizer option is that the user chooses a quantizer level for the encoding process. The default option for control rate preference is minimizing distortion. We have evaluated the frame rate for HP iPAQ PocketPC that is varied from 14 to 20 fps when the user chooses default minimizing distortion option. Figure 5.a and 5.b show results of choosing the channel rate option with 22 fps and 25 fps, respectively.

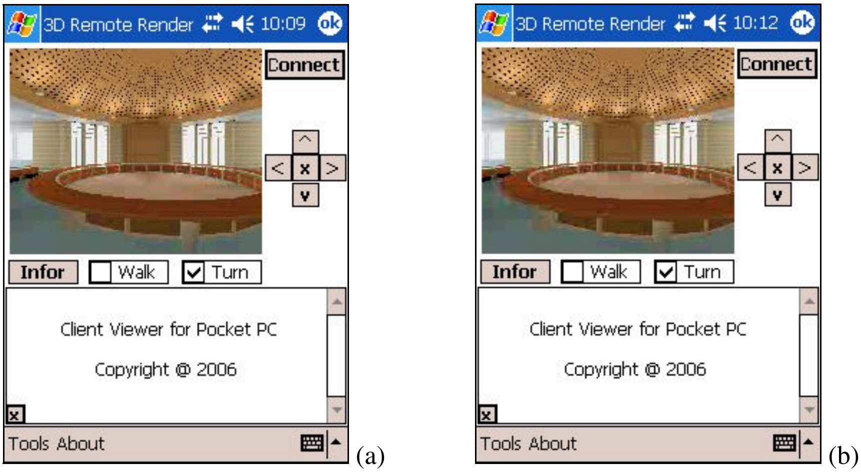

Fig. 5. The screenshots of the client viewer based on the two channel rates (22 and 25 fps)

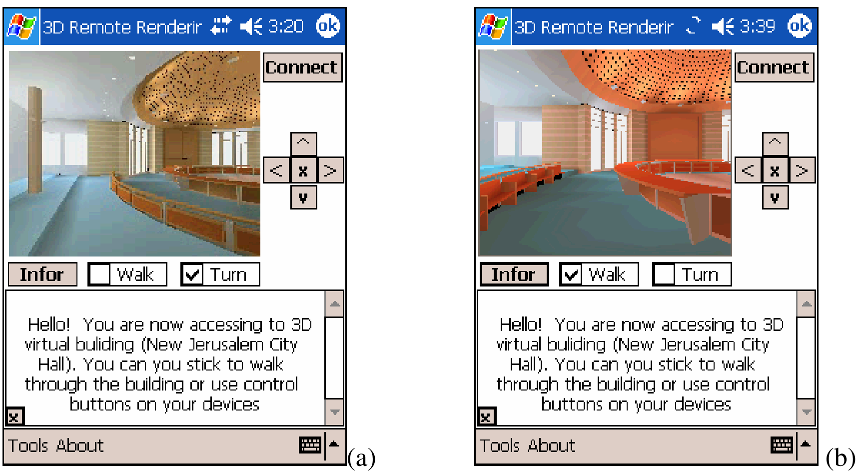

Fig. 6. The screenshots of the client viewer for navigating the 3D virtual building, (a) without setting of vision deficiency, (b) with setting of vision deficiency for red-color at degree of 0.5

Figure 6 is a demonstration for the user walking through the 3D virtual building (New Jerusalem City Hall). Figure 6.a and 6.b are results at two different viewpoints. In figure 6.a, the video frame is represented with the original color. Figure 6.b shows an instance of color adaptation that describes color vision deficiency characteristics of the user who has a certain type and degree of color vision deficiency. In this example, red-color is set as color deficiency of the user and the degree is equal to 0.5.

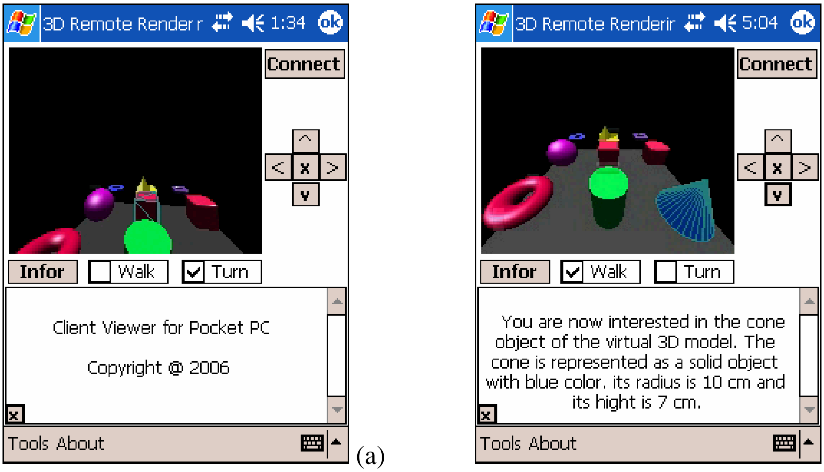

Fig. 7. The screenshots of the client viewer for navigating the primitive 3D object model and selecting object of interests and querying its text description

Figure 7 shows a demonstration for walking through the primitive 3D object model and selecting an interested object. In figure 7.a, the user selected the cube object and queried its text description that was not existed in the Media DB so that the AMS server can not serve. In figure 7.b, the user selected the cone object and queried its description that was displayed in the user interface. The text description of the cone object is a simple one for introducing about the chosen object.

4 Conclusion

In this paper, we proposed a graphics adaptation framework for an inter3DV system. The system takes the advantages of video streaming technique for reducing burden of storing and rendering process on the client side as well as reducing transmitted data (the end-to-end transmission delay). Our proposed system works well for mobile devices with low computational power, memory capacity.

The Inter3DV system has been implemented with an AMS server and a client viewer. We have experimented on 3D virtual building (New Jerusalem City Hall), and a primitive 3D object model. The client viewer, run on a HP iPAQ PocketPC device, allows the user to rapidly represent, easily navigate a complex 3D scene and interact with interested objects for studying according to their text descriptions. Responding to the user preferences, interactions, and the condition of wireless, the media contents are adaptively represented on the client.

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Fuzzy Face Vault: How to Implement Fuzzy Vault with Weighted Features*

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Abstract. Ari Juel et al from ISIT 2002 presented a fuzzy vault scheme, which is a framework to encrypt a cryptographic key with a fuzzy key[5]. Following their framework, many trials to implement mainly a fuzzy finger vault have been proposed that enables us to keep secretly a key with our finger print. Our work is to focus on instantiating the fuzzy information of the fuzzy vault scheme with human faces instead of fingers. Most of face authentication algorithms are dependent upon weighted features, which are incompatible with the original fuzzy vault scheme. To reflect the level of importance of individual features from feature set, we introduce another layer between captured feature set and points in the polynomial to be interpolated.

1 Introduction

Biometrics are very versatile tools, but information privacy of biometrics also must be fully guaranteed because once revealed, it cannot be canceled unlike the traditional cryptographic keys. Thus, researches on biometrics protection have been extensively performed both by biometrics society and by cryptographic society[2,3,4].

Ari Juel et al from ISIT 2002 presented a fuzzy vault scheme, which is a framework to encrypt a cryptographic key with a fuzzy key. Following their framework, many trials to implement mainly a fuzzy finger vault have been proposed that enables us to keep secretly a key with finger prints[6,7].

Our work is to focus on instantiating the fuzzy information of the fuzzy vault scheme with human faces instead of fingers. Face is usually open to public and thus, it is easier to capture a certain person's face image than her finger print. So it might be thought that using face images as a biometric key is more vulnerable

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compared with using hidden biometrics such like finger prints and iris patterns. However, considering unobtrusiveness of face recognition, protection of a key with features from face images are very convenient and thus, it is quite necessary to protect features from face images against the attack on database that stores large number of cryptographic keys encrypted with features from many person's face images. Assume the situation that features from many person's face images are not protected. Then, attacker can easily obtain large number of people's face features by cracking the database. However, if the features are protected using a scheme such as fuzzy vault, then the attacker does not obtain any good.

Because images capturing a human face are not always the same, it seems that human face is fit exactly into the framework of the fuzzy vault. The fuzzy vault scheme, however, depends on the error correction code such as Reed-Solomon code. So, only the number of correct features from freshly captured features determines whether the key can be correctly recovered or not. This is because one feature encrypts only one share of a key, where the share is a secretly-split share of a key using secret sharing scheme. Thus, the fuzzy vault framework cannot give an individual feature a weight, and this property of the fuzzy vault makes it hard to incorporate face features into the fuzzy vault framework. Because most face authentication scheme is based on classification algorithm such as the principal component analysis and the linear discriminant analysis, the feature set is composed of eigen vectors, among which some eigen vectors having large eigen values have more importance than others. Thus, direct incorporation of the existing face authentication schemes into the fuzzy vault does not reflect the degree of importance of individual features and consequently, it will substantially degrade the original classifier's classification capability. Our aim is to design a fuzzy face vault scheme that can reflect the importance of individual features, which results in more exact incarnation of face fuzzy vault. With our fuzzy face vault scheme, one can keep secretly a midterm key by encrypting it with one's face image.

2 Background: Fuzzy Vault

In [5], the fuzzy vault is created by making a generalized Reed-Solomon codeword representing a secret as a corresponding polynomial p. This codeword is computed over x- coordinates corresponding to elements in the feature set. To hide the codeword, chaff points are added, i.e., random noise in the form of random (x_i, y_i) pairs.

To unlock a vault, one must determine the codeword that encodes the secret. Recall that the feature set specifies the x-coordinates of "correct" points that lie on the polynomial that encodes the secret. Thus, if freshly captured feature set is close to the key feature set, then one can identify a large majority of these "correct" points. Any discrepancy between those feature sets will introduce a certain amount of error. Provided that there is sufficient overlap, however, this noise may be removed by means of a Reed-Solomon decoding algorithm. Consequently, the polynomial that encodes the secret can be successfully reconstructed

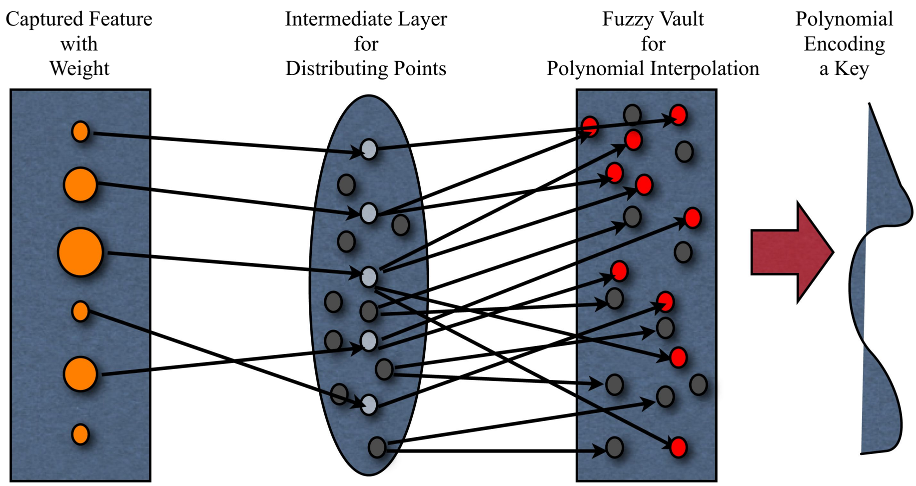

Fig. 1. Fuzzy Vault with Weighted Features

by one who has a "similar" feature set with that in the fuzzy vault construction. For more details, refer to [5].

3 Fuzzy Face Vault Scheme

As noticed in the previous section, the original fuzzy vault can neither be locked nor be unlocked by a weighted feature set. This is because irrespective of its importance of a certain feature it can hold only one share of a secret value. In this section, we show how to build a fuzzy vault scheme with weighted features.

To reflect the level of importance of individual features from feature set, we introduce another layer between captured feature set and points in the polynomial to be interpolated. In the original fuzzy vault, closest points to the captured feature set are directly chosen to reconstruct the polynomial that encodes the secret key. The intermediate layer of our scheme includes genuine weight values of the registered face image and counterfeit weight values as chaffs. In the intermediate layer, features with high weight values will give more information of points on the polynomial than ones with low eight values. This can be achieved by composing the fuzzy vault with points in the following way:

$$(h(f_1||0), f(h(f_1||0))), (h(f_1||1), f(h(f_1||1))), \ldots (h(f_1||m_1), f(h(f_1||m_1))),$$

$$(h(f_2||0), f(h(f_2||0))), (h(f_2||1), f(h(f_2||1))), \ldots (h(f_2||m_2), f(h(f_2||m_2))),$$

$$\cdots$$

$$(h(f_N||0), f(h(f_N||0))), (h(f_N||1), f(h(f_N||1))), \ldots (h(f_N||m_N), f(h(f_N||m_N))),$$

where f_i is a feature, m_i is an integral weight of a feature f_i, h() is oneway and collision free hash function such as SHA-1, f() is the polynomial that encodes the secret key and finally || represents concatenation. That is, if more significant feature is found, then more points on the polynomial are obtained. This contrasts to the original fuzzy vault scheme, because this reveals only one point on the polynomial for one feature:

$$(f_1, f(f_1)), (f_2, f(f_2)), ...(f_N, f(f_N)).$$

Because given a face image from the same user, classifiers such as PCA and LDA usually give roughly-the-same dominant features, one has high probability that obtain many points on the curve and thus, one is prone to restore the stored secret key from the polynomial.

Followings is our fuzzy vault construction algorithm, where all parameters regarding security are the same as those in [5].

Public parameters: A field $\mathcal{F}$, a Reed-Solomon decoding algorithms RSdecode.
Input: Papameters k, t and r such that $k \leq t \leq r \leq q$. A secret $\kappa \in \mathcal{F}^k$. A feature set $F = \{f_i\}_{i=1}^{t}$, where $f_i \in \mathcal{F}$.
Output: A set R of numbers $\in \mathcal{F}$ and a set S of points $\{(x_i, y_i)\}_{i=1}^{r}$ such that $x_i, y_i \in \mathcal{F}$.
Algorithm LOCK

```
X, R, S ← ∅;
p ← κ;
for i = t + 1 to r do /* Chaffing */
    R ← R ⋃ r, where r ∈ F and randomly chosen.
    x_i ← r;
    Choose randomly m, where 1 ≤ m ≤ weight_max;
    for j = 1 to m do
        y_j ← F − {f(h(x_i||j)};
        S ← S ⋃(x_i, y_j);
for i = 1 to t do /* Inserting Genuine Features */
    R ← R ⋃ f_i;
    x_i ← f_i;
    m ← weight_{x_i};
    for j = 1 to m do
        y_j ← {f(h(x_i||j))};
        S ← S ⋃(x_i, y_j);
```

Resulting two sets (R, S) are the fuzzy vault with weighted features. The set R does only have genuine features and a number of chaffs, where the chaffs are not points on the curve but single noisy numbers. The second set S has points on the curve f, but it also has chaffing points that disturbs an attacker. The set R plays a role of the intermediate layer, and thus, a genuine feature in the set maps into multiple points in the set S. Naturally, chaffing numbers in R do have also multiple points in the set S. By doing this, we achieved both the same level of security of original fuzzy vault and the applicable characteristic of weighted features.

To unlock our fuzzy vault, following unlock algorithm will be used.

Public parameters: A field $\mathcal{F}$, a Reed-Solomon decoding algorithms RSdecode.
Input: Papameters k, t and r such that $k \leq t \leq r \leq q$ and two sets (R, S).
Output: A value $\kappa' \in \mathcal{F}^k \bigcup 'null'$.
Algorithm UNLOCK

```
Q ← ∅;
for  i = 1 to  t do
    x_i ←(b_i,o)— R;
    for  j = 1 to  m_{x_i} do
        y_j ← f(h(x_i||j))
        Q ← Q ⋃ (x_i, y_j)
κ' ← RSdecode(k, Q);
output  κ';
```

Here, the unlock algorithm finds firstly closest numbers from the set R, from which it can derive multiple points on the curve if the found number is significant. More important the feature it finds, more points on the secret curve will be revealed. Errors from mistakenly capturing odd numbers can be recovered with Reed-Solomon decoder if the number of errors is not so big.

4 Cost Evaluation

The cost to construct and maintain our fuzzy face vault is small in terms of computation, because only added operation is evaluation of one way hash function. However, in view of storage, our scheme requires several times bigger memory than the original fuzzy vault framework because intermediate layer is introduced and also more than one points from one feature are built. However, the size of memory is feasible in most applications because the fuzzy vault itself will be stored usually in the server. Even though it is to be stored in devices with limited memory such as smart cards, by reducing dimension of classifier without sacrificing much security, we can make it fit to those kind of devices.

5 Conclusion

In this paper, we presented a method to incorporate a biometric scheme with weighted features into the fuzzy vault scheme for cancelable biometrics. We specify a method to implement the framework using well-known face authentication schemes such as PCA and LDA. Here, the fuzzy face vault fortunately does not involve in such problems like pre-alignment in fuzzy finger vault, which is an obstacle to practical implementation of fuzzy finger vault systems.

In other biometrics schemes that are heavily depending upon weights of extracted features, our scheme can be a guide to construct fuzzy vault in efficient and secure manner.

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DEVAL – A Device Abstraction Layer for VR/AR

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Abstract. While software developers for desktop applications can rely on mouse and keyboard as standard input devices, developers of virtual reality (VR) and augmented reality (AR) applications usually have to deal with a large variety of individual interaction devices. Existing device abstraction layers provide a solution to this problem, but are usually limited to a specific set or type of input devices. In this paper we introduce DEVAL – an approach to a device abstraction layer for VR and AR applications. DEVAL is based on a device hierarchy that is not limited to input devices, but naturally extends to output devices.

Keywords: Device Abstraction, Input Devices, Output Devices, Virtual Reality, Augmented Reality.

1 Introduction

Multiple input and output (I/O) devices are essential parts of VR and AR applications. They allow users to interact with the environment, modifying its state and properties and perceiving the results of the interactions. For VR/AR applications, a large variety of heterogeneous interaction devices exists. Among them are several tracking systems [9], 3D pointing and mouse-related devices, projection and personal display systems, tactile and force-feedback gloves, optical gesture and mimic recognition systems, speech recognition and synthesis systems as well as less common, application specific sensors and actuators [2].

There are several ways to integrate an interaction device into a VR/AR application. An application can directly connect to a device by sending data to or receiving data from an I/O device using the hardware drivers provided. While this approach offers a high degree of control over device-specific functionality, it couples the application tightly to the I/O device limiting its portability to different hard- and software setups. Additionally, it puts a huge workload to the developer, who would have to deal with an individual interface for each device. Thus, it is common practice for VR/AR applications to decouple the application from specific interaction devices via device abstraction layers.

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Device abstraction layers describe sets of devices in abstract device classes. Typically, devices are standardized and structured based on the data types they provide or require (e.g. 3-DOF (degrees of freedom) vs. 6-DOF trackers). Applications that integrate devices via device abstraction layers do not need to be modified if a device is exchanged by a device of the same device type. Ideally, the application even does not need to be restarted but can seamlessly switch at run-time between different I/O devices.

In this paper we present our approach of a device abstraction layer for VR/AR input and output devices extending beyond existing device abstraction layers. Our intention was to include not only common groups of VR/AR interaction devices such as 6-DOF trackers or a space mouse, but also to look at devices that are less frequently considered by device abstraction layers such as temperature sensors or gesture recognition systems, since these devices play a role in upcoming mobile and context-aware VR/AR applications. The result is a general device abstraction layer, that is clearly defined and that can therefore be easily extended by new device types.

The proposed device abstraction layer defines device classes and structures them hierarchically. Devices in this hierarchy inherit the properties and characteristics of their parent classes. One benefit is that applications requiring specific device type functionality may use any device of the corresponding class hierarchy sub-tree. Additionally, characteristics of device subclasses are not hidden, but can be accessed by the application if required.

Another contribution towards more flexible and less device-dependent VR/AR applications are adapters that can be used to transform and filter the data of input and output data.

The paper is structured as follows: Section 2 describes work related to device abstraction layers in the field of VR/AR and in the desktop computer domain. Section 3 gives an overview of the device abstraction layer proposed in this paper and points out our initial objectives. Section 4 deals with input devices and explains the different groups of input devices with their characteristics. Section 5 deals with output devices, respectively. Section 6 explains the concept of adapters. Section 7 concludes the paper and points out possible future directions.

2 Related Work

The requirement to support a wide range of input and output devices is not limited to VR and AR environments. However, within those environments such support is critical, as interaction devices represent an essential part of the user interface and interaction techniques are often employing non-standard interaction devices. In this section, we will focus on related work in the area of VR and AR frameworks, but we will also highlight some fundamental similarities to other environments or libraries providing a flexible support of I/O devices.

OpenTracker [8] provides an object-oriented approach to access input devices, and to fuse, to filter, or to transform their input. While the approach in general is applicable to arbitrary devices, it has a clear focus on tracking devices. Using an XML configuration it allows a flexible combination and processing of tracker data flows by defining a behavior graph, where nodes generate output upon one or several inputs from sources or other nodes. Combiners and adaptors used in our approach provide a more flexible but also more complex approach to combine or separate data streams. In contrast to our approach, OpenTracker-based applications do not use a unified API, but rather access the appropriate nodes directly as no inheritance of devices is used. Similar to our approach devices may be accessed using a server push, a polling, or a fixed frequency approach. Other similarities are the cross-platform approach and the support of decoupled simulation.

Gadgeteer [3] is a device management system. Similar to our approach, applications may access individual devices through rather generic device types, allowing for replacing the device without any modifications to the actual application. Other similarities include the cross-platform support, the ability to deal with device failure, and the possible distribution of the input devices across several computers. In contrast to our approach where the device class hierarchy uses simple generalized devices as a basis and inherits or composes more complex ones from those, Gadgeteer sub-divides input devices according to their data type (analog, digital, position, etc.). While this approach allows easy replacements of one device of a particular data type by another one of the same type, it does not take advantage of the possible relation between devices by inheritance.

Additionally, both approaches -OpenTracker and Gadgeteer- are limited to pure input devices. Contrary, our approach extends to ouput devices, allowing supporting combined input/output devices. Further, our approach fully integrates streaming devices, not supported by those two approaches.

VRPN [10] implements a network-transparent interface between application programs and physical devices and allows for a dynamic discovery of interaction devices. VRPN is an open-source project and the current version supports a wide variety of input as well as output devices. In contrast to our approach the device hierarchy is rather broad, limiting the exchangeability of devices required by a VR/AR application.

Microsoft provides two device abstraction layer APIs as part of DirectX, which are related to this work. DirectShow [7] is an abstraction layer for streaming media such as video and audio. It allows accessing a wide variety of different devices to be handled equally, no matter if the source is an internet stream, a file or direct input from a device. The second abstraction layer of DirectX for mouse, keyboard and joystick (including force feedback) devices is the DirectInput API. It is basically to allow direct access to these devices by bypassing the Windows messaging mechanisms. The API provides functionalities like iterating through the available devices and acquiring the state of a device. Our approach is quite similar to the DirectInput API, by using the Broker of the Morgan framework; an application can iterate through the devices of a specified type and access them directly. Our approach also goes beyond this abstraction since each device may have an extended interface of its own to provide additional functionality.

3 The Device Concept – An Overview

The common understanding of a device is that it is a piece of hardware attached to a computer. While such a definition is quite intuitive, it is not very precise and even restrictive when it comes to a general description and classification of arbitrary input and output devices. Thus, in this paper, we define devices as follows:

> *A device is a combination of a hardware component and a software component, sending or receiving data. The software component may contain a driver, a library, or a software development kit.*

Including software in this definition provides a useful generalization as for computer devices software actually is an integral component as it would not be possible to access the hardware otherwise. However, in many cases the software even provides the characteristic functionality of a device. A typical example of such a device is a speech recognizer. While capturing of the sound of course requires some piece of hardware (at least a microphone), the more important part is actually the software, which recognizes the speech and translates it into some input, which can be further processed by the application.

The goal of our approach was to provide a general taxonomy covering all (input/output) devices used in VR and AR environments. A realization based on this classification should enable application developers to realize VR and AR applications faster and more efficient, providing a significant higher flexibility regarding the devices actually used. The main requirements for achieving these goals were:

- The approach should allow any new device or device type, not already part of the classification to naturally extend it, without requiring any changes to the original taxonomy (i.e. it should be obvious how and where a new device fits into the existing hierarchy).
- Where devices can be sub-divided into logical sub-units or may only be used in part, this should be reflected by the device hierarchy.
- Users should be able to replace one device by another of similar functionality or even a set of other devices at runtime (i.e. the application developer does not need to be aware of the particular device).
- It should be possible to connect devices to any machine in the system, running an arbitrary operating system.

Our approach has been realized as part of our Morgan VR/AR framework [6] [1] development. Consequently CORBA is used as the general communication mechanism. This results not only in a device hierarchy, but also in an appropriate inheritance of the corresponding interfaces. Developers are free to choose a rather general interface of an abstract base class, allowing any other device inherited from this interface to be used alternatively, or to apply a specific interface, potentially offering some device-specific features, but restricting exchangeability. Typically, all devices actually used within a specific setup are configured using a configuration file. A propriety text based description exists in addition to an XML-based description. Independent of this configuration, new devices may be added or replaced at run-time.

In our approach all devices are derived from one device base class, providing general interfaces required for input as well as for output devices. This includes setting or querying a device label and querying the operational state of a device, or specific device features (the latter using a universal XML-based query format).

In the following sections the details of our approach regarding the concepts and realization of input and output devices will be described in detail.

4 Input Devices

Input devices represent the most prominent subgroup in the device hierarchy. This is also reflected by the fact that most existing device abstraction layers are actually restricted to this particular group of devices. Input devices cover the whole range of devices used for interaction or for providing sensor information. Although, the definition of an input device may seem obvious, we define it for completeness based on our definition of devices.

> *An input device is a device, sending data into the system, based upon input from reality.*

In general, new input data will be provided by such a device either at specific intervals or in an unpredictable manner. System components interested in input data from the device may either query the current state of the device on a regular basis or at the particular time when the specific data is required, or the device may send the input data upon availability of new data. The first alternative may lead to unnecessary communication resulting in higher latencies due to the round-trips necessary. However, especially components, which do not need regular updates can significantly reduce the update rate by deciding themselves if and when they actually need an update of the current status. This especially applies to applications executed in an environment depending on a low bandwidth connection or temporary disconnections such as smartphones. The second alternative requires the device to keep a list of interested components and to forward the input data whenever new information is available. This minimizes unnecessary data communication and makes it easier for the interested components to receive the data. However, devices using a rather small bandwidth connection might be flooded by too many updates. In our approach we support both alternatives, giving the application developer the freedom to choose the most appropriate one. Hence, system components or applications may subscribe themselves at the input device and will receive state changes regularly using the *publish-subscribe* pattern [3]. Additionally, the current state can be queried without the need of a subscription.

In order to reduce the communication load, subscribers may also choose rather to specify a maximum or a minimum update rate resulting in a minimum or a maximum period between two subsequent updates transmitted. This however, is only applicable to specific devices (see Section 4.2). Using queries rather than the device push mechanism implies another important difference: The queryable state of an input device is the information available at the time of the query, e.g. the current tracked location of an object for a tracking device. However, depending on the individual device, the input data may not result in a state change. One example is a speech (command) recognition device. While the command recognized will be transmitted to components subscribed; it will not become part of the queryable state and thus cannot be accessed by this mechanism.

We distinguish two major subcategories of input devices: *Discrete Input Devices* e.g. a keyboard (see Section 4.1) and *Continuous Input Devices* e.g. a 6-DOF tracker (see Section 4.2). See **Fig. 1** for an overview of the input device hierarchy.

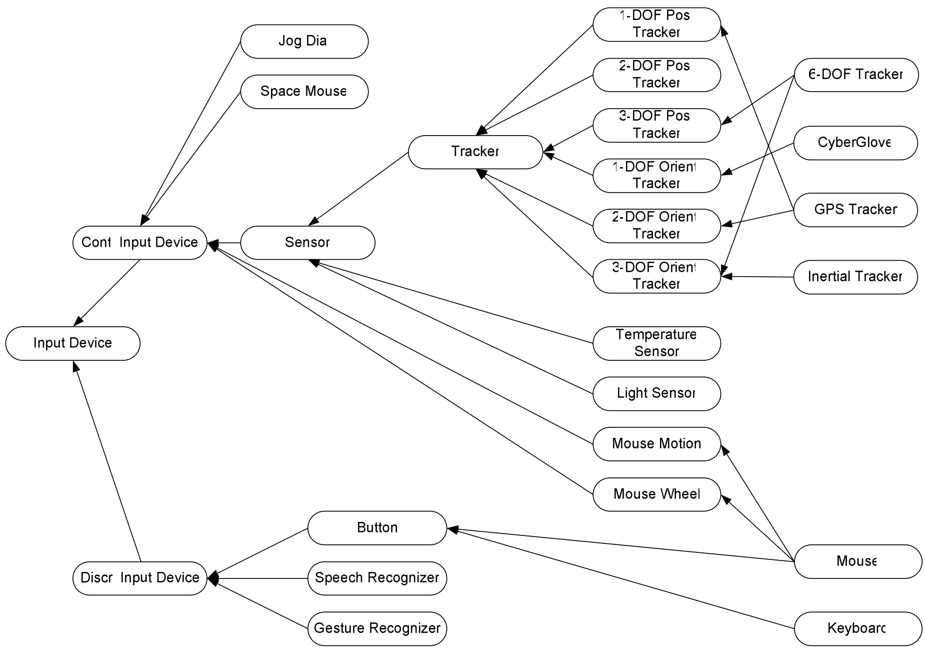

Fig. 1. The hierarchy for input devices. Interfaces for common device classes are inherited by derived device classes.

4.1 Discrete Input Devices

Some input devices generate input data from a finite set of values. Often those values are non-numerical, but rather enumerable, e.g. a light switch may either be *on* or *off* or a button may be *pressed* or *released*. However, the cardinality of the set of values is not restricted to two. Imagine for instance the input selector of an amplifier. It may have six different states {tape, cd, aux, dvd, microphone, tuner}. We define such devices as *Discrete Input Devices*:

> *A discrete input device is an input device, providing decisive input data values from a finite set of discrete values.*

The following devices are currently supported as part of this hierarchy, i.e. the classes representing these devices are derived from the abstract class *DiscreteInputDevice* (compare **Fig. 1**): *Button, GestureRecognizer and SpeechRecognizer*. Button may be e.g. a mouse button or a keyboard button with the states *pressed* and *released*. The gesture and speech recognizer are able to recognize a finite set of hand and finger gestures or spoken commands, respectively. The latter two devices actually do not have a state, which represents the current gesture or word, but they issue an event after recognizing it.

4.2 Continuous Input Devices

In contrast to *Discrete Input Devices*, *Continuous Input Devices* are characterized by continuous input values continuously issued during the usage of the device. The input data may be any value within a certain range of numerical values. The volume knob of an amplifier for instance may have a state within the range [0…100]. Hence we define *Continuous Input Device* as follows:

> *A continuous input device is an input device, continuously providing input data values within a certain (continuous) range.*

The data type of continuous input devices may be any continuous data type. Examples include but are not limited to integer and floating point numbers, 3D vectors, n x n matrices, etc. The state of a temperature sensor may be a value within the range [-20°C…40°C] or the input from a slider may result in integer values within the range [0…3]. The data values provided by continuous input devices have a limited decisiveness, as intermediate values are typically not decisive and may be omitted (e.g. to reduce network traffic). Continuous input devices allow transformations and filtering on their data, which is not possible for discrete input devices.

As mentioned above, in our approach subscribers may choose a maximum update frequency. However, restricting the update frequency usually is only useful for Continuous Input Devices as skipping of a state change in a Discrete Input Device will quite frequently render the transmitted data useless. Beside the maximum update frequency, continuous input devices provide the possibility to specify a desired update frequency. As many of these devices can be sampled or can be configured to deliver events at an application dependent frequency (at least within a certain range), this allows to access a specific device in an optimized manner. An application rendering a 3D scene at a fixed frame rate for example, may choose this frequency for a specific input device to achieve a steady execution. However, the desired frequency of course must not exceed the maximum update frequency (if specified).

The most important sub-hierarchy of continuous input devices are sensor devices:

> *A sensor device is a continuous input devices estimating or measuring a real property and allowing for calibration (in order to provide the desired input)*

The measurement of the property will influence the current state of a Sensor. A typical example for a Sensor device (which is not a Tracker – see below) is a thermometer. Sensors have to be calibrated in order to work properly. However, this does not necessarily have be done by the developer or user, but could have been done by the manufacturer of the device. Nevertheless the software (interface) should allow for a re-calibration or re-adjustment. This is not true for the other continuous input devices, such as the mouse motion device. The mouse motion device provides (depending on the used driver) relative position information about the mouse's movement, but it does not have an absolute position, since it can be picked up and placed somewhere else without changing its state.

Trackers are a subclass of Sensor Devices, which estimate the position or orientation of a real object in 1-3 degrees of freedom (DOF) – a 6 DOF tracker is in our hierarchy a combination of a 3 DOF position and a 3 DOF orientation tracker. They are essential for all kind of VR and AR systems as they require to track the user's location allowing to render the appropriate viewpoint dependent view as well as realizing 3D input such as wands, 3D pointers, or tangible interfaces. All trackers share the same common interface, allowing for setting a transformation matrix containing the individual calibration data. Thus, we define tracking devices (trackers) as follows:

> *A tracking device is a sensor device whose measured property is a position or orientation (1-3 DOF each)*

As already mentioned, tracking devices, which combine position and orientation tracking derive from the appropriate classes, e.g. a GPS tracker derives from 1 DOF position tracker (altitude) and 2 DOF orientation tracker (a direction vector representing longitude and latitude).

Since all devices also provide their data through their derived interfaces, one of the major advantages of this hierarchy is that it allows direct subscription to the interfaces of the actually desired or required device. For instance, a subscriber may only be interested in 3 DOF position data of an object; it will only receive this information and does not have to care whether the object is maybe tracked by a 6 DOF tracker.

5 Output Devices

Output devices represent the second large sub-hierarchy of devices. They are able to represent or to emit information. Again, we define it for completeness based on our definition of devices as follows:

> *An output device is a device, receiving data from the system, affecting its output to reality.*

It either puts the device into a new state or it invokes the device to emit this information, e.g. the state of a relay is set or a speech synthesizer emits the words. Similar to input devices, the state of the output devices can be defined as the information currently represented by the device at the current time. Accordingly, the state is not necessarily identical to the latest output data sent to the device. Similar to input devices, the state of output devices is queryable.

In general, the sub-hierarchy of the output device resembles that of input devices. This also extends to the individual data types and data values. Actually, for many input devices a corresponding output device exists. While for instance a 3-DOF position tracker provides location information, a 3-DOF positioner (output device) allows positioning an object within a specified 3D coordinate system.

According to the sub-hierarchy for input devices, we also distinguish between discrete output devices and continuous output devices. An example for a discrete output device is a switch, which may represent two or more states, e.g. {on, off} or {low, medium, high}. Examples for continuous output devices are relays, positioners and rotators. A concrete example of a positioner and a rotator is the CyberForce, a force feedback device, which is able to control the position of the hand and the angle of each joint. An industrial robot is another example.

6 Adapters

Adapters [3] represent a powerful software design pattern [4], which can be used in this hierarchy as a software component for converting between different interfaces. Adapters allow for using a device in a different way and/or with a different interface than the one originally provided. Thus, an adapter makes a device behaving like a different one. In order to achieve this, an adapter inherits from the destination interface and from the subscriber of the source interface, adapting the input interface to the desired output interface.

For example, an application uses a 3-DOF position subscription to a 6 DOF tracking device to update its camera position, e.g. using an ARToolkit [5] based 6-DOF tracking. In order to be able to use a GPS tracker instead, an adapter can be used to convert the information of the GPS tracker (2D orientation and 1D position) into a 3 DOF position tracking device and publish this data through the interface of a 6 DOF tracker (see **Fig. 2**). This enables the application to subscribe to the GPS tracker adapter. Thus, the two devices may be exchanged without any modification to the application.

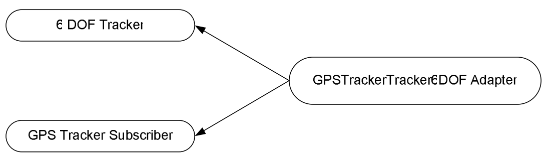

Fig. 2. Inheritance diagram for the GPS tracker to 6 DOF tracker adapter

Since adapters are not limited to one input device, they can also be used to combine the data of several devices and provide them through one interface. The GPS tracker adapter could e.g. also subscribe to a 3 DOF orientation tracker, e.g. an Intersense InertiaCube, in order to provide the full 6 DOF information of the user.

Filters represent another major application area of adapters. We use for instance adapters to provide interpolation and extrapolation filters to input data. Inheriting the original interface of the input device, this allows adding filter chains between a device and the actual application, without the need to change the application.

7 Conclusions and Future Work

In this paper we presented DEVAL, our approach to a device abstraction layer, developed to provide a universal device hierarchy for VR and AR applications. Our goal was to provide an approach which would not only classify existing devices, but also easily extend to any new devices in the future. Using inheritance not only for the device classes, but also for the networked interfaces allows users to use devices which did not even exist at the time the application was developed. Further, our approach provides the application developer with the full flexibility on how to receive the input data from a device. We introduced the major subcategories of input devices within our device abstraction layer: discrete input devices, continuous input devices, sensor devices, and tracking devices. We further showed how our approach naturally extends to output devices. We finally showed how adapters can be used to convert and combine input data from several devices, or to apply filters.

In our future work we intend providing support for streaming input and output devices as well as for alternative network distribution channels beside CORBA.

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A Portal-Based Tool for Developing, Delivering and Working with Guidelines

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Abstract. Guidelines and standards are gaining increasing importance worldwide. However, their process of development is still in a state of flux. The same stands regarding the means for spreading, retrieving and utilising such knowledge. A portal-based approach is proposed here for supporting all lifecycle phases of guidelines and standards. The proposed approach has significant advantages: (a) it allows contributors from all over the globe to form working groups, share virtual working spaces and, thereby, collaborate for the development of guidelines and standards; (b) it facilitates the rapidly spread and effective use of produced knowledge; and (c) it tackles the demand-supply gap by bridging developers and consumers of knowledge.

Keywords: Guidelines, standards, portals, working with guidelines.

1 Introduction

Guidelines and standards are gaining increasing importance worldwide. For instance, guidelines, as directives to perform certain tasks effectively and efficiently, provide designers and developers with a framework for making appropriate and sound decisions. Overall, guidelines can raise the awareness of new concepts, assist in design choices, offer strategies for solving design and development problems, and can support evaluation. On the other hand, standards, as a stricter form of guidelines in terms of preparation, presentation and use, aim at transforming values criteria (e.g., quality, safety, efficiency and effectiveness) into real attributes of products and services. In general, standards contribute to economic and social progress since they facilitate global trade, improve quality, safety, security, environmental and consumer protection, promote the rational use of natural resources, and disseminate technologies and good practices.

For many years, guidelines and standards have constituted an inexpensive and widely used tool. However, despite their indisputable value and importance, several studies investigating the use of guidelines and standards by designers and developers [e.g., 1] have concluded that they are frequently ignored. This is mainly due to the

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way that such knowledge is developed, communicated and used. Guidelines are often developed by organizations as part of internal and time consuming processes and there are no specialized IT tools available for facilitating their. On the other hand, regarding the dissemination of such knowledge several issues arise, mainly due to the fact that they are not exploited easily [4], and partly due to the nature of their typical incarnation medium (i.e., paper based-manuals), which usually raises issues of ineffectiveness and lack of user-friendliness [2]. Other issues involve the fact that guidelines are usually context of use - dependent, they often conflict with each other, and they may need supporting references, best practice examples and illustrations.

These limitations, in combination with the emerging need for interactive tools to support development activities, have given rise to a new generation of tools, which are usually referred to as *Tools for Working with Guidelines* (TFWWGs). TFWWG [11] are interactive software application or service that offer support for the use and integration of guidelines-related knowledge at any stage of an IT product development life-cycle. In this direction, preliminary efforts were targeted to the integration of guidelines into hypertext-based tools [e.g., 4, 11] or digital libraries [e.g., 4]. TFWWGs were also designed to assist the user interface usability inspection process and provide active support to various phases of the development process.

The use of portal technologies is proposed as an alternative mean for developing, and working with (i.e., dissemination and deployment) guidelines, through the incorporation of several well-explored mechanisms, such as search and browse facilities, online communities, communication and collaboration mechanisms, project administration facilities and digital libraries.

2 A Process for Collaborative Development of Guidelines

Overall, efforts in the field of TFWWGs have mainly focused on the effective and efficient delivery of such knowledge to potentially interested parties, putting limited attention to the lifecycle (development, dissemination and use) of guidelines and standards. To address this issue, a portal-based approach is proposed here as an innovative mean for developing and using guidelines, thus promoting a paradigm shift, from TFWWGs to *Tools for Developing, Disseminating & Deploying Guidelines* (D^3Gs). In this direction, this paper defines a generic framework for the Collaborative Development of Guidelines and Standards (CDGS) involving all major stakeholders, and the appropriate computerization of this consensus building process so that it can be accessed from anywhere at any time.

The objectives set during the specification of the process for CDGS were to facilitate guidance and standardisation activities in various application domains; support the remote and collaborative development of such knowledge; bridge the gap between knowledge developers and knowledge consumers; and avoid the under-utilisation and regeneration of existing knowledge. The processes followed by a number of standardisation bodies were reviewed, paying particular attention to processes that involve approval from the public and / or external standardization bodies. The final outcome is instantiated into two slightly different variations, one for developing guidelines (brief) and one for standards (extended).

Research and development of guidelines and standards for a specific domain can be organised into general Working Groups (WGs) in order to ensure coherent coordination, planning and programming of all activities. The stakeholders involved in such a process are briefly analysed in Table 1.

Table 1. Stakeholders of the CDGS process

Working Group Members (WGMs)	Persons[1] with expertise or direct interest in a specific WG, and who can potentially participate in a new CDGS Project[2]. They can also be responsible for conducting collaborative an analysis of the state of the art within the WG, and brainstorm ideas for New Work Proposals[3] (NWPs).
Working Group Leader (WGL)	One person per WG, delegated to moderate (invite, accept, etc.) the corresponding WGMs and lead technically all WG Projects.
Originator	A person proposing the preparation of a new set of guidelines or standards (i.e., a new CDGS Project). This is achieved by means of editing and submitting a NWP.
Editor	Typically the same person as the Originator of a NWP. Upon the approval of the NWP, the Editor is responsible for drafting the new set of guidelines or a standard, i.e., for running a new CDGS Project and editing the corresponding CDGS Report[4]. The Editor is also responsible for co-ordinating the work of all involved Authors (see below).
Authors	Upon approval of a NWP, the corresponding Editor specifies the authors (i.e., a team of experts) to participate to the new CDGS Project and contribute to the preparation of the corresponding CDGS Report.
Board of Executives (BoE)	A group of persons responsible for any operational issues and general decision making across all WGs.
External Experts (ExEs)	External (i.e., other than corresponding WGMs) persons with technical expertise related to the topic of a CDGS Project, and who are willing to review and provide their comments upon (draft versions of) the corresponding CDGS Report.
Interested Parties (IPs)	Persons who represent the target market of a WG. Interested Parties are offered the right to vote and comment upon NWPs and CDGS Reports of the WG in question.
Focal Points (FPs)	A WGM, nominated by the corresponding WGL and required to administrate and act as contact persons to the WG's IPs.
Guidelines & Standardisation Experts (GSEs)	Persons with expertise in procedural and normative matters. They act as peer quality reviewers of submitted CDGS Reports.

From the moment a WG is created, a **Brainstorming** activity begins and runs until the WG gets annulled. Throughout this activity, the members of a WG participate to special interest discussions aiming at reviewing the state of the art across the corresponding WG, and brainstorming ideas for new work proposals.

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[1] Or organizations.
[2] CDGS Project: A project for the Collaborative Development of Guidelines / Standard.
[3] New Work Proposal (NWP): Is an abstract document specifying the objectives of a new CDGS Project and suggesting potential authors for the corresponding CDGS Report.
[4] CDGS Report: This is the main outcome of a CDGS Project, i.e., a collection of guidelines or (a set of recommendations for) a standard.

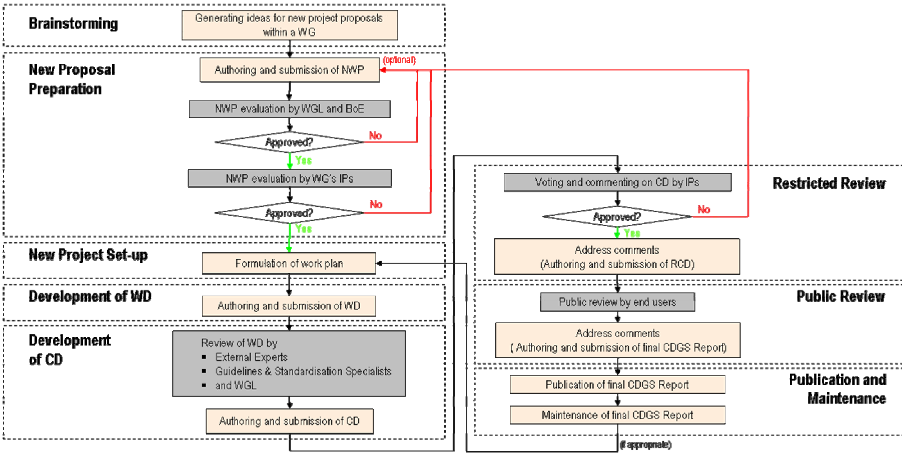

Fig. 1. Overview of lifecycle of guidelines development

The development lifecycle of guidelines and standards (see Fig. 1) involves:

- **New Proposal Preparation.** Once the concept for a new CDGS Project has been formed by an Originator, the preparation of the corresponding NWP is initiated.
  a. First, the Originator drafts a NWP and submits it to the relevant WG. The NWP must specify the Editor and Author(s) of the new CDGS Project.
  b. Then, the NWP is assessed by the corresponding WGL and BoE.
  c. Upon approval, the NWP is disclosed to IPs for their comments.
- **New Project Set-up.** Upon approval of a NWP by the IPs, the WGL announces the launch of new CDGS Project. At this point, the Editor, in communication with the Authors, formulates an appropriate work plan (i.e., stages, deliverables and deadlines).
- **Development of Working Draft (WD).** The Editor and the Authors are responsible for the development of the first draft of the CDGS Report, namely the Working Draft (WD), which is the submitted for review.
- **Development of Consensus Draft (CD).** Then, the WD will undergo a review by ExEs, GSEs and the relevant WGL. The comments of these people are then addressed, leading (through iterations) to the Consensus Draft (CD).
- **Restricted Review.** The CD is put to the ballot among IPs, gathering their comments. The outcome of this phase is the Revised Consensus Draft (RCD).
- **Public Review.** Then, the RCD is made publicly available (e.g., to industrial users) for gathering further comments, which are addressed accordingly leading to the creation of the Final CDGS Report.
- **Publication and Maintenance.** The final stage of the CDGS Process is the publication and maintenance of the Final CDGS Report. Publication makes the Final CDGS Report available for public use, and -if appropriate- submitting it to external standardisation bodies. On the other hand, maintenance is concerned

with keeping a Final CDGS Report up-to-date. Depending on the results of evaluations (e.g., annual), one of the following processes can be initiated:

a. Collaborative Revision of Guidelines and Standards (CRGS). This process aims at revising a CDGS Report (similar to the CDGS Process).
b. Withdrawal. This involves archiving and removal from public view / use.

Guidelines- and standards-type documents produced by means of the CDGS process (i.e., CDGS Reports) are developed according to strict rules that ensure transparency. However, it can take time to achieve consensus among the interested parties and to go through the public review process. In some cases thought, and particularly in cases related to fast-changing technology sectors, it may be more important to agree on a technical specification and publish it quickly. Therefore, a range of different categories of reports can be produced, allowing publication at an intermediate stage before full consensus (see section 3.2).

3 Toward a Support Tool

This section presents some of the main aspects of a D^3G tool (see section 2).

3.1 Generic User-Requirements

In terms of functional requirements, the development of knowledge (i.e., the CDGS process) requires the employment of technological solutions for the development of *online communities* [8], including communication and collaboration facilities. Additionally, the process of knowledge development, in order to achieve consensus and quality, entails formal and informal reviews of the developed documents by a number of parties. Therefore, a flexible reviewing and annotation mechanism is also required. Consensus in the context of an online WG can be achieved through the incorporation of voting mechanisms.

The CDGS process constitutes of a complex workflow that needs to be computerized integrating a mechanism that facilitates the administration of projects. Such mechanism shall enable Editors to breakdown the activities involved in the development of report into sub-tasks, and assign specific responsibilities to authors and deadlines for each task. Another crucial issue is notifying participants, e.g., about pending tasks. This can be achieved through a notification facility for sending messages to each member of the process personally and according to their assigned roles. Finally, a specialised task manager mechanism is required to provide to each participant, upon demand, a detailed overview of the process.

Another critical issue concerns the dissemination and use of developed knowledge. One of the most effective ways to organize knowledge in the context of a web portal is the provision of a *digital library* [1] with facilities such as browse, search, rating and bookmarks. Additionally, *user profiles* can be used when performing knowledge retrieval operations in the digital library for filtering the retrieved results [6, 9]. Finally, online communities can support the *social navigation* [2] of knowledge.

On the other hand, the administration of knowledge entails the need of mechanisms used for administrating the available collections of knowledge and the types of resources stored in the knowledge base, and for enriching the knowledge base by adding new resources.

3.2 Resource Classification and Organisation

There are two main types of resources (i.e., digital documents) that can be developed and disseminated throughout the process:

- *Single Elements*. These constitute resources that can been perceived as stand alone sources of knowledge and include: (a) Single Guidelines or Rules; (b) Code Templates; (c) Design Patterns; (d) Experiments; (e) Best Practice Examples; (f) Hardware products; (g) Software products; and (h) Reference materials.
- *Compilations*. These are compilations of Single Elements in the form of the following document types produced following the CDGS process: (a) NWP[3]; (b) Publicly Available Specification; (c) Technical Report; (d) Technical Specification; (e) Internal Workshop Agreement; (f) Guidelines Collection; (g) Recommendations for new or revised standard; (h) Draft Standard; (i) Internal Standard.

The 'knowledge base' of the pilot D^3G is organised as follows: At a first level, the knowledge base consists of Datasets; each Dataset has an administration team, user group and may contain one or more Compilations and/or Single Elements.

4 An Interactive Prototype

This section presents some of the main aspects of a prototype D^3G developed in the context of the EC[5] Network of Excellence (NoE) INTUITION[6] ("Virtual reality and virtual environments applications for future workspaces". The rationale and motivation for developing the *Portal for guidance and standards for Virtual Reality*[7] is to take advantage of the spread excellence shared among the INTUITION partners, and establish an *online communication and collaboration community* for developing, spreading and working with guidelines, including recommendations for standards. The main objective of the portal is to bridge the gap among all key stakeholders (end-user from the industry, VR developers, academia and research, standardisation bodies and other experts) and to facilitate the coordination and smooth operation of their collaborative activities.

The INTUITION portal is the first platform worldwide of it's kind, and serves as a leading platform providing, among others, consensus building mechanisms, multi-sector coverage and ability to efficiently disseminate and promote a range of deliverables relied upon by industry. Notably, the ISO Strategic Plan 2005-2010, in identifying the actions to be pursued from ISO towards realising the global vision for the organization in 2010, consists of seven key objectives, among which stands the following: "*Providing efficient procedures and IT tools to support the development of*

[5] INTUITION project (IST-NMP-1-507248-2) is partly funded by the Information Society Technologies Programme of the European Commission – DG information Society.

[6] Project website: http://www.intuition-eunetwork.net/

[7] Currently available at: http://hci-web.ics.forth.gr/Intuition

a coherent and complete range of deliverables ... implemented by members and participants in the technical work".

The developed portal consists of three main areas with different looks-and-feel in term of presentation, functions and navigation models.

The **Dissemination Area** is an open area informing the public about the scope and objectives of the INTUITION work on guidelines and standards. In addition, a visitor's entrance has been implemented for increasing the user-perceived usefulness of the tool (see Fig. 2) along with a public module introduced for gathering user requirements and feedback, which enables users to communicate, anonymously, their comments and ideas to relevant WGs and, ultimately, further inspire knowledge developers in their brainstorming activities.

The **Deployment Area** is a restricted area that builds on previous practices on TFWWGs and which provides personalised services to knowledge consumers. Users of this area can explore and exploit the knowledge stemming from the development activities, participate to public reviews and user forums, and take advantage of social navigation and other facilities (see Fig. 3). In particular, access to available knowledge resources is provided, along with a personalisation mechanism for filtering information to specific interest areas. Resources are in the form of data (e.g., a guidelines collection), accompanied with supporting metadata (e.g., applicability, user reviews, reference materials) for enhancing the usefulness and usability of provided knowledge. Finally, facilities of traditional online communities are incorporated in order to promote socialisation and consultation among consumers.

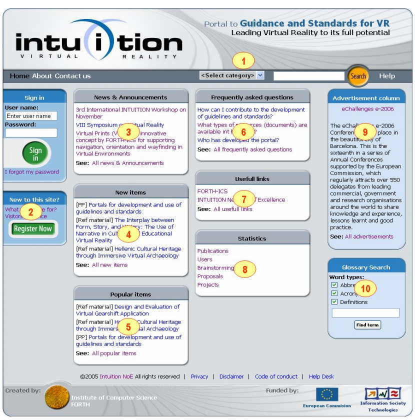

Fig. 2. *Dissemination Area*: (1) Search area, (2) Registration, (3) News & Announcements, (4) New items, (5) Popular items, (6) Frequently asked questions, (7) Links, (8) Statistics, (9) Advertisements and (10) Glossary

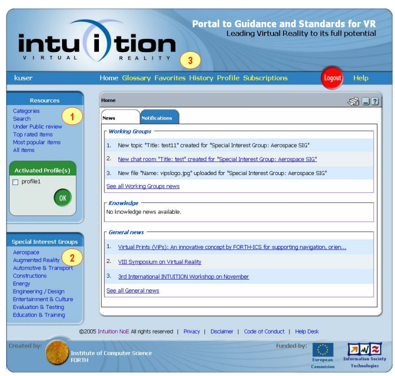

Fig. 3. *Deployment Area*: (1) Resources, (2) Special interest groups and (3) Additional Functionality

The **Development Area** is a restricted area too, and serves as virtual space for collaboration among knowledge developers (see Fig. 4). In essence, this area constitutes the implementation of the CDGS process briefly described in section 2. A fundamental requirement, emerging from the process itself, is the need to support multi-roles per user (see section 2). To address this issue, an incremental portal structure was developed. The initial level provides knowledge developers with two different views; the developer's view (working area) and the users' view (in order to be able to quickly check on the way artefacts are presented to knowledge consumers. Then, the developers view is structured around the core role of WGM (see Fig. 5). This way, WGL, Originators, Authors, etc. are presented with supersets of the functionality for simple WGMs. As it can be seen in Fig. 5, contributing roles such as IPs, ExEs and GSEs are horizontal and distinct. Nonetheless, all views have consistent and similar designs in order to avoid confusion, as one user may participate to more than one WGs undertaking each time different roles.

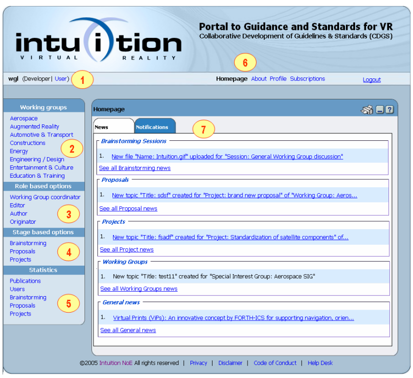

Fig. 4. *Developement area*: (1) The role - layout switching bar, (2) Working Groups, (3) Role based options, (4) Stage based options, (5) Statistics regarding knowledge development and use, (6) Additional functionality and (7) News & Notifications

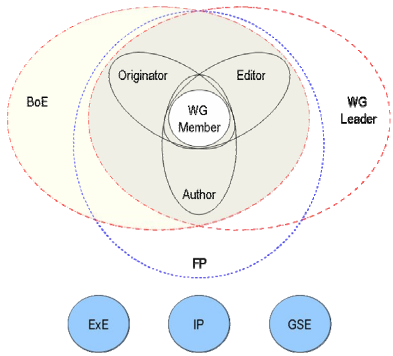

Fig. 5. Incremental functionality in order to support multiple roles per user (within a single WG). For instance, a WGL is offered a superset of the functionality for WGMs, and can act as Editor in one Project and as Author in another one.

5 Discussion and Conclusions

Our early experience with the proposed approach, thought the presented prototype system in the domain of virtual reality, has provided valuable feedback in all of the three major aspects of this work: (a) the employment of advanced portals technology for guiding and facilitating the collaborative *development* of guidelines and standards, (b) the integration of various information retrieval, communication and collaboration mechanisms for empowering various interested parties in *deploying* the available knowledge appropriately, and (c) use of the same platform for achieving easy and rapid *dissemination* of knowledge, as well as direct user support and feedback.

Towards the first of the above objectives, one of the main challenges encountered was the specification of an appropriate process. A generic process for the *collaborative development of guidelines and standards* (CDGS) was elaborated and computerised in order to be operated via the Web. The difficulties involved were: (a) the need to ensure that the process is generic and adaptable to increase its applicability in various application domains, (b) the need to be solid and compliant with the processes followed by a number of standardisation bodies, (c) the need to be easily operated also by people with little experience in the field of guidance and standards development, and (d) the necessity to be configurable and capable of producing a wide range of documents. Additionally the computerisation of this process was itself a major challenge. The difficulties involved included: (a) a wide range of user roles with different goals and tasks in the context of development activities had to be supported, often in combination, leading to an increased complexity of functionality and user interface, (b) the development of a mechanism for implementing the various sequential and conditional stages and tasks involved in the CDGS process, and (c) the design of an appropriate mechanisms for collaborative document editing and reviewing, as this incorporates various issues of privacy, authorship and intellectual property rights, and coordination of read and write rights. Overall, a potential drawback is the current lack of mechanisms for tracking document changes; especially in cases where a large number of authors are involved.

The second of the above objectives was addressed by providing a wide range of services for knowledge retrieval, such as search and browse facilities, user profiles for results filtering, as well as mechanisms for maintaining personal collections of knowledge, social navigation and community based communication. The main challenge involved here was the provision of mechanisms for role layout switching for the case of knowledge developers where the role of developer and consumer may coexist. Another major challenge was the design and development of the knowledge base of the system so that the process could be applied in various application domains. This implied: (a) the development of a knowledge base that can be extended to support new resource types and (b) the provision of a mechanism that enables the translation of process outcomes to comprehensive and structured digital publications.

Finally, concerning the third objective, several mechanisms were implemented and made available to web-surfers and visitors of the portal. More specifically, a number of alternative ways for accessing metadata regarding available publications were provided, accompanied with peripheral facilities such as news, dictionaries, advertisements, useful links, frequently asked questions, etc.

Planned enhancements of the existing mechanisms include process customisation, which can be of particular importance for integrating the system in various contexts and generating alternative processes. In order to fully support the development of standards, additional steps of the CDGS process should also be incorporated. Furthermore, semi-automatic classification of the knowledge stored in the system's database could be investigated and implemented, based on various existing cross-referencing techniques for ergonomic resources (e.g., [4]). The provision of enhanced accessibility features and user profile adaptation could be considered in order to accommodate the needs of users with disability.

Finally, in order to evaluate the prototype tool, identify possible shortcomings, and provide suggestions for potential improvements, expert-based and user-based evaluations have been planned.

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From "Design for All" Towards "Design for One" – A Modular User Interface Approach

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Abstract. The paper describes an approach to specifically tailored user interface design, to adapt the user interface to the specific needs of mobility impaired travellers. Given a user has some interaction impairments or s/he is in a situation that causes an interaction impairment (i.e. noisy environment has the same consequences as hearing impairment), another modality is to be used or adapted to compensate this impairment. As sound has other interaction characteristics than graphical user interface elements (e.g. information can not be presented in parallel, but sequentially), rules for substituting some modalities through others are described.

Keywords: Design for all, mobility impaired people, user interface design, adaptive user interfaces.

1 Introduction

1.1 Universal Design and User Interface Adaptation

Universal design, being a design for all approach, aims at "… designing products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Story et al. 1998).

What should a universally designed product fulfil according to this definition? All people should be able to use it, but maybe not the full functionality. This would be a real disadvantage for these people. The other requirements that can be derived from the definition are that adaptation and specialized design should not be needed to use the product. Why? Because there should not be any extra effort or burden for some people to use the product – adaptation normally implies tedious configuration procedures and often requires expert knowledge. This is where the research project ASK-IT aims to provide a solution.

C. Stephanidis (Ed.): Universal Access in HCI, Part I, HCII 2007, LNCS 4554, pp. 517–526, 2007.

1.2 ASK-IT Project

ASK-IT[1] is a research project, that aims to support mobility impaired people with information on accessible routes, travel information, guide them around, provide assistance - enable them to travel independently. Mobility impairment in ASK-IT is defined in a very broad sense: all people who are hindered in one way or another in their mobility are mobility impaired. This can be an impairment of the upper or lower limbs, as well as illiteracy, a visual impairment or deafness.

The main ASK-IT user groups are listed below. The names of the user groups refer to an impairment or difficulty that can limit the user's activity. To each of the named user groups 2 to 5 sub-groups have been identified (Simões & Gomes, 2005). As you can see, the user interface has to take into account very diverse interaction requirements.

1. Lower limb impairment.
2. Wheelchair users.
3. Upper limb impairment.
4. Upper body impairment.
5. Physiological impairment.
6. Psychological impairment.
7. Cognitive impairment.
8. Vision impairment.
9. Hearing impairment.
10. Communication producing and receiving difficulties.

The user interface design approach in the project ASK-IT aims to solve the problem of tedious configuration: the user interface is adapted automatically to the interaction requirements of a specific person: if this person is blind, the contents are given in audio, if the person is in a wheelchair, standard graphical user interface elements can be used.

One main challenge of the project is to provide an adapted user interface to the very heterogeneous interaction requirements mobility impaired people bring in. To achieve this in an economic way and to make sure that the overall system has a consistent look and feel, ASK-IT adopts a modular approach in user interface design: user interface elements for all modalities are developed, tested and defined and – given the specific interaction requirements of a person – combined to the individual user interface. This builds on the principles of Unified User Interface development (Stephanidis & Savidis, 2003).

1.3 Interaction Restrictions vs. Functional Requirements

Mobility impaired people bring in specific requirements for the design of applications and services. On the one hand they have specific functional requirements that need to be met. Thinking about travel planning, accessible routes and accessible places mean something different for different user groups: for a wheelchair user an accessible route means that s/he needs a route without steps, not too steep and without cobbled

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[1] The project ASK-IT is funded by the EC in the 6th framework program, priority IST-2002-2.3.2.10 eInclusion. Contract no.: IST-2003-511298.

pavement. For a visually impaired person, an accessible route might be the one with good lightning, big direction signs and with handrails in staircases in buildings. So, for each user group, their specific functional requirements are used for calculating the best route for them. The issue what accessibility means for each of the user groups is dealt elsewhere (Wiethoff & Sommer, 2005).

The issue of this paper is how to consider the diverse interaction requirements of mobility impaired people in user interface design. It is easy to figure out that blind people do not profit from visually presented information and people with upper limb impairments often use assistive devices to interact with software applications. On the other hand, the solution for this issue is more complicated than simply replacing text display by speech output for blind or sounds with a vibration signal for deaf people. This replacement has to take into account context factors (e.g. privacy in public surroundings), as well as the interaction characteristics of the different modalities.

2 ASK-ITs Modular Approach for UI Design

The challenge to meet the requirements of the heterogeneous user (sub-)groups ASK-IT will support, requires a user interface that will be automatically configured, according to the user profile (Bekiaris & Gemou, in print). The aim is to develop user interface concepts and elements to support user preferences and context-driven services. Therefore the approach to user interface development is to develop generic user interface patterns, that fulfill a set of interaction requirements and to define a schema to allocate them to user group and context requirements. This schema is based on a suitability analysis of a range of user interface elements and an assessment of interaction characteristics of the respective user interface elements. The approach is sketched out in the following paragraphs.

2.1 Interaction Characteristic of Selected User Interface Elements

An overview on interaction characteristics of selected user interface elements of different modalities is provided in figure 1.
The term *interaction characteristics* refers to what a specific user interface element can be used for, concerning its *reaction potential* and the *complexity of information* that can be displayed.

The *reaction potential* can be either no specific potential to evoke reaction, e.g. simple display of information, that is noticed only when attention is especially paid to it. The other options are user interface elements that grab attention and others that have the potential to evoke alert. The difference between attention and alert is seen, if a change of some variable is noticed by the user or if the user understands that actions have to be taken immediately.

This can easily be understood on the example of the user interface elements used nowadays by a standard mobile phone. Text display and graphical elements are used to generally display information. If the user should pay attention to a system reaction, e.g. when there was a failure sending an intended text message, this message is not only given by text, but additionally supported by a sound signal. Sound and vibration elements are used to indicate when a new text message has been received. This would

Interaction characteristics		Text (Output)	Graphics, Icons	LEDs (i.e. in-car)	Sound	Acoustic icons, earcons	Speech (Output)	Vibration	Tactile display	Smell	Braille (Output)	Sign language (Output)
Reaction potential	Attention (notice about change, but not immediately)	1	1	1	2	2	2	2	1	2	0	1
	Alert	0	0	0	2	2	0	2	0	0	0	0
Complexitiy of information that can be displayed	Binary type (i.e. present/not present)	-	-	X	X	-	-	X	-	X	-	-
	Information differing on one dimension (ordinary scale, i.e. timeline until event starts), few distinct codes (i.e. status)	-	X	X	-	X	-	X	X	X	-	-
	Complex information (i.e. explanations)	X	-	-	-	-	X	-	-	-	X	X

Fig. 1. Interaction characteristics of different user interface elements: reaction potential and complexity of information that can be displayed (reaction potential: 0/red = UI element does not have respective reaction potential, 1/yellow = UI element partly has respective reaction potential, 2/green = UI element has respective interaction potential; complexity of information that can be displayed: - = respective information can not be displayed by UI element, X = respective information can be displayed by UI element)

probably be overseen by the user, because in most times the display of the mobile phone is not monitored for a change in information display. Not in all cases an immediate reaction is needed, but the attention grabbing characteristic of sound and vibration allows the user to check the information and react, if needed. If a phone call comes in, in most cases an immediate reaction (pick up the phone) is to be taken. Here, not only a text display on the caller and vibration elements to gain attention are used, but also the sound element that indicates the phone call can be personalised, to support not only attention, but also semantic interpretation and focused action. Additionally, the sound element is displayed, until the user has taken the appropriate action.

In figure 1, a selection of user interface elements are evaluated concerning their reaction potential: the scheme worked out, for indicating the reaction potential of a specific user interface element, uses three levels: “0” stands for user interface element does not bear this characteristic, “1” indicates that under specific circumstances the user interface element shows the specific characteristic, and “2” indicates that the specific characteristic is prominent in the respective user interface element. For a better overview, the levels are additionally colored, using the traffic light metaphor (red for “characteristic not supported”, yellow for “partially supported”, green for “fully supported”).

As indicated by the mobile phone example, all displays that target the visual channel (e.g. text display, graphical elements, LEDs) are useful to gain attention only under specific circumstances – only if the display is in the vision field and is actually paid attention to already or uses attention gaining mechanisms, like blinking. To gain attention, sound-related elements or vibration can be used.

The *complexity of information* that can be displayed is an indicator of how rich a specific user interface element is in displaying information. As a starting point, three levels of complexity have been defined: if “binary type” of information can be displayed, it means that the user interface element is either present or not present. An example for that are LEDs in cars, that indicate that there is either a problem with the battery or there is no problem. This type is easy to understand but works only for few pre-known events. The next level of complexity is “information differing in one dimension" or in only "few distinct codes". The first could be an ambient display, that codes the time until an event is due in a continuously changing color display from "yellow" via "orange" to "red". The second could be acoustic icons, that stand for different events, e.g. new email, new appointment, reminder on event due. The highest level of complexity is "complex information". The interaction with a system also requires displaying more complex information to the user, e.g. explanations. As indicated in figure 1, there are only a few user interface elements, which are suitable for this type of information, especially when the information is abstract in a way. These are text and speech output, Braille and sign language.

2.2 Assessment of Suitability of a User Interface Element Per User Group, Context, and Information Type

User interface elements can be understood as building blocks of the respective user interface. They can be split into categories, according to the sensory channels they address: "visual elements", "acoustic elements", "haptic elements", and "olfactoric elements". The user interface elements are divided in input and output interaction whereas some elements are only sensible as either input or output (e.g. only olfactoric output) (see table 1).

Table 1. User interface elements analysed for their suitability for user groups and context requirements

UI element category	UI elements analyzed
Visual elements	Text, graphical elements (icons), LEDs, ambient displays, gaze-based interaction
Acoustic elements	Acoustic icons, earcons, acoustic input (e.g. paraverbals, humming), speech input and output
Haptic elements	Touch, vibration, tactile displays, gestures, motion, pressure, interaction with tangible objects
Olfactoric elements	Smell & taste output

To define which user interface elements are used in the respective ASK-IT user interface for each impairment group and context of use, these UI elements have been assessed by their suitability for a) user requirements and b) context requirements.

2.3 Interaction Requirements Per User Group

The approach is illustrated by the following example: One UI element, using the visual channel, is the display of text. In the examination of suitability of UI elements for user groups, it turned out that text display is "suitable" for the following user groups:

- Lower limb impairment
- Wheelchair users
- Upper limb impairment
- Psychological impairment

For the following user groups it is "partly suitable". That means it is either not suitable for all user sub-groups (e.g. it is suitable for some people with communication impairments but not suitable for users who can not read) or suitable only with adaptation to specific requirements, like “only with adaptable text size”, “only very few and easy words”. Here specific guidelines for design have to be formulated:

- Upper body impairment
- Physiological impairment
- Cognitive impairment
- Vision impairment
- Hearing impairment
- Communication producing and receiving difficulties

In the next step, the “text output” for ASK-IT will be defined for the respective use cases and used in user interface design of all groups, for whom the user interface element is suitable or partly suitable. In this case, the type of adaptation needs to be defined additionally. Sharing of interaction requirements leads therefore to common UI patterns.

An example for a UI element being “not suitable” for a specific user group is the haptic element “Gesture input”. “Gesture input’” is not suitable for people with upper limb impairment. Accordingly, the user interface for people with upper limb impairments should not contain gesture input, but e.g. speech input. Speech input itself would not only be suitable for this user group but also e.g. for people with severe vision impairment.

2.4 Interaction Requirements per Context of Use

The requirements are not only shared by user groups. The context of use also brings in interaction requirements. The following contexts of use are to be considered for nomad device applications:

- Car
- Home
- Public place (e.g. public park, shopping mall, pedestrian zone)
- Transportation station (e.g. airport, train station)
- Transportation means (e.g. bus, train)

In table 2 the interaction requirements, in terms of interaction limitations for the different contexts of use, are described:

Table 2. Interaction limitations of contexts of use

Context of use	Interaction limitations
Car	Parallel task driving/attention switching, hands and eyes mostly involved in primary task, noisy, vibrations
Home	None
Public place (e.g. shopping mall, pedestrian zone)	Can be noisy, no privacy
Transportation station	Very noisy, no privacy
Transportation means	Very noisy, no privacy, vibrations

The suitability of user interface elements, for a given context of use, has therefore be assessed in a similar way than for user groups.

In the car context, none of the user interface elements really seems to be ideal, because the visual sense, as well as the haptic sense, are involved in the primary task of driving. How noisy it is in the interior and how good the ability of the person will be to distinguish different sounds depends on the car and the actual speed. The same holds true for vibration outputs. Additionally, vibration can cause an alert reaction, which is not wanted in the context of car driving. As a consequence, the user interface in the car will consist of a combination of adapted visual and acoustic-related elements. Adapted means that, compared to the user interface the respective ASK-IT user uses being not in the car, s/he will have bigger interaction elements and louder acoustic signals – the same holds true for a person with light visual and hearing impairments.

Whereas the home as usage context usually does not imply impairing interaction characteristics, public places and especially transportation related contexts bear challenges for interaction design. They can be quite noisy and in transportation means also vibrations are prominent. This makes interaction using haptic senses more difficult and vibration output is often not noticed – only if the vibration is at the body it may be noticed. The characteristic of reduced privacy leads to some restrictions in speech output, depending on what output is given. For that, visual user interface elements are very suitable. But for gaining attention, providing alerts and for people with severe visual impairments, other solutions have to be found. For ASK-IT, it is planned to implement on the one side sounds for information presentation, e.g. for navigation support for blind people. They are less intrusive than speech output and allow a higher level of privacy. If it is too noisy, an earphone can be used and a combination with haptic elements, placed suitably at the body, needs to be considered.

2.5 Interaction Requirements of Information Type

The information offered by the ASK-IT system has to be displayed, according to the underlying requirement, each by single messages to the user. This is especially true, if an immediate reaction is required or if it is the system reaction to a user-triggered request. Table 3 gives an overview on the requirements, based on the characteristics of each information type. More information can be found in Gemou & Bekiaris (in print).

Table 3. Interaction requirements of information type

Information type	Example	Characteristics	Requirements
Pushed information	Information provider sends according to user interests	Non-critical, not urgent, importance low, attention level low	Attention and complex information
Information (non-critical)	Pull information, i.e. get train timetables	Non-critical, not urgent, importance high, attention level high	Complex information
Critical information	Get of the bus the next station	Critical, not urgent, importance high, attention level low	Attention/Alert and some information
Emergency	Get of the bus immediately!	Critical, urgent, importance high, attention level not specified	Alert and some information

For a modular approach in UI design, the respective UI elements have to be carefully chosen and combined to only replace UI modalities, that have similar interaction characteristics. E.g. if a person is deaf, the allocation schema should not allow to provide notifications in very big visual elements, because they will only be noticed in the vision field, in contrast to acoustic elements.

3 Integrated User Interface

The integrated user interface, to be developed in the ASK-IT project, contains all user interface elements used in the ASK-IT application and develops rules for combination and substitution of these elements, to meet user and context requirements. This integrated user interface is not what a single user will be confronted with. The user will use the part and combination of UI elements that is suitable for him/her and that will allow fulfilling the interaction characteristics needed for the specific content. To sum up, the user interface for a specific user is firstly defined by his/her interaction range. Within this interaction range, the most suitable interaction for the given context is defined and the suitable building blocks for the information type are selected.

The user interface for a blind person would therefore use, e.g. acoustic elements, to indicate an important unforeseen event and explain that in more detail, in either speech output or Braille, depending on the context of use and the abilities of a person to understand Braille. For a deaf person, the attention could be gained by vibration feedback, while more information on the event is provided in text or graphical elements. For deaf and blind people, only a combination of haptic elements can be used, with the problem of how to display really complex information.

As a consequence, the design of adapted user interfaces is not as trivial as to substitute one user interface element by the other, because persons´ impairment allows them not to understand all possible user interface elements. A substitution only makes sense for user interface elements that have the same interaction characteristics.

4 Next Steps

On the basis of the selected user interface elements, to be developed in ASK-IT, according to the suitability analysis of user and context interaction requirements prototypes are developed, tested, and optimized with users within the project. The prototypes show how the ASK-IT user interface will look and work in principle. This way ASK-IT follows a user-centered design process (ISO 1999), specifying requirements, building prototypes and optimizing them iteratively with users and implementing them when the requirements are met.

The prototypes cover a specific cutout of the whole ASK-IT system to target the user interface specification for all user groups, application domains and devices. The dimensions targeted in ASK-IT are shown in figure 2.

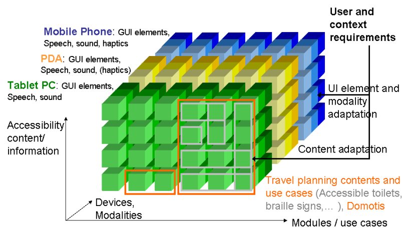

Fig. 2. Integrated user interface ASK-IT with relevant dimensions targeted

The approach of ASK-IT user interface development is modular and can be compared to a more-dimensional dice. The selected prototypes cover specific parts of the dice and the integrated user interface will then fill the remaining parts through transfer of the knowledge gained in prototypes development.

Therefore the prototypes are a:

- Selection of use cases
- Selection of user group related content and functionalities
- Selection of modality (depending on user and context requirements)
- Selection of device (depending on user and context requirements)

I.e. the prototypes show specific examples for the overall integrated ASK-IT user interface. Concerning pedestrian navigation, e.g. a prototype using graphical user interface elements (text and graphical elements) was developed. Another prototype shows how pedestrian navigation for blind people can be achieved with sound elements. For the integrated user interface, the conceptual integration of all user interface elements will be achieved. An analysis of replacement of different modalities according to user and context interaction requirements will be done, the learnings and principles of each prototype and the transferability to other user groups, devices, use cases, etc. will be discussed.

5 Conclusion and Outlook

In this paper, a modular approach to user interface design, using defined user interface elements, was presented, to fulfill very diverse interaction requirements. This design approach allows specific individual adaptation and therefore a "design for one". This approach is not meant to be the opposite of a "design for all" approach, but to take the ideas in that approach a little further and solve arising problems with the help of self-adaptation mechanisms. The algorithms being the basis for that are dealt elsewhere (Ioannins & Savidis, 2006) – this paper provides the conceptual basis for the respective adaptation.

The advantage of the approach of defining user interface elements according to the interaction requirements is that, not only the useful schema for user interface development for mobility impaired people, but also for user interface adaptation to contexts of use: a person with hearing impairments has the same interaction requirement as a hearing impairing context of use – e.g. a train station.

Further systematic research still needs to be done in acoustic user interface elements and haptic interface elements. For using them not only as an enhancement of graphical user interfaces, but also for replacing these elements, systematic knowledge on how many elements can be distinguished, given a specific set of parameters, is needed. For haptic elements, it is especially important to know how to design haptic elements that they can convey more complex information and what restrictions have to be applied.

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Mobile Application Model for the Blind

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Abstract. This study presents a model to design and implement mobile applications to support the displacement and dynamic decision making of users with visual disabilities. To identify the real added value of using mobile technologies as support aids for decision making in dynamic contexts for users with visual disabilities, we provide an application case. By using a graph to represent the computer model of a real school for blind children, for whom a system was already developed using our model, we provide a real example application of this model. This provided enough input to enrich, improve and redesign the model; ending up with a usable mobile application model to assist the mobility and orientation of blind users.

Keywords: Mobile, learning, model, software, blind learners.

1 Introduction

The massive use of mobile tools in every life has motivated researchers and implementers to design software applications in order to provide users with high demand data processing services always available including useful and upgraded information. Diverse efforts have been made to give accessibility to these applications for users with visual disabilities.

Diverse applications have offered critical improvements in accessibility [7], [20] and learning [5], [9], [14], [11], [17] for users with visual disabilities. However, these applications have been designed for users in a rather static working context without integrating dynamic and upgraded information about the surrounding area. The world around us changes constantly with irregular situations that modify and alter it through time. Sighted people can easily order the environment through the use of the visual sense, but people with visual disability can hardly make decisions when unexpected situations occur. Thus, the development of technology for users with visual disabilities should imply user-centered methodologies, identifying clearly interaction modes and their immediate consequences in the user's performance.

Educational software for people with visual disabilities usually lacks of critical interface elements commonly present in software for sighted children. Most software does not include things such as explicit model knowledge and skills learners to be enhanced when using the software, explicit learner model, and appropriate feedback to improve the learners' performance. To many authors, designers of educational

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software for children with disabilities conceive the software with interaction constrains in their minds, fixing the interaction modes from the very beginning. Educational software for learners with visual disabilities should design without considering from the beginning the users' disabilities. Rather, they should take into consideration aspects such as a model representing existing or artificial interacting world, a model for representing the knowledge to be learned, and model for the learner. The learner's capabilities and disabilities should be considered when mapping inputs and outputs of the model into an interface.

Since educational software development depends on people, tools, and methodologies involved, and considering there is no a clear methodology to carry out this process for children with visual disabilities, the results mainly depends on the skills of the involved people. This situation can cause many drawbacks typical of a handcrafted process. Rather, software engineering uses methodologies to help to reduce the craftsmanship level of software development by using the best methodological practices.

The navigation of blind users in real environments exposes them to higher risks than sighted users because they cannot use the physical cane to help them to identify objects in the space. For this reason, some cues should be provided to users with visual disabilities to get a more reliable mobility, allowing them to access to richer information from the environment [4],[5],[6]. Then, it is necessary to extend the model to mobile contexts, to allow designer to create educational software for mobile devices.

We present a model that extend the process model already described in Sánchez et al. [10],[13], by instantiating it for mobile contexts. This extension involves users with visual disabilities in contexts and situations behaving autonomously. Thus, through the support of digital technology they can define strategies to solve problems that sighted users can solve rapidly by using their vision input.

2 Related Work

Burgstahler [1] proposes a way technology can be used by learners with visual disabilities, allowing them independence, productivity, and participation in academic activities and everyday life, proposing the following ways technology can provide to people: (a) Gain access to the full range of educational options, (b) Participate in experiences not otherwise possible, (c) Succeed in work-based experiences, (d) Secure high levels of independent living and (e) Work side-by-side with peers.

Roschelle et al. [8] recommend avoiding a process of software development centered on just software professional by including multidisciplinary teams in the design and development, concentrating in specific domain aspects. The main idea is to produce specific domain software components to better manage the expected results of educational software.

We have described elsewhere a model for educational software for people with visual disabilities [13]. It is mainly based on tasks to be solved by the user. The model consists of the stages of analysis, design, development, and validation (see Figure 1). ***Analysis***. Cognitive goals to be achieved by the learner are designed as well as the definition of software requirements. Cognitive evaluations define procedures and functions to evaluate the achievement of cognitive goals. ***Design***. A metaphor is defined for a virtual environment or scenario where the learner constructs knowledge through interaction within the virtual world. Normally, this is gaming software so the playing rules are defined. All of this leads to define the model of the virtual world and the knowledge to be constructed. ***Development***. This stage implies three sub-processes: first, the computational implementation of models of the world and learner, second, the implementation of the evaluation process and feedback to the student, and third, the projection of the models. It is important to implement these actions after setting the model to avoid constraining from the beginning the software design. ***Validation***. This stage consists of two sub-processes. First, we develop usability tests to gather data about how well the system fit our objectives in order to attain the cognitive goals set at the beginning. In this stage, the emphasis is on the analysis of some elements of human-computer interaction. Second, we analyze these results and study how the metaphor, models, and the projection of input/output variables can be improved. An error in the integrity of the system for learning can imply to review the metaphor and models used. Usability issues can lead to review the projection.

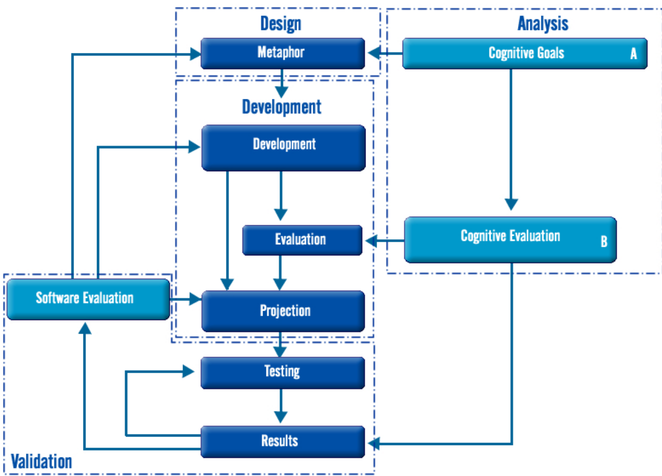

Fig. 1. Schema of model for educational software [10]

Diverse intents have been made to adapt mobile devices to the requirements of users with visual disabilities, obtaining hardware prototypes oriented to specific users. For instance, a pocketPC specially targeted for blind people contains screen readers with buttons instead of a tactile screen [3]. Wobbrock proposes the use of specific hardware to complement the features of standard pocketPC. However, this adaptation has two major constrains: the high cost and the loss of mobility when using the mobile device.

Sánchez and Aguayo [12] emphasize the development of two interface modules to allow interaction with a pocketPC by users with visual disabilities. The first is the input module consisting in a virtual keyboard of nine buttons placed on the tactile screen of the device, letting users to write in the same way as they do with their cellular phone without needing external devices. The second is the output module based on a text-to-speech engine adapted to the user needs.

AudioStoryTeller [15] is a pocketPC application to support the development of reading and writing skills in learners with visual disabilities through storytelling, providing diverse evaluation tools to measure these skills. This software application has been implemented through auditory interfaces to support actions and provide feedback.

Software for a pocketPC, mBN [16], contains a metaphor that represents a simulation of a subway travel through a wagon. Travels are developed in a logical way without considering spatial representations of virtual spaces. The metaphor considers notions of consecutive stations, transfer stations, and terminal stations. Interaction is achieved by using the corners of the pocketPC screen, joining the adjacent points. Hence, the software watches, analyzes and interprets the movements of the pointer without special devices.

The system PGS (Personal Guidance System) proponed by Loomis [2] was developed as an outdoor navigation tool depending completely on a GPS. The system provides instructions to mobilize from one point to the other through verbalized instructions and descriptions by using dual earphones.

The navigation and guidance system NOPPA [19] is oriented for blind user to travel through the city without interruptions by using buses, trains, and walking. It is based on a client-server architecture accessing to information through internet from a terminal. Information is communicated through voice synthesizers.

In [2] is presented PINS (Personal Indoor Navigation System), an indoor navigation system to provide an independent and efficient navigation to users with visual disabilities. The system allows to solve navigation tasks and route plans, but is does not include obstacles avoidance. PINS use a positioning and orientation system, a spatial data base and a user interface. The input of information is through audio and a Braille keyboard, allowing the downloading of navigation maps when entering to a place.

Other aids include tactile maps that through talked voices provide directions. These maps have low resolution, hard to get and use while the user is moving, so they don't solve users' orientation problems [20].

Finally, a related work was done by Sasaki [18], presenting how mobile technology can support mobility and orientation of visually impaired users when utilizing public transportation buses.

3 A Model for Developing Mobile Applications for Blind People

The need for models to develop educational software has already been recognized in order to generalize and replicate good practices. We have designed a model for developing software for mobile devices targeting people with visual disabilities when learning how to mobilize more efficiently to accomplish certain tasks in a known area (see Figure 2). This model is based on the initial model presented in chapter 2 [11] aiming to develop educational software for people with visual disabilities. Since our goals are focused on software for the mobile scenarios we can instantiated the model for mobile purposes and make a detailed description of its parts.

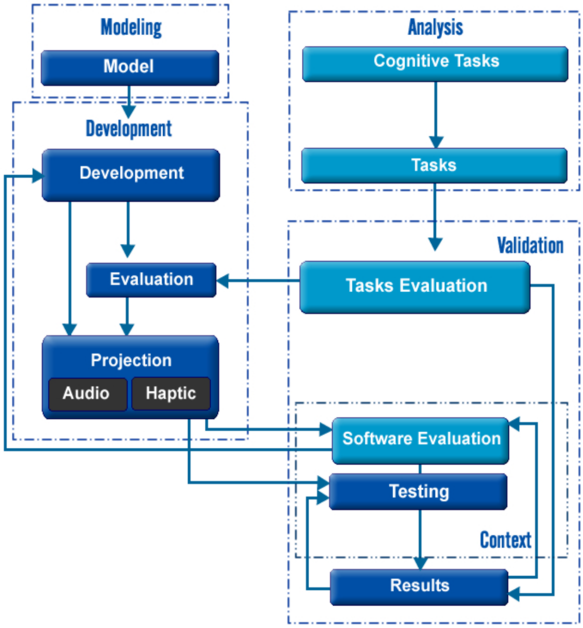

Fig. 2. Mobile Application Model

The model itself is a workflow consisting of four principal phases:

Analysis: This phase takes as input the learning goal of the application. This learning goal will define the cognitive tasks the learner should acquire by using the system. Based on these cognitive tasks, we can specify the concrete tasks the user has to perform with the help of the system in order to reach the learning goals. The cognitive goals established in this phase will be later used to produce the metrics in order to evaluate the correct achievement of these tasks and will serve for validating the application in its effectiveness.

Modeling: In this phase the tasks supported and the environment are modeled. The main product of this task is the Model. It is the computer's internal representation of the knowledge the user has to acquire. For the mobile case, this is the real world including the environment in which the user should move and all the relevant information needed to accomplish the tasks defined in the previous phase. A good way to computationally represent such an environment is using a graph. In such a graph the nodes are called spots, and represent only the relevant objects of the environment the user can recognize (a corner, a booth, or even a trash bin if relevant) which can be used by the user to recognize the place. The links of the graph are called ways, including relevant information about the characteristics of shortcuts paths to go from one spot to another. The type and amount of information of ways depends on the kind of the cognitive task the system is assisting the user to accomplish. In some cases, relevant information may be the distance between spots measured in meters, or the average time a user would take to go from one spot to the other. In other cases a number identifying the user's degree of confidence to cover the distance or the safety degree of walking through that way may be useful. (see figure 3).

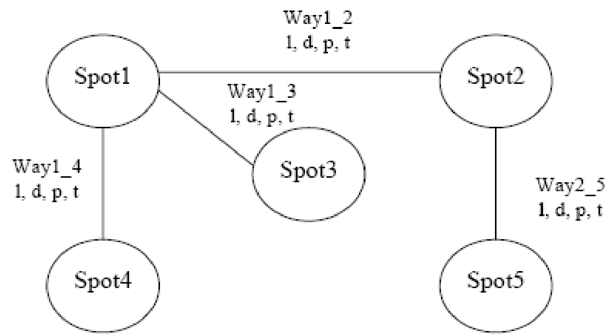

Fig. 3. An example of a graph representing spots and ways. The values l, d, p, t represent the evaluation of different characteristics of the way, such as the time needed to cover it, the distance, the degree of safety, etc.

Having a graph representing the real environment where the user has to accomplish tasks makes it easy for the computer to calculate all possible paths (collection of ordered ways) for moving from one spot to another by applying well known algorithms over graphs like Dijksta's. Applying different values of the ways as input for the algorithm, we can find different kind of paths between two spots. For example, using the distance value we can find the shortest path, using the time value we can find the faster path. Moreover, the system can find the best path for a combination of safety and speed by giving weights to these numbers.

As already described in [2] a very important issue of the modeling phase is to establish the state, input, and output variables. State variables are those describing the state where the user is. A very important state variable of the model is the user's current position, which can be on a spot or on a way. The mechanism to update this variable depends on the environment where the user moves and the resources available. Whenever the distances are long enough, a GPS mechanism can be used. The user must update this variable otherwise. Input variables are those received from the user and/or the environment to update the state variable. Output variables are those used by the system to provide relevant information to the user.

The model component should also include a user model. A user model is the information the system uses to compute what the user knows, does not know, and if the user has wrong knowledge about something. With this information the system should be able to assist the user providing the right information at the right time to accomplish the task. For the mobile case, the simpler, yet most effective way to implement a model of use is using the overlay technique. In this case, an overlay user model will be a graph containing the collection of spots and ways he or she already knows. Figure 4 shows the graph representing the computer model of a real school for blind children in Santiago, Chile, for which a system was already developed using this model. The ways and spots belonging to both, the user's model graph and the computer's knowledge representation graph, are shown in white color. The ways belonging to the computer's graph are shown in black

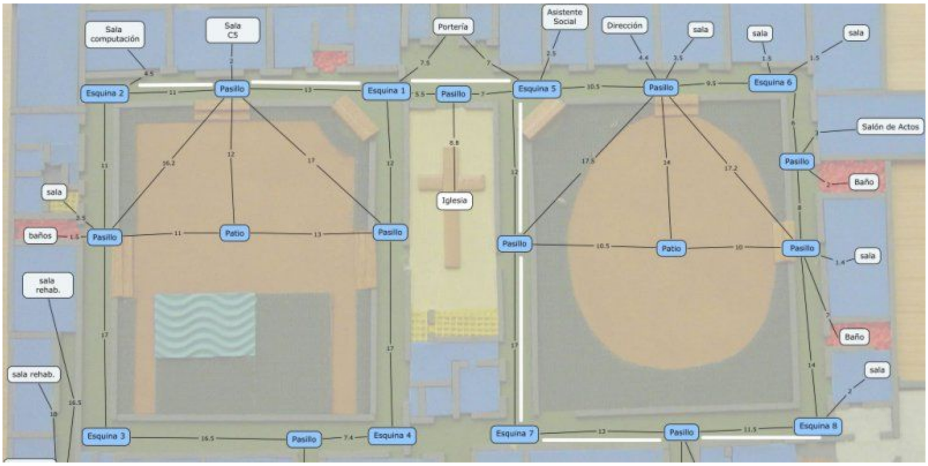

Fig. 4. The figure shows a scale model of the school for blind children and both graphs for implementing the computer's knowledge model (all nodes and lines) and the user's model (only white lines and nodes)

The user's model can be initialized with the graph representing the spots and ways the user usually uses to move from one point to another. It should also be updated when the user uses a new way between two spots. This represents a learning step of the user. By overlaying the user model's graph to the one representing the computer's knowledge, it easy for the system to decide whether at a certain point it can provide useful information to the user. The system computes the most convenient path from that point to the target arrival point. If the first way in the path is not on the user model, the system can provide this information to him or her.

Development: Graphs along with algorithms and procedures are implemented. The methodologies and procedures for evaluating the user's performance are also developed. The evaluation methodologies will depend on the cognitive tasks supported by the system. For example, if the original task is to find the faster way between two places, the evaluation should consider the time invested by the user and compare it against the "normal" time an average user will need when using the fastest path. If the task is to find the shortest path, then the system will have to consider the length of the path used and contrast it with the shortest path the system can compute using the algorithms. The projection component of the development phase is the process of mapping input and output variables on proper input and output devices of the mobile computing device. Since mobile devices have more restricted possibilities for good input and output, especially for people with visual disabilities, in most cases, the input variables will be mapped on haptic devices (such as buttons or keys) and the output devices on audio signals. Considerations that should be regarded for implementing these projections are described in [1] for the non-mobile scenario. In the mobile scenario we should also consider that audio output must be even clearer and concise because of the presence of environmental noise.

Validation: During the validation phase the usability and effectiveness of the software is evaluated. The usability is for the user's acceptance and how well he or she interacts with the model. This will depend on how good input and output variables of the model have been projected on the input and output possibilities available for a mobile case. The effectiveness is evaluated by finding out the user's performance with and without the application. The first step is it to define the tasks evaluation strategies and methodologies in accordance with the tasks defined in the analysis phase. These will in turn serve as input to develop the evaluation methodologies for the user's performance and at the same time, to evaluate whether the system makes a contribution to the performance of the user.

4 Conclusions

This study introduces a model for implementing mobile applications for users with visual disabilities. We have also provided an application example by using a graph to represent the computer model of a real school for blind children, for which a system was already developed using our model.

We are implementing a research study to applying this model to real mobile cases such as the subway, neighborhood, and the school. The result of this new study will validate more fully our model for designing mobile applications for decision making in dynamic contexts.

The use of mobile applications should not be reduced to sighted users even though the whole interface is thought for their mental models. There is no need for producing devices specially tailored for them that have a high cost because of the limited target population. The design of interfaces to provide efficient input/output access and interaction is sufficient to exploit the potential of these devices in the everyday life of blind users.

Software applications should be implemented specially tailored for users with visual disabilities. It is not enough to adapt existing software; rather there is a huge need for software specially tailored for the needs and mental models of users with visual disabilities. This will allow these users to take advantage of the benefits of pocketPC devices closing the gap between the unique features of mobile technologies and the actual use by these users.

The model proposed here allows designing diverse applications to help users with visual disability to improve their mobility and orientation skills in everyday contexts. The availability of a mobile aid that provides information about shortcuts and efficient ways and routes, helps them to mobilize efficiently and autonomously in different scenarios and thus helping them to become more socially included.

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Easy Model-Driven Development of Multimedia User Interfaces with GuiBuilder

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Abstract. GUI builder tools are widely used in practice to develop the user interface of software systems. Typically they are visual programming tools that support direct-manipulative assembling of the user interface components. We have developed the tool GuiBuilder which follows a model-driven approach to the development of graphical (multimedia) user interfaces. This allows a meta-design approach where user interface developers as well as prospective users of the system are supported in modelling the desired functionality of the GUI on a high level of abstraction that is easy to understand for all involved stakeholders. The model consists of compositional presentation diagrams to model the structure of the user interface and hierarchical statechart diagrams to model its behaviour. GuiBuilder then supports the transformation of the model to Java, i.e., the generation of a working user interface and the simulation of the modelled behaviour. Interactive sessions with the user interface can be recorded and replayed.

Keywords: Model-driven development, meta-design, user interface, prototype generation, capture-replay.

1 Introduction

Recently, *meta-design* has been proposed as a novel approach to system development where end users play an active role not only in using a software system but also in designing it. In [2], G. Fischer et al. state: "Meta-design characterizes objectives, techniques, and processes for creating new media and environments allowing 'owners of problems' (that is, end users) to act as designers. A fundamental objective of meta-design is to create socio-technical environments that empower users to engage actively in the continuous development of systems rather than being restricted to the use of existing systems."

In [1], M.F. Costabile et al. refine this approach and introduce the notion of "Software Shaping Workshops (SSW)", where groups of stakeholders focus on certain aspects of system development. They state: "We view meta-design as a technique, which provides the stakeholders in the design team with suitable languages

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and tools to favour their personal and common reasoning about […].” Futhermore, they follow G. Fischer’s arguments, who characterizes end users as persons who want to be a “consumer” (i.e., user) of a software system in some situations, and in others a “designer”, who adapts the software system to her personal needs and desires.

In our approach, we exemplify these ideas by presenting a model-based development approach for graphical user interfaces (GUI). The overall idea is to provide high-level sophisticated design languages and tools, which allow end users to be involved in designing and testing graphical user interfaces of a software system.

Following the approach of model-driven development (MDD) techniques [4,9], such a platform-independent model of a GUI is automatically transformed into an executable GUI realisation in a common programming language like Java.

Graphical user interfaces of (multimedia) software applications provide users with the presentation of information and interaction capabilities with (media) content and functionality. The user interface is a complex part of the overall system and often requires software engineering effort comparable to building the application functionality itself. In addition, the user interface has to meet the user’s requirements and expectations in order to yield a high acceptance rate by future users. Thus, user interface development should be done cooperatively by software engineers and prospective end users. Due to the inherent complexity of user interfaces, model-based development processes which are nowadays well-accepted in software development should be applied for user interfaces, too. GUI builder tools that merely support visual programming of the user interface are overstrained with this task.

Model-based development of user interfaces promotes structuring of the resulting implementation and allows developers and prospective users in teamwork to prevent errors or to detect errors earlier and more easily by already analysing the model of the user interface. The models can also be used as documentation and for guiding the maintenance of the software system. *Model-driven* development even goes a step further by automatically generating from the model an executable user interface in a common programming language like Java.

The objective of this work is to develop a model-driven and tool-based development technique for graphical user interfaces (GUI). The model of the GUI combines structural and behavioural aspects. The model-driven development of the GUI is then supported by a tool called GuiBuilder. GuiBuilder provides developers and prospective users with an editor for GUI modelling and an execution environment for GUI simulation. A prototype user interface can be generated from the model, executed and tested. External tools can also connect to the simulation and are notified about the simulation progress. Simulation runs can be recorded and replayed. The simulation logs can also be used to support regression testing based on the capture-replay paradigm.

A number of model-based approaches have been proposed in past years to deal with user interface modelling at different levels of abstraction (see e.g. [10]). GuiBuilder is targeted towards concrete user interface modelling. The idea of combining statechart and presentation diagrams originally stems from the OMMMA approach [8]. Statecharts have also been used in [3] for describing GUI behaviour. UsiXML (e.g. [11]) uses graph transformations instead. It provides a variety of GUI elements which are currently not completely supported by GuiBuilder due to its early development state. In MOBI-D [7] the process of constructing a GUI is guided and restricted by domain and task definitions, which are the building blocks of user interfaces in MOBI-D. A UML-based approach towards model-driven development of multimedia user interfaces is described in [5]. Recently, model-driven development of user interfaces has attracted wider interest in the research community [6].

In the next section, we will introduce the different models that are supported by GuiBuilder and their interplay. Section 3 presents the tool GuiBuilder. We draw conclusions and outline future perspectives in Section 4.

2 Models of GuiBuilder

The model of the multimedia user interface in GuiBuilder consists of two parts: the presentation model and the dynamics model. The *presentation model* captures the structure and layout of the user interface, the *dynamics model* uses UML statecharts to specify the behaviour of the GUI. Dynamic behaviour is enacted by user interaction or other events that cause a change of state in the user interface (and the application). Events that are caused by user interaction are modelled as signals which can be handled by the presentation elements. Signals can also be sent as the actions of triggered state transitions.

The basic concept of the compound model is to assign a presentation design to a state, which describes the structure and layout of the user interface while in that state. At any point in time, the GUI of an application is in a specific, possibly complex state. An event occurrence causes a state change and thus a change of the presentation.

The presentation model consists of presentation elements (see Fig. 1). Typically they are graphical elements that are part of the application's presentation. Such elements can e.g. be geometric shapes, widgets, or graphics elements for rendering images or video. In addition to graphical elements, audio elements can be included for playing music or sound effects. The presentation elements have properties which can be assigned with values. The properties depend on the type of presentation element and determine the presentation of the element. The types of presentation elements are organized in a class hierarchy.

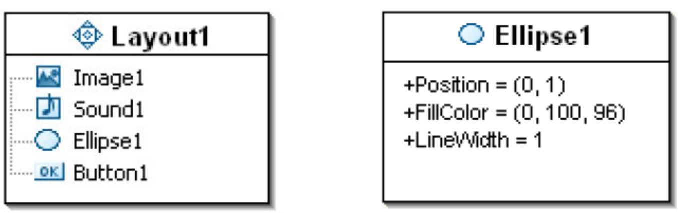

Fig. 1. A presentation consists of presentation elements (left), where each presentation element is characterized by its property values (right)

The presentation elements within one presentation diagram are ordered. The topmost element is upfront and possibly covers parts of other elements if they overlap.

If the GUI is in a simple state, the presentation is a composition of presentation elements with their property values. The presentation is completely described by the presentation diagram that is assigned to this state.

However, it is also possible to assign presentation diagrams to complex states in our model. Complex states allow us to hierarchically structure the state of the user interface. The actual presentation is then composed from the presentation diagrams that are assigned to the current simple state and all its parent states, where the complex states can even be concurrent (i.e., AND-superstates). Fig. 2 shows an example, where the presentation diagrams Layout1 and Layout2 are assigned to State1 and its substate State2, respectively.

The actual composition of the presentation is determined by the hierarchical structure of the statechart diagram. If the behaviour of a superstate is refined by substates, the assigned presentation is also refined by the presentation diagrams that are assigned to the respective substates.

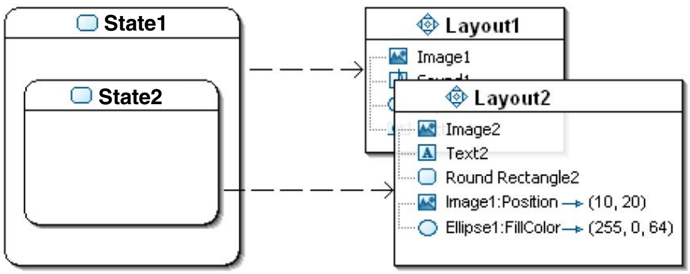

Fig. 2. Presentation diagrams can be assigned to hierarchical states, new presentation elements can be added for substates or properties of existing elements be modified

The composition of the presentation diagrams according to the state hierarchy works as follows:

First, presentation diagrams are stacked on top of each other. The order is determined by the state hierarchy: presentation diagrams of substates are put on top of presentation diagrams of their superstates. The former are intended to be the more specific. Their presentation elements override (cover) the presentation elements of the latter. For concurrent states, an order is not defined.

Secondly, since presentation diagrams can not only contain new presentation elements, but also property changes (i.e., modify the properties of presentation elements contained in presentation diagrams that are assigned to superstates), the modified value also overrides the 'inherited' value. All presentation elements that are introduced in presentation diagrams of the superstates of a state can be altered by modifying their property values. A property change thus specifies the modification of a property value of an inherited presentation element in a substate (see Fig. 3).

Consequently, a hierarchical presentation can be interpreted as a list of modifications where the instantiation of a presentation element is a specific case. This list can then be processed to construct and compose the actual presentation for a particular state: for each presentation diagram, the list of modifications is processed, whereby the order of the lists of different presentation diagrams is determined by the hierarchical state structure from superstates to substates.

With respect to execution semantics, this means that when a state is left, the modifications of its presentation diagram to the user interface become ineffective and are replaced by the modifications of the presentation diagram of the successively entered state. Modifications of the presentation diagram of the possibly still active superstates remain unaffected, yet may be overridden.

Structured specification of a user interface is facilitated by this composition mechanism. GUIs typically contain a limited number of fundamentally different views which are then subject to a larger number of smaller (local) modifications for representing the particularities of different states within the overreaching context. Our incremental composition mechanism eases the specification of such modifications and prevents the developer from having to specify the complete presentation design for each, even simple modification. The GUI design thus requires less effort and the GUI models become easier to extend and modify even by end users, especially since redundancy is limited and controlled.

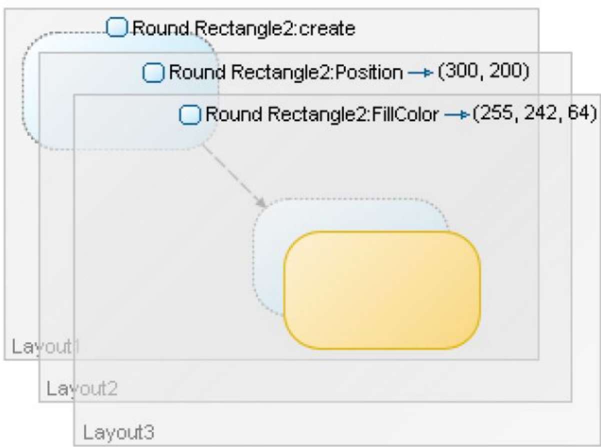

Fig. 3. Stepwise modification of a presentation element through hierarchical presentation diagrams

In addition to presentation, interaction also profits from the incremental specification. User interaction results in events which are received by presentation elements as signals. Since signals are properties of the presentation elements as well, they can be 'inherited' and modified like presentation properties. Functionality can thus be adapted in the same way by modifying the signal specification.

Thus, since we follow a clearly structured approach toward user interface construction and limit the GUI modelling language to a selected number of modelling concepts and elements, it is suited for professional software developers and end users as well. The integration of end users in the software development tasks is further promoted by the strict distinction of interactive control behaviour that is modelled here and possibly complex algorithmic computations of the system that are developed separately.

3 GuiBuilder - The Tool

GuiBuilder has been developed as a plug-in of the Eclipse tool environment and platform. We used the Plug-in Development Toolkit PDT for its implementation and the Graphical Editor Framework GEF for implementing the graphical editor of the GuiBuilder plug-in.

GuiBuilder supports user interface software developers as well as prospective users in the development of graphical (multimedia) user interfaces. Audio and video can be integrated in the presentation of the application that is developed. In the current version of GuiBuilder, executable GUIs are generated from the model and executed using Java SWT, and the Java Media API is deployed for rendering of multimedia artefacts.

The main view of GuiBuilder is the GUI editor. Additional views of GuiBuilder are the Eclipse standard views problems view, outline view, and properties view as well as the presentation view. The problems view lists the detected errors and warnings. The outline view presents an outline page for each window of the GUI editor when it is selected. The properties view shows properties of a selected model element (statechart element or presentation element). Properties can be edited directly in the properties view or in an explicit properties dialog. The presentation preview is a GuiBuilder-specific view that presents a preview of the presentation (see Fig. 6). In our development of GuiBuilder we tried to keep the tool as simple as possible—despite its diverse functionality—to be usable even by end users.

The tight integration of editing and simulation tools allows users to dynamically switch between the roles of software developers who design the structure and behaviour of the interactive graphical user interface by the use of design models and users who interact with the application that is being designed.

3.1 Editor

The editor of GuiBuilder is a graphical tool that supports the direct-manipulative construction of dynamics and presentation diagrams. The GUI editor is a multi-page editor that can manage windows of two different types for statecharts and presentation layouts, respectively.

3.2 Model Validation

The GUI editor calls the validator to validate the correctness of the edited model. The diagrams of the dynamics model have to be valid UML statechart diagrams where only a limited subset of modelling elements is used to control the model's complexity. In addition, we require that the specified behaviour is deterministic. Thus, the statechart diagrams are validated before code is generated from them by the generator function and the simulation can be started. To effectively support the developer as well as prospective user, we provide syntax-directed editing to prevent from fundamental syntactic errors and static model analysis to detect more complex and context-sensitive problems. For example, missing start events or non-deterministic transitions are identified by our model analysis. Two categories of problems, errors and warnings are recorded and presented to the user of the editor in the central problems view, in the outline view (see Fig. 4), and directly at the relevant modelling elements in the editor view. The identified problems are accompanied by correction procedures (i.e., quick fixes). These features are altogether intended to support users of the editor as much as possible in detecting and correcting defects. Only after all errors have been resolved, the generation can be enacted. Warnings need not to be resolved; however, they should not be ignored since they mark weaknesses of concept or style within the model. Thus, the static analysis supports both the syntactic correctness of the model and its quality in accordance to modelling guidelines.

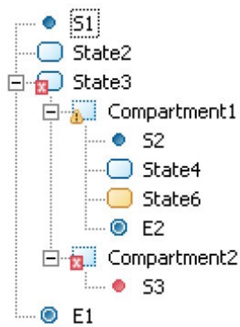

Fig. 4. Problems are marked at the causing model elements

Since the static analysis is the powerful core of the validation module, the syntax-directed editing restrictions can be kept low, not to unnecessarily hinder the flexibility of model editing. For example, inconsistencies or incorrectness can be temporarily tolerated as long as the developer does not want to start the prototype generation process.

Despite the wide range of checks in the static analysis, some problems can still only be detected during dynamic analysis. Dynamic analysis is integrated with the simulation and executed at runtime. Dynamic errors that are detected then are for example infinite loops or non-deterministic behaviour. Such errors cause the termination of the simulation run.

3.3 Generation and Simulation

The simulator view shows the simulated GUI. The GUI editor passes the GUI model via a generator function to the simulator view. The generator function flexibly implements the transformation rules to build a prototype GUI from the GUI model. It can be replaced for generating a different target language or for tailoring of the generation results.

The simulator view starts the simulation in the simulator and registers the GUI editor with the simulator. The simulator then notifies the GUI editor about state changes.

Simulation of the user interface is accomplished by interpreting the model. The GUI simulator uses a statechart simulator which interprets the statecharts of the dynamics model. Connected objects are notified by the statechart simulator about state transitions and triggered actions (signals). The GUI simulator constructs the composite presentation view for the active state configuration and passes it to the simulator view of GuiBuilder. The simulator view renders the current GUI view. The user can then start the simulation in the simulation view, and the simulator executes the generated GUI. Events can be raised either by interacting with the simulated GUI elements directly or by using the ‘remote control’ that we implemented as an external plug-in. It can be operated remotely to generate the required signals.

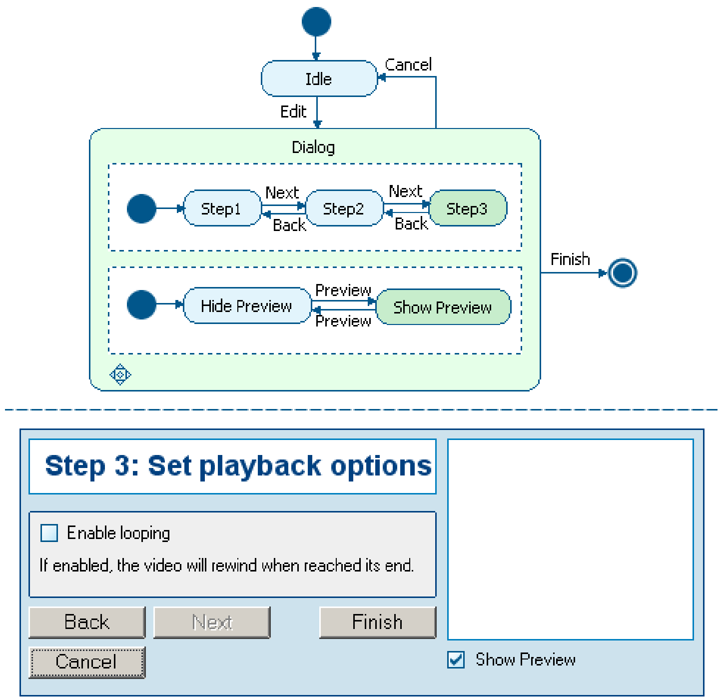

Fig. 5. Simulations can be tracked in the model

The interpretative approach has the advantage that the user interface model can be altered at runtime, and these changes can directly influence the succeeding simulation behaviour. GuiBuilder provides this functionality in a separate hot-code replacement mode.

External tools and other Eclipse plug-ins can connect to the simulator and are thus notified about state changes in the simulated model. They can assign specific actions to the signals and specifically respond to their occurrence. With this mechanism it is possible to actually control a fully fledged application. Besides, the simulation recorder that we developed uses this mechanism for recording a simulation run. The recorder logs the simulation execution. The recorded log can later be used to replay the simulation or to do regression testing after the GUI model has been modified.

External tools can themselves send signals to the simulation and raise events to change the state of the simulated GUI. Thus, the GUI can react to application or external events, too.

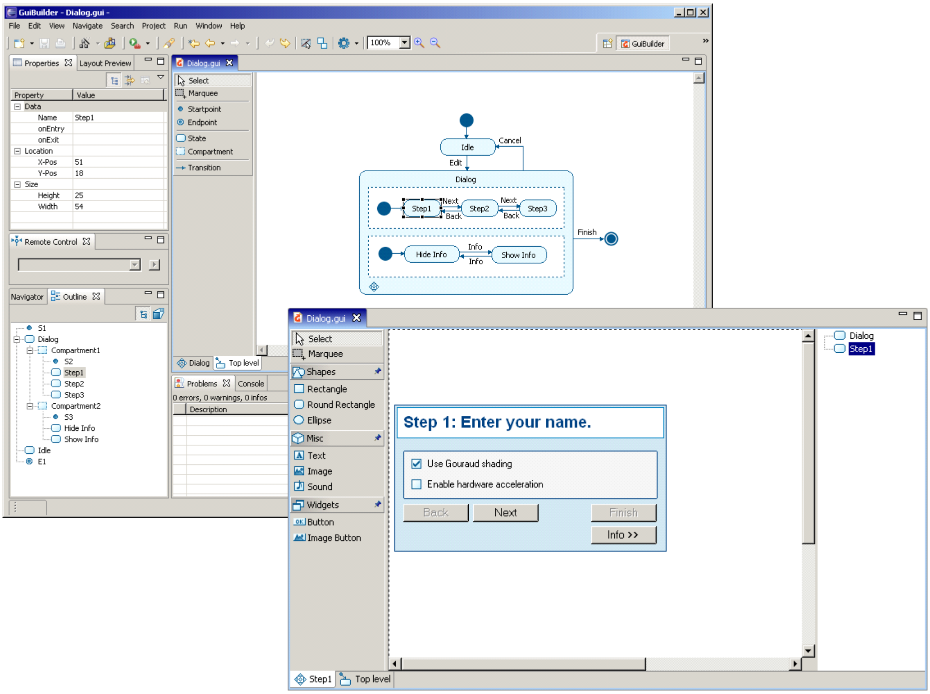

Fig. 6. The GUI of GuiBuilder

While a simulation is running, the editor view of GuiBuilder highlights the current state of the dynamics model in its statechart in green colour (composite state “Dialog” and its concurrent substates “Step 3“ and “Show Preview” in the example of Fig. 5). Thus, dynamic information is fed back into the model representation and can be used e.g. for model debugging.

4 Conclusions

We have integrated the model-driven development paradigm with the GUI-builder tool concept. This provides user interface developers as well as prospective end users with a tool for constructing graphical (multimedia) user interfaces in practice. The GUI model consists of presentation and dynamics models from which a prototype user interface can be generated and simulated.

In a next step, we plan to further improve the capabilities of multimedia processing by extending the dynamic model to deal with timed procedural behaviour. We also want to demonstrate the flexibility of the transformation approach by tailoring the generator function to different target representations.

We have evaluated GuiBuilder in several workshops with high-school students and people who are interested in software development, but not professional software developers or programmers. After a presentation of the tool of about half an hour they were capable of using the tool for constructing, changing and simulating simple applications like a traffic light control with only very limited support by our tutors. Thus, the tool has shown its capability to support end users with little programming skills in building and simulating interactive graphical user interfaces.

Additional information about GuiBuilder can be found at http://www.s-lab.upb.de/Tools/GuiBuilder/

Acknowledgments. The authors are indebted to the three computer science students Dennis Hannwacker, Marcus Dürksen, and Alexander Gebel, who contributed to the concepts of GuiBuilder and implemented the tool.

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Security Analysis on the Authentication Mechanisms of Korean Popular Messengers*

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Abstract. The "NateOn" messenger is the most popular messenger in Korea (It has 17,160,000 users in Korea). In this paper, we will analyze the security of authentication mechanism of the NateOn. We will show that the "NateOn Ver 3.5.15.0(600)" is very vulnerable to the replay attack and the dictionary attack. Furthermore, we will show that other messengers such as "BuddyBuddy Ver 5.8" (It has 5,980,000 users in Korea), "Daum Touch Ver 5.06101300" (It has 2,384,000 users in Korea), etc. have the similar security problems.

1 Introduction

There are 4 messengers in wide use in Korea. They are "NateOn" messenger from SK Communication, "BuddyBuddy" from www.buddybuddy.com, "Touch" from Daum Communication, and "Tachy" from www.sayclub.com. These messengers provide users with services that include conversations with friends, e-mail, club, SMS(Simple Message Service), MMS(Multimedia Message Service), and so on. The NateOn messenger is interlocked with www.cyworld.com using SSO(Single Sign on).

The NateOn messenger transfers encrypted authentication information. But the encryption process of the NateOn messenger has some problems. Whenever a user logs in the NateOn messenger, the authentication information of the user is a word same. This has points of vulnerability. First, if the attacker can snatch the information off the network, he can perform a replay attack and disguise himself as an authorized user. Second, the attacker can perform a dictionary attack and extract the password of the user from the authentication information.

In this paper, we will analyze the authentication mechanism used in the NateOn messenger using authentication packets captured by the Ethereal packet capture

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program or the CommView packet capture program. And the authentication mechanism of the other messenger will be also analyzed using the same method. We will write a replay attack scenario and an attack program for the NateOn messenger.

2 The NateOn Messenger Authentication Mechanism

In this section, we analyze a secret communication of the NateOn messenger program for a user authentication. We use the Ethereal and the CommView packet capture program for an analysis of a secret communication of the NateOn messenger program.

2.1 The Analysis of the NateOn Messenger Authentication Packets

For the NateOn messenger authentication packet analysis, we capture normal packets that include an encrypted authentication information. The packet, which includes encrypted authentication information, is consisted of "LN IN1" string, the 256 bits string, and "MD5 3.600 UTF8.." string, as in Figure 1.

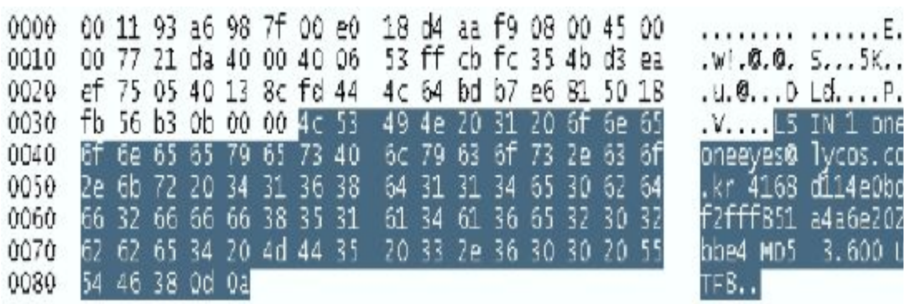

Fig. 1. The Authentication Packet Structure of the NateOn Messengere

Therefore we analyze the 256 bits string with using a MD5 hash function. In the result, a 256 bits string is only consisted of a user e-mail address and a password. In other words, whenever a user logs in the NateOn messenger, the authentication information is the same. Therefore an attacker can perform a replay attack.

Table 1. NateOn Messenger Authentication Information Structure

Section	Authentication Information
nate.com e-mail user(xxx@nate.com)	MD5(Password xxx)
the other e-mail user(xxx@abc.com)	MD5(Password xxx@abc.com)

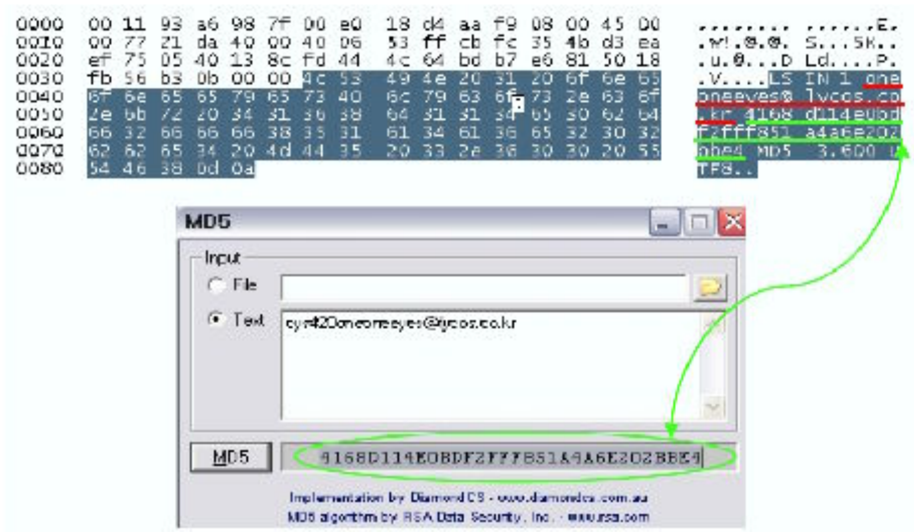

Fig. 2. When a user ID is “oneoneeyes@lycos.co.kr” and a user password is “cys420”, “4168D114E0BDF2FFF851A4A6E202BBE4” is encrypted authentication information in an authentication packet

2.2 The Analysis of the NateOn Messenger Authentication Mechanism

In this section, we analyze how a user is authenticated with an authentication information that is described in section 2.1. The NateOn messenger program have to communicate with two servers for a user authentication. First, to obtain an authentication server IP address, the NateOn messenger program communicates with dpl.nate.com:5004 server. The NateOn messenger program sends/receives packet that include fixed strings as in Figure 3.

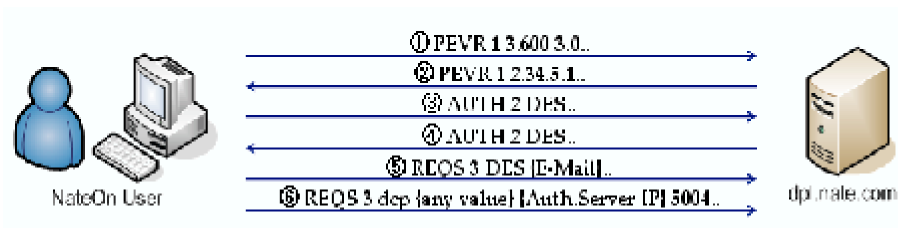

Fig. 3. The communication to dpl.nate.com:5004 server

In Figure 3, the “E-Mail” is an e-mail address of user who wants to log in the NateOn messenger. After the NateOn messenger program sends “REQS 3 DES (E-Mail Address)” string to dpl.nate.com:5004 server, dpl.nate.com:5004 server sends “REQS 3 dpc (Any Value) (Authentication Server IP Address) 5004..” to the NateOn messenger program. The user, who uses "E-Mail Address" in packet , can be authenticated at the server of "Authentication Server IP Address". After the NateOn messenger program receives an IP address of the authentication server, the NateOn messenger disconnect to dpl.nate.com:5004 and connect to the authentication server. If the NateOn messenger program successfully connect to the authentication server, the NateOn messenger program makes an authentication information with a user e-mail address and password and generates the packet that includes the authentication information and sends the packet to the authentication server as in Figure 4.

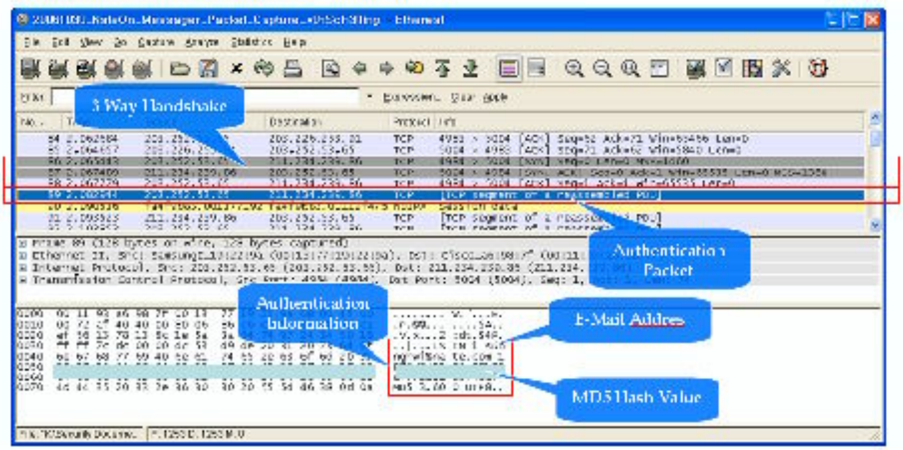

Fig. 4. Before a user authentication is complete

Fig. 5. The communication to obtain friend list

After the authentication server checks that the authentication information is correct, the authentication server sends user information to the NateOn messenger program. After the authentication server sends an user information to the NateOn messenger program, the NateOn messenger program sends/receives fixed strings to the authentication server as in Figure 5.

Then the authentication server sends the friend list to the NateOn messenger program as in Figure 6.

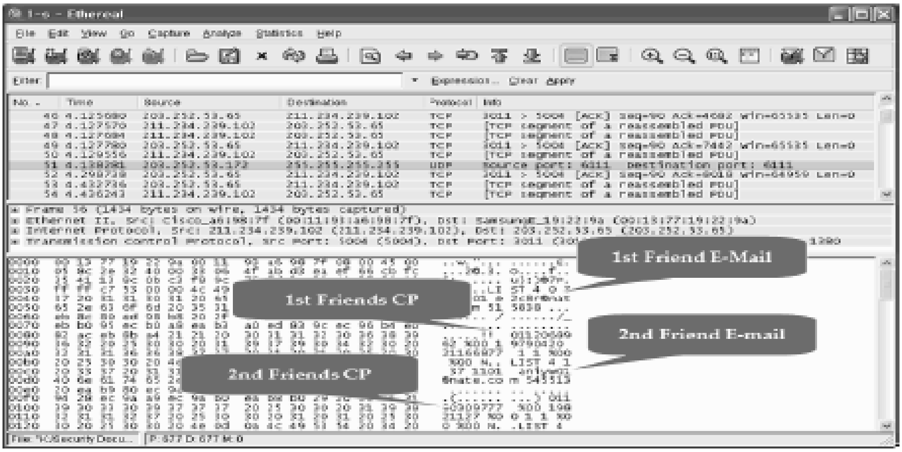

Fig. 6. Friend list that the authentication server sends

3 Vulnerabilities of the Authentication Mechanism of Korean Popular Messengers

Arguments are used in authentication information creation are fixed. Therefore authentication information is the same whenever a user logs in the NateOn messenger. We also know that the string is the same for communicating with dpl.nate.com:5004 server and an authentication server. If an attacker performs a replay attack according to the procedure that is described in the section 2.1 and 2.2, he can disguise himself as an authorized user and he can receive the friend list. Also he can extract a user password from authentication information through a dictionary attack.

This problem is not only a problem of the NateOn messenger but also the other popular messengers in Korea. The “Touch Ver 5.06101300”(Daum) messenger, which has 2,384,000 users in Korea, has the same problem with the “Touch Ver 5.06101300”(Daum) messenger.

Both the “BuddyBuddy Ver 5.8” messenger, which has 5,980,000 users in Korea, and “Tachy Ver 2.9.5” messenger send a password to servers in a plain text form.

4 The Solution of the NateOn Messenger Authentication Mechanism Vulnerability

The reason of the NateOn messenger vulnerability on a replay attack and a dictionary attack is that values are used in authentication information creation are fixed and authentication information is made using a MD5. This problem is solved by a method using a challenge-response and time-stamp and is solved by providing a stronger password policy for a user.

First, the NateOn messenger must use the SSL(Secure Socket Layer) in authentication step as the Mircrosoft MSN messenger. SSL encrypts packets between the NateOn messenger program and servers. And whenever a user logs in the NateOn messenger, authentication information is changed. Though an attacker capture packets from network, he can't decrypt packets without an encryption key and perform a replay attack.

Second, the NateOn messenger user must select a strong password. A user tends to select a memorable password. In other words, a user tends to select an easy password. These passwords have some patterns. For example, an 8 alphanumeric characters long password usually consists of 5 characters and 3 numbers or 6 characters and 2 numbers. If an attacker knows this password pattern, he is easy to perform a dictionary attack. Therefore the Nate portal site must provide a stronger password policy for a user. The password policy leads a user to select a password which is strong and is difficult to predict a pattern. If a user password is strong, though an attacker gets authentication information from network, he can't extract a user password from authentication information.

5 Conclusion

We studied the authentication mechanism of the NateOn messenger through the analysis of network trac up to now. We knew that the NateOn messenger was vulnerable to a replay attack and a dictionary attack from an analysis result. An authentication of portal sites is better than in the past but they have a authentication problem of messenger service. Therefore, the messenger of portal sites that has a vulnerability that is described in this paper must be solved the vulnerability by appropriate methods.

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Advanced Identification Technologies for Human-Computer Interaction in Crisis Rooms

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Abstract. The advances in computer and communication technologies increased both the number of users and the amount of data shared over the Network. Many times the amount of complex and articulated information available makes it difficult to retrieve what is really required for a given task. For these reasons, the efficient, easy and trustworthy transfer of data is now of paramount importance in many everyday scenarios, especially concerning environments and situations where security and data protection are mandatory. On the other hand, data protection often implies the adoption of security means which create virtual (and sometimes even physical) barriers to data retrieval. In this paper, advanced identification technologies, based on the processing of biometric data, are presented. These techniques provide a number of tools to facilitate the seamless human interaction with the data, and the security barriers, by enabling the environment to recognize and learn from the user, shaping the data available on the basis of his/her identity. The presented techniques are based on the extraction of invariant features from face and fingerprint images to process static biometric features, also allowing the enhancement of identification accuracy by data fusion.

Keywords: Personal identification, Visual recognition, Computer Vision, Biometrics, Pattern Recognition.

1 Introduction

The advent of Internet in the mid-80's boosted the requirement for new technological solutions for fast and reliable data communication. In the first 10-15 years the population in "the Net" increased from few hundred thousands to more than 40 million hosts. In the last 6 years, from the beginning of the current century, the number of hosts in Internet increased to more than 400 million: an increase of ten times in only six years. The growth in the number of users carried a gigantic amount of data transmitted over the Network by many different means. For these reasons, the efficient, easy and trustworthy transfer of data is now of paramount importance in many everyday scenarios, especially concerning environments and situations where

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security and data protection are mandatory. On the other hand, data protection often implies the adoption of security means which create virtual (and sometimes even physical) barriers to data retrieval. In this context, advanced identification technologies (also termed biometric identification), based on image understanding techniques, may allow to provide a number of tools to enable the environment to recognize and learn from the user, shaping the space and the data available on the basis of his/her identity. At the same time, the user may learn or receive advice from the environment on how to parse the data or dialogue with other users [1-5].

The identification process can be based on several measurements performed on the human body. This requires the placement of several sensors in the environment to record visual, tactile and acoustic data. The identification is based on a confidence level which can be different depending on the sensing modality. At the entry level, face images, or image streams, can be used to identify each user in the room [6,7].

Depending on the required reliability of the identification more sensing modalities can be required. The user can then be required to touch a particular spot in the room where a fingerprint sensor is located and/or to utter a phrase or his/her name to perform speech-based user identification. Different sensing modalities can be invoked within a layered architecture, depending on both the security level required (for example visual data only for entry level security, visual and tactile for enhanced security and include speech for highest the security level) and the confidence level associated to the classification performed [8].

A proper interaction of the users with the environment can not be limited to the identification of each user's identity but also requires the understanding of gestures, motion and general attitude of the users which convey messages to be converted into actions by the environment. The cameras placed in the environment, deployed to identify the user's identity, can also be used to allow the recognition of motion and gestures of the users [9-12]. The basic recognition of human motion and gestures can be performed in a similar manner as the face recognition process, in this case the extraction of shape information must be coupled with the analysis of motion, to describe the temporal evolution of dynamic features [3,4].

In this paper two advanced identification technologies, based on the processing of biometric data, are presented. These techniques provide a number of tools to facilitate the seamless human interaction with the data, and the security barriers, by enabling the environment to recognize and learn from the user, shaping the data available on the basis of his/her identity. The presented techniques are based on the extraction of invariant features from face and fingerprint images to process static biometric features, also allowing the enhancement of identification accuracy by data fusion [7-12,15,16].

2 Face Recognition from Invariant Features

The recognition of human faces relies on a two step process, which is common to most biometric identification technologies:

- Characteristic features of the biometric trait (the face appearance in this case) are learnt by the system by means of an ***enrollment*** phase. This process is accomplished by acquiring several instances of the user's biometric data to synthesize a compact and hopefully unique representation of the user's biometrics called *template*. The user's template is stored in either a personal storage device (such as a *smart card*) or in a centralized database. This procedure is generally performed off-line, within a controlled environment.

- During on-line ***identification*** or ***verification*** of the user's identity, biometric data is acquired from the user's and compared to the stored template (verification) or to a number of templates in a database (identification). Toward this end, the raw data acquired is processed to obtain the same representation stored as template. This is a fast, on-line process, which requires only a fraction of a second.

The face recognition system presented in this section is based on a complete graph representation derived from face images. The graph representation is drawn on feature points extracted using the SIFT operator [13,14]. The on-line verification or identification is performed by matching the graph representation (the template) according to some constraints [16].

2.1 Invariant and Robust SIFT Features

The scale invariant feature transform, called SIFT descriptor, has been proposed by Lowe [13] and proved to be invariant to image rotation, scaling, translation, partly illumination changes, and projective transform. The basic idea of the SIFT descriptor is detecting feature points efficiently through a staged filtering approach that identifies stable points in the scale-space. This is achieved by the following steps:

- select candidates for feature points by searching peaks in the scale-space from a difference of Gaussians (DoG) function,
- localize the feature points by using the measurement of their stability,
- assign orientations based on local image properties,
- calculate the feature descriptors which represent local shape distortions and illumination changes.

After candidate locations have been found, a detailed fitting is performed to the nearby data for the location, edge response, and peak magnitude. To achieve invariance to image rotation, a consistent orientation is assigned to each feature point based on local image properties. The histogram of orientations is formed from the gradient orientation at all sample points within a circular window of a feature point. Peaks in this histogram correspond to the dominant directions of each feature point.

In order to achieve illumination invariance, eight orientation planes are defined. The gradient magnitude and the orientation are smoothed by applying a Gaussian filter and then sampled over a 4 x 4 grid with 8 orientation planes.

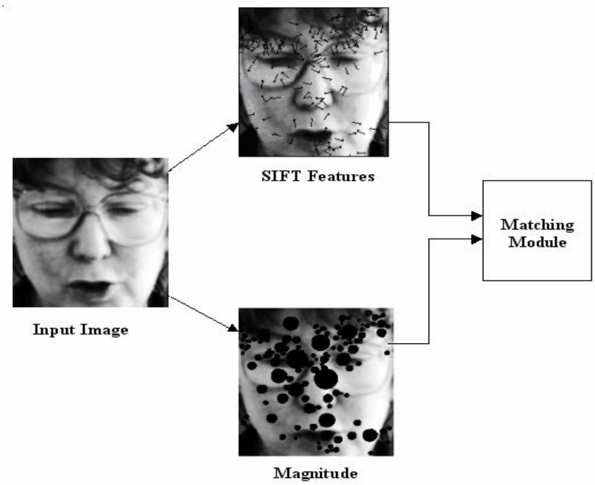

Fig. 1. Example image used for face recognition showing the SIFT Features locations and orientation (top) and the magnitude (bottom) coded by circles of different radius

2.2 Graph-Based Matching

From each face image a set of invariant and stable features (SIFT) are extracted. All features extracted from a single, static face image, are used to build an invariant representation of the subject's face. This representation is obtaining building a complete graph, whose nodes are the feature points extracted using the SIFT operator [13,14]. In order to perform the identification or verification process, several matching constraints can be applied to reduce the probability of mismatching when pairing the template and user's graphs [15,16]:

- *Gallery image based match constraint*. It is assumed that matching points will be found around similar positions i.e., fiducial points on the face image. In order to eliminate false matches a minimum Euclidean distance measure is computed by mean of the Hausdroff metric.
- *Reduced point based match constraint.* In addition to the previous constraint, all false matches due to one way assignments are eliminated by removing the links which do not have any corresponding assignment from the other side.
- *Regular grid based match constraint.* To further improve the robustness of the graph matching, the image is divided into a set of overlapping sub images. The matching is determined by computing the distances between all pairs of corresponding sub-image graphs, and finally averaging them with dissimilarity scores for a pair of sub-images.

All these techniques are aimed to find the corresponding sub-graph in the probe face image given the complete graph in the gallery image.

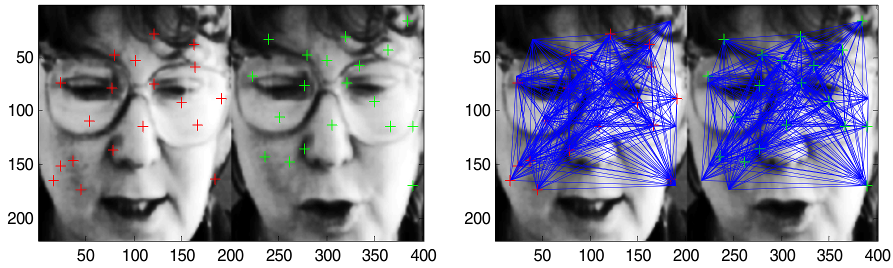

Fig. 2. An example of reduced point based match constraint. On the left, all matches computed from the left to the right image. On the right, the resulting complete graphs with a few numbers of false matches.

Table 1. Prior EER on G1 and G2 for the two methods: 'GIBMC' stands for gallery image based match constraint, 'RPBMC' stands for reduced point based match constraint and 'RGBMC' stands for regular grid based match constraint

	GIBMC	RPBMC	RGBMC
Prior EER on G1	10.13%	6.66%	4.65%
Prior EER on G2	6.92%	1.92%	2.56%
Average	8.52%	4.29%	3.6%

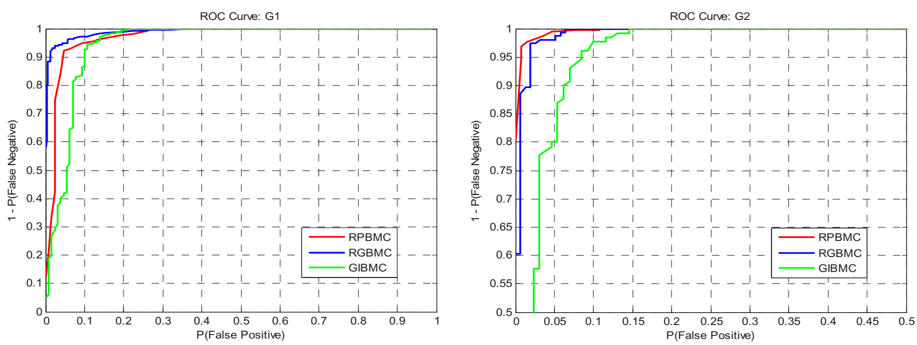

Fig. 3. ROC curves for G1 (left) and G2 (right): 'GIBMC' stands for gallery image based match constraint, 'RPBMC' stands for reduced point based match constraint and 'RGBMC' stands for regular grid based match constraint

2.3 Experimental Testing

The proposed graph matching technique was tested on the BANCA database [17]. The database used is composed of four image sets captured from 52 subjects in different acquisition sessions. For this experiment, the Matched Controlled (MC) protocol is followed, where the images from the first session are used for training, whereas second, third, and fourth sessions are used for testing and generating client and impostor scores. The testing images are divided into two groups, G1 and G2, of 26 subjects each. The error rate was computed using the standard procedure described in [17]. The reported errors are detailed in figure 3 and table 1. The obtained results show the capability of the system to cope for illumination changes and occlusions. This is a desirable feature for real applications in environments where both the lighting conditions and the subject's face position can only be partially controlled. From the ROC curves in figure 3, it is worth noting that the level of security can be increased by reducing the number of wrong acceptance (i.e. the risk of a false positive). This is obtained by tuning the matching threshold, which has the effect of moving the error on the abscissa toward the left, at the cost of an increased number of false alarms (enrolled users which are not recognized).

3 Multibiometric Recognition

From a system point of view, redundancy can always be exploited to improve accuracy and robustness which is achieved in many living systems as well. Human beings, for example, use several perception cues for the recognition of other living creatures. They include visual, acoustic and tactile perception. Multibiometric systems [6,7] remove some of the drawbacks of the uni-biometric systems by grouping the multiple sources of information. These systems utilize more than one physiological or behavioral characteristic for enrollment and on-line matching [8]. It has been demonstrated that a biometric system that integrates information at an earlier stage of processing provides more accurate results than the integration of information at a later stage, because of the availability of richer information [7]. This section illustrates a novel approach to fuse face and fingerprint biometrics at the feature extraction level. The improvement obtained applying the feature level fusion is presented over the score level fusion technique.

3.1 Face Representation Based on SIFT Features

The face recognition system introduced in the previous section, is based on the SIFT [13,14] features extracted from images of the query and database face. The face representation module is based on the spatial, orientation and keypoint descriptor information of each extracted SIFT point. Thus the input to the face module is represented by the face image itself, while the output is the set of extracted SIFT features $s=(s_1, s_2,\dots\dots s_m)$, where each feature point $s_i=(x ,y ,\theta, k)$ consist of the (x, y) spatial location, the local orientation θ and k is the keydescriptor of size $1x128$.

3.2 Fingerprint Representation Based on Minutiae

The fingerprint recognition module has been developed using the minutiae-based technique discussed in [18]. In order to achieve the same rotation invariance as the facial SIFT features, the fingerprint image is processed to detect the left, top and right edges of the foreground to calculate the overall slope, and by fitting a straight line to each edge by linear regression. A rectangle is fitted to the segmented region and rotated with the same angle to nullify the effect of rotation. The input to the fingerprint module is the fingerprint image and the output is the extracted minutiae $m=(m_1, m_2, \ldots m_m)$ where each feature point $m_i=(x, y, \theta)$ consist of the (x, y) spatial location and the local orientation θ [19].

3.3 Feature Level Fusion Scheme

The feature level fusion is realized by simply concatenating the feature points obtained from different sources of information. The concatenated feature pointset has better discrimination power than individual feature vectors. The procedure followed for concatenation is as follows:

- *Feature set compatibility and normalization*. The minutiae feature pointset is made compatible with the SIFT feature pointset by making it rotation and translation invariant and introducing the keypoint descriptor along with the minutiae position. The keypoint descriptors of each face and fingerprint points are then normalized using *min-max normalization* technique (s_{norm} and m_{norm}) to ensure that all the *128* values of a keypoint descriptor are within *0 to 1* range.
- *Feature Reduction and Concatenation.* The feature level fusion is performed by concatenating the two feature pointsets; This results in a fused feature pointset, which we call $concat=(s_{1norm}, s_{2norm}, \ldots s_{mnorm}, \ldots m_{1norm}, m_{2norm}, m_{mnorm})$. Feature reduction is applied to eliminate irrelevant feature points both before or after feature concatenation.
- *Matching.* The concatenated features pointset *(concat and concat')* of the database and the query images are processed by the matcher to compute the proximity between the two pointsets. The point pattern matching technique is applied, where the similarity between two concatenated features is based on the number of matched pairs found in the two sets, for both monomodal traits and for the fused feature pointset.

3.4 Experimental Testing

The multibiometric system has been tested on two different databases: the first consists of 50 chimeric individuals composed of 5 face and fingerprint images for each individual. The face images are taken from the controlled sessions of BANCA Database [17], while the fingerprint images were collected by the authors. The fingerprint images were acquired using an optical sensor at 500 dpi.

The following procedure has been established for testing mono-modals and multimodal system:

- *Training*: one image per person is used for enrollment in the face and fingerprint verification system; for each individual, one pair face-fingerprint is used for training the fusion classifier.
- *Testing*: this represents a thorough test made on the first chimeric dataset. Four samples per person are used for testing and generating client scores. Impostor scores are generated by testing the client against the first sample of the rest of the individuals, in the case of monomodal systems. In case of multimodal testing the client is tested against the first face and fingerprint samples of the rest of the chimeric users thus in total *50x4=200* client scores and *50x49=2450* imposters scores for each of the uni-modal and the multimodal systems are generated.

Table 2. FAR, FRR and accuracy values obtained from the multimodal fusion

Algorithm	*FRR(%)*	*FAR(%)*	*Accuracy*
Fingerprint	5.384	10.97	91.82
(Face+Finger) score level	5.66	4.78	94.77
(Face+Finger) Feature Level	1.98	3.18	97.41

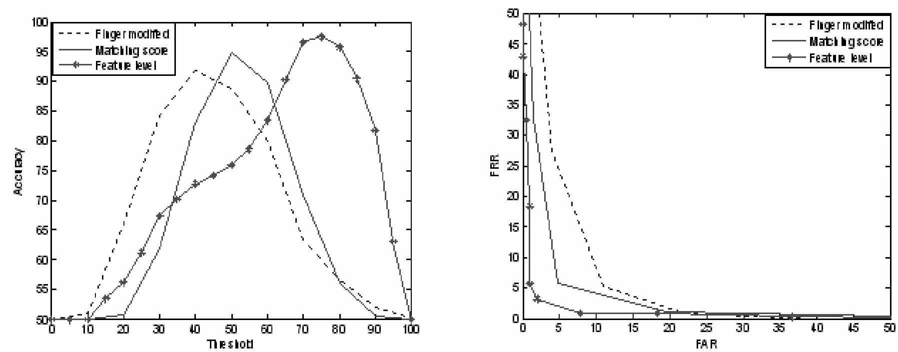

Fig. 4. Comparison of recognition performance. The accuracy (left) and ROC curve (right) for modified fingerprint, fusion at matching score and at feature level.

As multiple information sources can be exploited to gain a better recognition performance, this section outlined the possibility to augment the verification accuracy by integrating multiple biometric traits. The reported results show that a remarkable improvement in the accuracies are obtained when properly fusing feature sets which do not constitute an end in itself, but rather suggests to attempt a multimodal data fusion as early as possible in the processing pipeline. The actual feasibility of this approach may heavily depend on the physical nature of the acquired signal and on the overall set-up of the data acquisition scenario. For this reason the architecture of the data acquisition system must be purposively designed to allow an optimal functionality of the system to identify individuals within the context of crisis rooms.

4 Conclusion

The dynamic man-machine interaction within the context of crisis rooms requires the implementation of advanced identity recognition strategies to provide a personalized access to secure data. Two advanced systems were presented based on unimodal and multimodal biometric systems, the latter based on the integration of face and a fingerprint traits at the feature extraction level.

Considering the general problem of identity recognition, redundancy can be always exploited to improve accuracy and robustness. This can be accomplished in several ways: processing repeated measurements of the same biometric trait, applying different algorithms to the same data, or processing data from different biometric traits. Human beings, for example, use several perception cues for the recognition of other living creatures. They include visual, acoustic and tactile perception. Starting from these considerations, this paper outlined the possibility to augment the verification accuracy by integrating multiple biometric traits. There are several advantages in multimodal biometric systems. Not only they provide an augmented performance, but also increase the easy of use (by minimizing the probability of false alarms and false rejections of registered users), robustness to noise, and the possibility to use low-cost, off-the-shelf hardware for data acquisition.

In most of the examples presented in the literature, fusion is performed either at the score level or at the decision level, always improving the performance of each single modality. In this paper a novel approach has been presented were both fingerprint and face images are processed with compatible feature extraction algorithms to obtain comparable features from the raw data. Reported results show that a remarkable improvement in the accuracies is obtained when properly fusing feature sets.

The presented approach does not constitute an end in itself, but rather suggests to attempt a multimodal data fusion as early as possible in the processing pipeline. Possibly this may even imply a normalization of the data at the sensor acquisition level to allow an early fusion of the raw data. The actual feasibility of this approach may heavily depend on the physical nature of the acquired signal. Several experiments, performed with different algorithmic solutions, have been presented on a chimeric multimodal database. Further experiments will allow to better validate the overall system performances.

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Development of a Multiple Heuristics Evaluation Table (MHET) to Support Software Development and Usability Analysis

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Abstract. Among the variety of heuristics evaluation methods available, four paramount approaches have emerged: Nielsen's ten usability heuristics, Shneiderman's Eight Golden Rules of Interface Design, Tognazzini's First Principles of Interaction Design, and a set of principles based on Edward Tufte's visual display work. To simplify access to a comprehensive set of heuristics, this paper describes an approach to integrate existing approaches (i.e., identify overlap, combine conceptually related heuristics) in a single table hereafter referred to as the Multiple Heuristics Evaluation Table (MHET). This approach also seeks to update these approaches by addressing existing gaps and providing concrete examples that illustrate the application of concepts. Furthermore, the authors identify three decision factors that support meaningful communication among stakeholders (e.g., product managers, engineers) and apply them to the MHET heuristics. Finally, this paper discusses the practical implications and limitations of the MHET.

1 Heuristic Evaluations

Of the many usability methods available, a low-cost, flexible approach is the heuristic evaluation, which involves comparing an interface to a given set of design rules or principles [1]. Unlike evaluation methods based on usability guidelines that can contain hundreds or thousands of items, heuristic evaluations use a limited set of design rules or principles [1].

As heuristic-based evaluations have gained popularity among practitioners, the number of available heuristics tables has increased accordingly. Among them, four paramount approaches have emerged: Nielsen's ten usability heuristics, Shneiderman's *Eight Golden Rules of Interface Design*, Tognazzini's *First Principles of Interaction Design* and a set of principles based on Edward Tufte's visual display work. Each of these approaches address unique aspects that others may overlook or discuss in limited detail. The following sections describe these four approaches and their unique contributions.

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1.1 Ten Usability Heuristics

Based on a factor analysis of usability problems, Nielsen outlines a list of ten usability heuristics [2] (see source for complete set of heuristics). The purpose of this set is to provide general rules for interface design. For each heuristic, Nielsen provides a description that provides a high-level overview of the heuristic. We suggest Nielsen's approach is unique because he addresses the importance of *help and documentation*, an area overlooked by other approaches. This heuristic describes the importance of providing help files and additional system documentation to support the user. In addition to addressing the necessity of providing such guidance, Nielsen's heuristic points to the importance of providing accessible and useful help documentation (e.g., easy to search, not too large, concrete steps). Because these issues support the user's ability to use a system successfully and efficiently, it is important not to overlook this issue.

1.2 Eight Golden Rules of Interface Design

Shneiderman has proposed a short list of underlying design principles, the *Eight Golden Rules of Interface Design* [3] (see source for the complete list of principles). For each principle, Shneiderman provides a short description that may contain variations or examples of how to implement the principles as well as notable exceptions. Shneiderman specifically addresses the use of dialogs within the interface, an area not addressed by other approaches. The principle *design dialogs to yield closure* outlines the importance of providing users with a clear sequence of actions and feedback when a group of actions is complete [2]. While aspects of this principle are addressed by other approaches (e.g., providing feedback, logical order), Shneiderman provides guidance for how to utilize these aspects when designing dialogs. These additional pieces of information provide usability professionals with more detailed design guidance.

1.3 First Principles of Interaction Design

In the *First Principles of Interface Design*, Tognazzini [4] proposes 16 design principles. (See source for complete list of principles.) Tognazzini [4] describes these principles as "fundamental to the design and implementation of effective interfaces." Similar to Shneiderman, Tognazzini provides a description for each principle, which includes detailed rationales and examples.

We suggest that Tognazzini's approach offers two distinctive heuristics categories. First, Tognazzini acknowledges the importance of providing *defaults*, for both system configurations and text-based field data. Second, the *learnability* principle acknowledges the importance of minimizing the learning curve [4]. A third contribution is use of metaphors in design. While this principle is in-line with other approaches in describing that user interface characteristics should match user expectations, Tognazzini places emphasis on the use of metaphors to help users quickly grasp details of interface design. A forth contribution of Tognazzini's approach is the attention to graphic design themes. Specifically, Tognazzini describes three graphic design themes: *Fitts' Law*, *color-blindness* and *readability*.

1.4 Graphics and Web Design Based on Edward Tufte's Principles

The Computing and Communications department at the University of Washington (UW) developed a list of graphic and web design principles, based on Edward Tufte's work on graphic displays [5]. (See source for complete list of principles.) This type of information is especially important when working on Graphical User Interface (GUI) design. This approach specifically addresses the use of graphs and charts when describing statistical analysis and thereby contributes unique, in-depth guidance related to the use of graphics in user interface design. Some examples include: using thumbnail sized graphics to permit overlay of images and rapid cycling, reserving bright colors for small highlighted areas, and using graphics and associated text in close proximity. This detailed guidance enhances the principles provided by other approaches.

2 Development of the Multiple Heuristics Evaluation Table (MHET)

While these approaches each highlight specific aspects of interface design, there is also a high degree of overlap among approaches. With this in mind, the authors integrated and updated these approaches in a single heuristic table – the Multiple Heuristics Evaluation Table (MHET) to simplify access to a comprehensive set of heuristics concepts. The steps taken to achieve this included: 1) Identifying overlap across approaches and grouping related heuristics, 2) Addressing emerging gaps, and 3) Providing concrete examples. In addition to these steps, we established a set of user group decision factors to support the accessibility to a range of potential stakeholders in software development (e.g., product managers, engineers, representative user group).

2.1 Overlap

Two types of overlap were identified during our conceptual analyses. First, overlaps emerged within approaches. The second type of overlap identified was between approaches. In these cases, the approaches describe related themes but often use different terminology to refer to the same heuristic. Examples of these types of overlap are described in heuristic descriptions.

2.2 Emerging Gaps

As heuristic categories developed, the authors identified gaps in the guidance provided to practitioners. When gaps were identified, the authors provided additional guidance based on usability testing experience.

2.3 Concrete Examples

In order to insure that each heuristic includes guidance related to the application of concepts, the MHET includes concrete examples of each heuristic category. These examples offer positive design examples of the heuristics as well as negative examples that demonstrate violations. The purpose of defining both do's and don'ts of software design is to illustrate concepts and make the MHET accessible to a diverse audience. While many of the do's and don'ts used to illustrate heuristics are based on the descriptions and examples provided by the existing approaches, additional examples were provided as gaps in guidance emerged. The main purpose of the MHET is not to provide an exhaustive list is design solutions; rather, the do's and don'ts are meant to provide examples from which users can gain insight into design solution possibilities without limiting design options and creative design solutions.

2.4 User Group Decision Factors

In order to support accessibility to a range of potential users (e.g., product managers, engineers, representative user group), we established a set of user group decision factors. Such a categorization allows multiple stakeholder groups to identify heuristics related to specific design characteristics. Three overarching categories were identified: 1) User Experience, 2) GUI Design, and 3) System Architecture.

The User Experience category identifies heuristics related to the subjective experience of the user. Heuristics that deal with visualization solutions and cognitive user support fall within the GUI Design category. Lastly, the System Architecture category encompasses heuristics related to the system characteristics (i.e., hardware, software) that support the optimization of the GUI design and user experience. Because many heuristics address complex design solutions and human-computer interactions, they may qualify for multiple categories.

3 The Multiple Heuristics Evaluation Table (MHET)

Our conceptual analyses of overlap and gaps revealed 12 design heuristics: Software-User Interaction, Learnability, Cognition Facilitation, User Control & Software Flexibility, System-Real World Match, Graphic Design, Navigation & Exiting, Consistency, Defaults, System-Software Interaction, Help & Documentation, and Error Management. The organization of the heuristics within the MHET is based on the aforementioned user group decision factors. Software-User Interaction, Learnability, Cognition Facilitation, and User Control & Software Flexibility heuristics are part of the User Experience decision factor. The GUI Design decision factor includes Cognition Facilitation, User Control & Software Flexibility, System-Real World Match, Graphic Design, Navigation & Exiting, Consistency, and Defaults heuristics. The final decision factor, System Architecture, includes Navigation & Exiting, Consistency, Defaults, Software-System Interaction, Help & Documentation, and Error Management & Data Back-Up heuristics. The following sections will discuss each heuristic by detailing the integration of conceptually related heuristics as well as describing the do's and don'ts associated with the heuristic.

3.1 Software-User Interaction

The heuristic Software-User Interaction provides design guidance that supports users' interaction with the software by providing the user with appropriate and necessary information. This heuristics integrates conceptual overlap identified across these approaches including: *Visibility of system status* [2], *Offer informative feedback* and

Design dialogs to yield closure [3] and *Autonomy* and *Latency reduction* [4]. Each of these heuristics describes design characteristics that affect the users experience based on the users' interaction with the software. In order to support this heuristic, developers must provide the user with assistance during software use. For example, software should inform the users with status mechanisms and software status displays (e.g., dynamic or animated display for extended delays, message panes, task completion confirmation) to prevent user actions from occurring without a response [2] [4]. Including symbols such as the animated hourglass means the user does not have to make assumptions regarding the time left until task completion. In addition, providing the user with feedback (e.g., error messages, type of input required) is pertinent so that the user can gain confidence in using the software [2] [3] [4]. For example, an invalid input or error should trigger feedback that provides the user with information such as why the input was incorrect and how to properly input information (e.g., alternative formats for entering dates such as December 11, 2006 and 12/11/2006).

3.2 Learnability

The *Learnability* heuristic, proposed by Tognazzini [4], provides guidance related to design that supports timely and efficient learning of software features. Examples of design solutions captured by this heuristic include training tools and learning aids that encourage users to explore as well as tools that support the users' ability to learn the interface. Tognazzini specifically addresses the need of software design to minimize the learning curve. In order to accomplish this, aids must be clear and concise; however, designers must be careful not to provide aides that are too brief, lengthy or difficult for a novice to understand. While limiting the learning curve is important, the authors acknowledge that software applications often require training in order for users to use the software effectively. In these cases, developers should aim to embed training within the software application (e.g., tutorials) to eliminate the need for users to alternative training sessions (e.g., workshops, courses).

3.3 Cognition Facilitation

The Cognition Facilitation heuristic was derived by integrating a variety of heuristics from all four approaches. These heuristics included: Nielsen's [2] including *recognition rather than recall* and *aesthetic and minimalist design*; Shneiderman's [3] including *reduce short-term memory load*; Tognazzini [4] including *anticipation* and *track state*; and UW Computing & Communications [5] including *basic philosophy of approach*, *data densities*, *data compression*, *small multiples*, *chartjunk*, *when NOT to use graphics*, and *aesthetics*. The integrated theme captured by the Cognition Facilitation heuristics is that the design should support the cognitive limitations of the human user. The focus of this heuristic highlights the importance of GUI design in software applications. This means that the display should be simplistic [3] and free of clutter, which prevents users from viewing irrelevant or rarely needed information [2]. In contrast, supplying the user ambiguous or too much information may lead to confusion or frustration. To alleviate this from happening, the interface should provide clear and timely information as well as graphics to support and clarify data [5], reducing short-term and long-term memory load [2] [3].

3.4 User Control and Software Flexibility

The heuristic User Control & Software Flexibility points to the importance of designing software that respond to user actions and is adaptable. The authors integrated overlapping contributions including Nielsen's [2] *flexibility and efficiency of use*, Shneiderman's [3] *enable frequent users to use shortcuts* and *support internal locus of control*, and Tognazzini's [4] *autonomy* heuristics. This heuristic suggests that programs be customizable, enhancing the user experience and increasing the flexibility of the software. For example, allowing GUI configurations to be set through user preferences permits the application to be more personable to the user and enhances the overall experience. In addition, software applications should make the user feel in charge and respond according to user actions [3] [4]. The user should not feel limited in exploration or be discouraged to use features within the software. Furthermore, the software should allow the user to tailor frequent actions or supply access to task accelerator features that expert and novice users could exploit during program execution [2] [3]. Examples of accelerators include shortcut keys, hidden commands and special toolbar icons that the user can benefit from while interacting with the software.

3.4 System-Real World Match

Overlap was identified in Nielsen's [2] and Tognazzini's [3] approaches related to the need to design products that match users' expectations based on user community expertise as well as similar available products. These heuristics include *match between system and the real world* (Nielsen), *efficiency of the user* (Tognazzini), *human interface objects* (Tognazzini), and *metaphors* (Tognazzini). The integration of these heuristics formed System-Real World Match. This heuristic supports user familiarization with an application. Specifically, terminology should fit the intended user group [2]. For example, if errors occur, the user needs clear information rather than technical jargon or code. Additionally, symbols are an integral part in graphical user interface design and represent common features. For this reason, icons should be well chosen and fit the task (e.g., disk icon to save file). Furthermore, one should not have to distinguish the differences between icons. With this in mind, icons should not represent different or multiple task items. The overarching goal of this heuristic is to match systems with the real world and design software referencing popular programs to ease the user with familiarization. Unique design approaches should only be implemented upon feedback from the user community or through usability testing that may suggest changes to the interface.

3.5 Graphic Design

The UW Computing & Communications [5] approach captured detailed information that supports the Graphic Design heuristic, which includes the following principles: *Basic philosophy of approach*, *Graphical integrity*, *Multifunctioning graphical elements*, *Colors*, *Increasing data comprehension*, and *Aesthetics*. Additional overlap was identified within Tognazzini's [4] approach, which includes guidance related to *color-blindness*, *Fitts' Law* and *readability*. These elements are captured within the

Graphic Design heuristic, which provides guidance related to the use of graphic elements to convey information and create effects. These characteristics aid the human visual processing of graphical user interfaces as well as address the needs of special users. Graphics can serve a multitude of purposes in a graphical user interface [5]. For example, graphical elements of an interface such as a comment or flag support specific functions that the user can execute. Furthermore, graphics that include text must support easy reading, while graphics without text should provide mouse-over descriptions [5]. Graphic Design also addresses the vital role colors play in graphical user interface design. Developers must take into account that the user may be colorblind. To compensate, secondary cues such as grayscale, different graphics and text labels may need to be considered for each color presented in the interface [4]. Finally, Graphic Design also addresses adherence to Fitt's Law (i.e., the time required to acquire a function is the function of the distance to the target and the size of the target). With this in mind, commands and icons that cancel each other or cause error should be separated.

3.6 Navigation and Exiting

The Navigation and Exiting heuristic defines characteristics that facilitate software exploration and provide outlets to terminate actions. Overlapping aspects of existing approaches that supported the development of this heuristic include: *User control and freedom* [2], *Permit easy reversal of actions* [3], *Explorable interfaces* and *visible navigation* [4]. This heuristic supports the user's ability to 1) terminate actions and 2) navigate the software interface. Ideally, cancel options should provide the user with means to escape an operation. In addition, because actions may occur accidentally, it is important to provide users with the ability to easily reverse actions [2] [3] [4]. Navigation should be supported by providing easily identifiable landmarks for the user [4]. For example, if the application provides multiple menu levels, higher-level menus should remain open and visible allowing the user to track options or back track to a previous menu for additional operations.

3.7 Consistency

While the name of this heuristic, Consistency, was adopted from Tognazzini's [4] approach, both Nielsen [2] and Shneiderman [3] propose consistency related heuristics. The Consistency heuristic emphasizes the importance of designing elements of an interface to provide standard and reliable terminology, actions and layouts. The use of consistent terminology, structures, responses and looks are essential to GUI design. For example, software should not use multiple words to refer to the same object or option [2]. On the other hand, when functions act differently, the design should employ notably inconsistent design options. Consistency also addresses the integration of the overall system. If multiple systems or parts of a system are required for normal operation, the user should be unaware of background operations; however, because there may be instances where the user needs access to specific systems that typically run in the background, the software should provide a means to access these systems.

3.8 Defaults

The *Default* heuristic, unique to the approach proposed by Tognazzini [4], provides guidance related to the use of default information. This guidance notes the importance of providing the user with default information as well as supporting easy adjustment of initial settings. Defaults are placeholders that indicate where the user can enter input. These placeholders should be descriptive, providing information or examples that relate to the type of input required [4] Terms such as *Default* or *Enter Text* do not provide any explanatory information [3]. In addition, defaults should be easy to change or delete [4]. For example, when dialogs contain a default, the default value should be highlighted to facilitate easy modification or deletion.

3.9 System-Software Interaction

Overlap across approaches associated with utilizing software designs that supports the interaction with hardware components was captured within the System-Software Interaction heuristic. Specifically, overlap was identified in *Visibility of system status* [2], *Enable frequent users to use shortcuts* [3], and *Efficiency of the user* and *Latency reduction* [4]. Various interactions occur between software programs and systems. For example, multiple applications often run on the same system. These applications, known as *processes* to the Operating System (OS), require memory and Central Processing Unit (CPU) utilization to function efficiently. Therefore, software should provide a reasonable speed of processing [4] and refrain from high CPU utilization. Additionally, software should be designed to support multiple concurrent tasks [3] [4] by not consuming an abundance of memory which would prevent other tasks or system processes from occurring.

3.10 Help and Documentation

Nielsen's [2] *Help and Documentation* heuristics was adopted to capture the importance of providing users with help files and documentation to support the use of software. Guidance related to help files address a variety of available help system options (e.g., HTML-based help files, wizards). These help systems should not provide every detail about the software, but rather provide task-oriented information [2]. Further, help messages should provide brief informative messages [4] without supplying additional information that is irrelevant to task [2]. In addition, this heuristic provides guidance related to documentation (e.g., user manual, quick reference guide) which states that it should be easy to search and navigate [2]. For example, information should be represented in an ordered list of concrete steps instead of embedding steps into a paragraph [2].

3.11 Error Management

The Error Management heuristic captures the need to design software that prevents, identifies, diagnoses and offers corrective solutions. Themes of existing approaches that support this heuristic include: Nielsen's [2] *error prevention* and *help users recognize, diagnose, and recover from errors*; Shneiderman's [3] *offer error prevention* and *simple error handling*; and Tognazzini's [3] *efficiency of the user* and *protect users work*. Because errors are inevitable due to the unpredictable nature of the user, designing software that supports management and data backup is pertinent. When errors appear, notify the user with messages that are succinct and written to be clear and informative [2] [3] [4]; cryptic or unclear messages may lead to miscomprehension of the problem and further increase the chances of causing another or even multiple errors. To support this, software should detect errors caused by software bugs or user issues [4] by providing some form of error checking. In addition, software can be designed to prevent errors [2] [3] by not allowing the user to click or open functions that are not currently available (e.g., gray out placeholders) or by auto-saving data.

4 Conclusion

In conclusion, the MHET provides an approach to heuristic testing that integrates and updates existing approaches in a single table with the intention to simplify access to a comprehensive set of heuristic concepts. This approach outlines do's and don'ts of GUI design and provides three decision factors to support access by a range of user groups.

This approach of providing do's and don'ts has practical implications for the use of heuristics. For instance, elusive or broadly defined conceptual heuristics may be useful for the academic classification of usability issues, but less useful to practitioners. This is because they provide little or no specific guidance on how to implement the heuristic concept. On the other hand, highly specific design guidelines do not qualify as rules of thumb (heuristics). Further, in order to support design or analyses, utilizing guidelines requires extensive checklists to assure that each item is addressed. In an attempt to overcome this challenge, the MHET provides a general, comprehensive set of guidelines supplemented by specific, detailed examples to clarify and guide testing and design. By doing this, the MHET provides access to a wide range of examples that demonstrate heuristics without limiting potential design solutions or creativity.

Whiles this approach is grounded in heuristics from existing approaches, the authors acknowledge the existence of limitations. One limitation is that the MHET has a limited focus on the development of software *graphical* user interfaces (GUIs). Therefore, future work should focus on expanding the examples to broaden the focus of the MHET to include alternative and multi-modal interfaces. In addition, while the MHET has the potential to support both development and analyses of GUI software, this approach has not yet been validated. For this reason, the authors encourage the use of this approach by practitioners. This work should focus on validating the applicability of the heuristics outlined within the MHET for GUI design.

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Accessibility Research in a Vocational Context

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Abstract. Current experience shows that vocational context has a vital role to play in research on inclusive information society technology, for at least four reasons. First, the occurrence of disabilities has a major impact on employability and employment. However, the potentially significant contribution of accessible and usable information society technology (IST) in employment has yet to make more than little difference in practice. Context of use is still often ignored. In other words, to ensure that applications can achieve as broad a customer base as possible, they are often designed for generic, rather than specific, cases. While this enables those applications to support a wide variety of use-case scenarios, the corollary is that not as much specific support is afforded to individual use-case scenarios as when designed for a more focused sets of tasks. Second, despite the impressive increases in computing power, innovations in interactive design, such as 3-D user interfaces (UIs), are rarely incorporated into mainstream IST products. One of the fundamental principles taught to most software UI designers is that of 'consistency', i.e. that similar functions should look the same and behave in similar ways across a variety of applications. The benefit of this approach is that once a user is familiar with the interaction metaphors being used, it will take minimal time to learn to use a new and unfamiliar application. The flip-side of this principle, though, is that it can stifle the development of new and innovative UI techniques, because they will not be 'consistent' with existing applications and UI designs. Greater emphasis upon the context of use in general and the vocational, educational and lifestyle context in particular could lead to better user uptake, as the resultant UI would be better suited to the individual needs ands wants of each particular user. This better uptake, in turn, gives better feedback to mainstream system designers. Third, without context, the identification of user and system characteristics is an unbounded problem. There are simply too many possible different design options to manage easily. The consideration of vocational or recreational context significantly reduces the scale of the problem and renders it more manageable.Fourth, accessibility research in a vocational context ensures that the participants not only gain indirectly from it but benefit directly too, often gaining an improved vocational standing. If so, emerging design methods like unified user interface design (UUID) methods should place much more concentration on the vocational context of use.

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1 Introduction

There are several urgent reasons why research on accessibility and assistive technology should include research within a vocational or educational context. For example, there is substantial evidence that acquired or inherited disabilities have a substantial impact upon the educational and vocational prospects of the individual and that the adaptation and deployment of personalised technology to support accessibility can improve vocational standing significantly (Adams and Langdon 2003; Adams, Langdon and Clarkson, 2002) Put simply, if a person is given the right tools to do a job, then it increases the chances of that person getting gainful employment.

Also, as Beaudouin (2004) points out, the capabilities of modern information society systems have increased many times over, but mainstream interface design has improved only modestly over the same time span. Accessibility considerations have often failed to transfer from assistive technology or design innovations to mass produced systems. The effective use of context has substantial implications for accessibility and usability of information society systems for all, including people with disabilities and the older adult. Mainstream interface design for all could be achieved by greater emphasis upon the context of use in general and the vocational, educational and lifestyle context in particular (Stary, 2002).. This could lead to better user uptake, in turn giving better feedback to mainstream system designers.

2 Impact on Employability

There has been considerable work on user modelling and monitoring that has identified a number of dimensions that could or should be assessed when attempting to establish the requirements of an individual or group of people for information society technologies for work or personal use (Adams and Langdon, 2003; Adams and Langdon, 2004; Adams, Langdon and Clarkson, 2002 etc). Such work has effective user modelling. However, whilst useful characteristics of the intended users of a system can be identified, it is not clear jut how many of those characteristics are relevant at any one time. There is some evidence that human cognitive features may be necessary but not necessarily sufficient. For example Adams (2004) has identified that levels of insight and performance awareness can be important, as can aspects of personality.

3 Participant Benefits of Research

Scientific research in the human-related disciplines often requires the involvement of human participants, as, for example, in medicine, psychology or HCI. There is rarely any indication of a direct benefit for those participants, not even when potentially relevant prototype systems are being explored. In many cases, the potential benefits are purely indirect through a generic contribution to knowledge. However, when participants are involved in a vocationally relevant way, they can potentially benefit directly from the acquisition of new insights about themselves and from expert vocational advice.

4 The Impact on Employability

First, there is substantial evidence for an impact of disability on employability. On the Wage website (http://www.wage.eu.com/articles/dda/stats.html), the following statistics are given from UK government sources.

- 42% of disabled people of working age are in employment contrasting to 81% of non disabled people in the same age range.
- Disabled people are over 5 times as likely to be out of work and claiming benefits.
- Disabled people in full time employment earn about 20% less than non disabled people considering all types of jobs

Broadly similar estimates are given by Harrison and Phipps (2006). When considering the link between employability and disability for disabled students in the UK. Harrison and Phipps (2006) point out that any consideration of the employability should remember that in the UK only 50% of people with disability and of working age are in employment as compared with 87% of nondisabled people of working age. There are both practical and legal reasons why it is important to increase this 50% figure. In practical terms, it may profit the individual in many cases in many ways to be employed and receiving a realistic salary and benefits, but it would also benefit the economy that is experiencing skills shortages. Initiatives like the Employers' Forum on Disability provide a voice for employers on disability as it impacts business in the UK. This is a not-for-profit membership organisation, funded and led by almost 400 private and public sector members, which between them employ circa 20% of the UK workforce.

5 Legal Mandates

From a legal perspective, in the UK the Special Educational Needs and Disability Act (SENDA) specifies that institutions should treat all students favourably and make all reasonable adjustments so that students with disabilities do not face substantial disadvantages. The student experience should enable those with disabilities to develop the skills and knowledge required for them to pursue their chosen vocations.

If so, students with disabilities should be given equal opportunities to demonstrate employability and to receive vocational advice that is relevant to them. Croucher, Evans and Leacy (2004) have provided a major AGCAS (Association of Graduate Careers Advisory Services) evaluation of the first destinations of UK graduates (2003) with disabilities. This is an important report, since it is issued only one year after the date of graduation. They considered 11,651 first degree graduates with a disability out of a total of 182,319 graduates. Croucher et al (2004) explored what happened to them, their success in getting a job and the types of jobs and further education they obtained. They also considered the vocational experiences of students with different types of disabilities e.g. dyslexia, blind/partially sighted, deaf/hearing impairment, wheelchair user/mobility difficulties, personal care support, mental health difficulties, an unseen disability, multiple disabilities and other disabilities.

Their findings include: 48.4% of disabled graduates were in full-time paid work compared with to 54.6% of non-disabled graduates, 8.4% of disabled graduates were in part-time paid work compared with 7.6% of non-disabled graduates. 8.2% of disabled graduates were engaged in work and further study relative to 8.0% of non-disabled graduates. 16.6% of disabled graduates were engaged in further study compared with 15.9% of non-disabled graduates. 9.6% of disabled graduates were assumed to be unemployed compared with 6.9% of non-disabled graduates. Observed differences between different industries were often absent or marginal.

They also examined differences between the different disability groups. As a baseline, they reported that overall 48.4% of disabled graduates and 54.6% of non-disabled graduates were in full time employment. The figures for entering full time work were: 52.5% of graduates with an unseen disability, 50.3% of graduates with dyslexia, 43.7% of blind / partially sighted graduates, 44.3% of deaf/hearing impaired graduates, 30.3% of graduates who are wheelchair users/have mobility difficulties and 29.5% of graduates with mental health difficulties.

These results, and others like them, demonstrate the complex nature of the relationship between student employability and disabilities. Overall, the results are encouraging, with overall high levels of employment. However, there are many unanswered questions, including the role of the specific disabilities in influencing employability. Within the overall figures, it is clear that individuals with mobility or mental health vectors present significantly lower levels of employment. The potential application of accessible and usable information society technology (IST) in higher education and initial employment is little understood, but it is suggested that much could be done to apply IST for the facilitation of people with different disabilities in different ways so that they may achieve the potentially best levels of employability. Recent examples of this type of work are now emerging, with an increasing emphasis upon inclusive design (Keates and Clarkson, 2003), cognitive user profiling (Adams, 2004) and policy development (Stephanidis et al, 2001).

6 Lack of Innovation

Pure research studies of the human computer interface in general and studies of usability and accessibility in particular seem to lead to little if any take up by major manufacturers and developers of system interfaces. Beaudouin (2004) has argued that whilst PCs have been increased in power over a thousand times in the last ten years, user interfaces have basically stayed the same. Comparatively few of the radically new concepts and techniques for user interfaces proposed and developed in research labs have found their way into new products and services. He argues that this problem can only be overcome by switching from a focus upon the design of user interfaces to the design of interactions themselves and to a “broader view of interaction in the context of use”.

7 Context of Use

The notion of context of use is well recognised in studies of universal access (Keates and Clarkson, 2003; Shneiderman and Plaisance, 2004; Stary, 2002; Stephanidis, 2001). Often the context of use is depicted as a specific model or set of models. For example, Stary (2002) considers model based development schemes and the types of models that can be used to develop a design for a user accessible interface. Such models include the development of task models (both existing and envisaged), user models, data models and interaction models that can be used to capture the essential requirements of a new interactive system design. However, present research, a much wider perspective of the context of use is envisaged and that wider view provides benefits for the end-users, the researchers and for practitioners.

8 Approaches to HCI

There are at least three approaches that can be taken to the issues of human computer interaction. First, the HCI expert can be seen as an evaluation specialist who is brought in at a later stage to evaluate a prototype or a system and give advice on the final design of the interface. In this case, the HCI expert may work as part of a large team working on mainstream applications for larger vendors. For example, see the discussion of different methods reviewed by Shneiderman and Plaisance, 2004). A second approach is the production of an accessible and usable prototype directed by an HCI practitioner and supported by technical staff who program the software to instantiate identified users and to revise that software in line with feedback. Such projects tend to be more modest in size until they are adopted by mainstream vendors. The third type of HCI research involves working with individual users in a vocational and assistive technology setting, identifying user requirements, building user models and adopting / adapting information society technology and assistive technology to meet the needs of individual users. In this approach, a substantial level of success can be delivered in terms of the present users, but mainstream applications and systems designs would not be altered or informed by it unless there is an active process of feedback to mainstream programmers and designers. It can be readily seen that the three approaches are all significantly different from each other in terms of focus and scale, though they all require feedback to mainstream developers if the latter are to be significantly informed by the outcomes of this work. The present purpose is not to compare and evaluate these three approaches, since there are others for which there is not space to mention here. The aim is to describe, present and advocate the third type of research which is much more akin to work with rehabilitation and assistive technology. However, it should be noted that the present focus is on research rather than practice.

9 Working with Individual Users

Typically, in this approach, an individual would consult with one or more experts with expertise in vocational psychology and assistive / adaptable technology. They would work with an expert on a one-to-one basis to work out how best to develop their education, career or lifestyle or some combination of these themes. This work would include a consideration of the ways in which IST can be adapted to meet their needs directly and / or through the use of assistive technology. Such an evaluation could take up to three days of contact time but, in the main, as the participants could perceive a benefit in participation, they were happy to do so.

10 Assessment Methods and User Models

The first problem to be overcome was the lack of a systematic selection of appropriate and relevant assessment methods. Whilst a wide range of cognitive, occupational and psychometric methods could draw upon, this seemed to be in danger of a lack of systematicity. This issue was addressed by Adams, Langdon and Clarkson (2002) in which the need for a systematic basis for cognitive assessment methods for assistive technologies were tackled. A review of the cognitive psychology literature led the authors of that paper to adopt and adapt Broadbent's Maltese cross (Broadbent, 1984) as a roadmap of the relevant psychological processes to be considered in user requirement evaluation and user modelling.

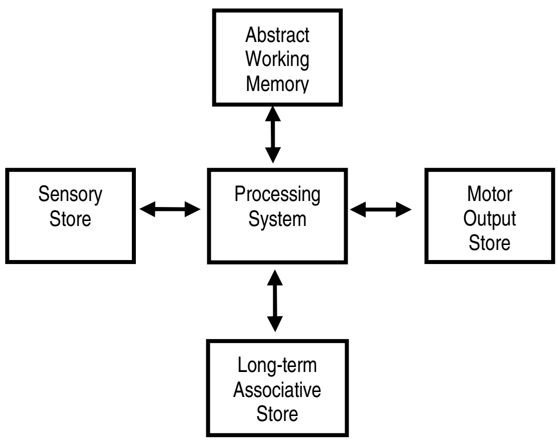

Fig. 1. The Maltese cross

This provided a simplistic model of human functioning i.e. powerful enough to take in pertinent research results but simple enough to be used to guide good practice. It also has the advantage of being based upon a considerable volume of high quality research. The model provided five components of user functioning, including input processes, output processes, working memory, long term memory and executive functions. These components constitute the first level of the model that can be unpacked to a second level in the model to consider IST activities e.g. select a menu etc. Whilst Broadbent's Maltese cross is intended as a theory of human memory, our own development of it is intended to provide a basis for user modelling and for user requirements assessment. It is a theory of cognition and in addition each module in the model has both memory and processing capacity, giving the model the power of a von Neumann machine. This model, a direct descendant of the Maltese cross is called Simplex One, used as a simplistic model in HCI in combination with concepts like the Inclusive Design Cube (Keates, Langdon, Clarkson and Robinson, 2001). Further work, reported by Langdon, Adams and Clarkson (2003) demonstrated that the new battery of tests could differentiate the needs of three different individuals with different types of head injury.

Whilst they did not expect to change the architecture of Simplex One, merely to refine the details, discussions with designers and meta-analyses of the literature (Adams, in press) convinced them of the need to add a further four components i.e. feedback, mental models, complex output and emotions, as presented by Adams and Langdon (2003) to produce Simplex Two. In addition, they were able to show that Simplex Two could be used to generate universal access heuristics for blind and visually impaired people using IST (Adams, Whitney and Langdon, 2003). In this study, the model was used to generate accessibility design heuristics to evaluate three systems for people with impaired vision.

11 Results

The work on user sensitive design methods for IST users with special needs led to the observation that the specific assessment techniques depended critically upon the insight and awareness of the users (Adams and Langdon, 2004). Considering different psychological assessment methods e.g. tests, questionnaires, structured interviews etc, it is typical to consider that these different options have different levels of accuracy, strengths and weaknesses, but otherwise confirm each other. It is now known that is not the case (Dix, Finlay, Abowd and Beale, 2004). In an evaluation of nine case studies, Adams and Langdon (2004) investigated the insight (defined as the long term knowledge of strengths and weaknesses) and awareness (showing short term appreciation of current performance), in individuals with muscular-skeletal and brain injuries. Of the nine case studies, eight showed some lack of insight into their problems and four also showed a lack of awareness when they had performed badly on a task. Clearly, the relationship between insight and awareness is more complex than anticipated and that methods that rely on either should be viewed more critically in future. This conclusion is supported by work reported by Adams (2004) in which self report, observed task performance and personality inventories were all used to evaluate user requirements in four case studies. However, the three methods showed diverse results, again showing that user modelling cannot rely on a limited range of methods.

12 Conclusion

Overall, working in a vocational context has a number of tangible benefits for all the stakeholders i.e. users, researchers and practitioners. Users were comfortable about participation as they saw it as a positive process. The process was designed to produce significant output in terms of educational, vocational, life style and technological developments.

In this paper three approaches to HCI research were identified. Whatever your chosen approach, it is clear that feedback must be provided for mainstream system / application design. If HCI is to influence mainstream IST product design, then it is argued that the wider context must be involved to a much greater extent and specific mechanisms for feeding the results of such research into mainstream design. If so, this will require a radical change in traditional HCI methods.

13 Suggestions for Future Work

It is clear from the above account of work in universal access that users' requirements and optimal system designs should take the context more strongly into account. It is already clear that the context-of-use is an important consideration for accessible system design and meeting the needs of specific users or groups of users. However, it is concluded here that the wider vocational (or lifestyle context) should be allowed, where appropriate, to have a major influence. Consider the following diagram.

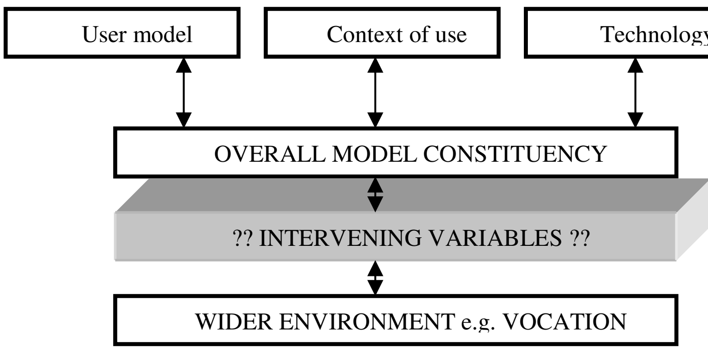

Fig. 2. Understanding context

As yet, there is not a clear understanding of the intervening variables that mediate the influence the impact of the wider environment like vocational context or lifestyle on the overall model constituency of the user (user profile, context of use / task context and the technology models). Perhaps concepts like social intelligence could cast some light here and that will be one line of future work. However, the long-term memory and cognitive modelling skills of the individual are, inter alia, of potential relevance here (Adams 2004). Whatever, the outcomes of such work, it is clear that a systematic consideration of the vocational and lifestyle context of the users will, almost certainly, contribute substantially to their effective inclusion in the Information Society.

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User Modelling and Social Intelligence

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Abstract. There is a growing body of evidence that key components of human cognition can be used to identify important aspects of accessibility design for universal access in the information society, through user modelling. However, there is an equal growth in an appreciation of the contexts within which any interactive system must function, including the vocational and social contexts. If so, there is an important need is to extend cognitive user models to respond to and make predictions about the vocational and social contexts that make up the information society. Whilst many aspects of social intelligence can, it seems, be subsumed under current cognitive architectures of the user, there is the practical danger that the contribution of social intelligence may be underestimated when considered as a subset of the knowledge domains or skills sets of human cognition. To counter this practical development problem, the concept of the social intelligence interface is introduced as a developmental construct to inform the inclusive design process.

1 Introduction

The essence of universal access is captured in the following words [19] "In order for these new technologies to be truly effective, they must provide communication modes and interaction modalities across different languages and cultures, and should accommodate the diversity of requirements of the user population at large, including disabled and elderly people, thus making the Information Society (IS) universally accessible, to the benefit of mankind". Recent work on universal access has found that it is possible to develop theories of human cognition that can be used to generate both generic and specific cognitive user models for use in accessible system design [4] [5] [15].

User modelling forms an essential component of design methodologies for universal access like UUID [20] [21] [22]. Universal Access is predicated on powerful and efficient methods with which to develop systems and resources that are acceptable and accessible to all, including the very young, the older adult and people with different types of disabilities or abilities (both long term and short term), avoiding the need for post hoc adaptations or redesigns. If so, then there needs to be conceptually powerful and pragmatically robust ways to draw out reliable and useful information about the people who are the intended users of these inclusive

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technologies, as an essential component of inclusive design methods. User modelling is one of the most powerful, such approaches.

2 The Importance of Cognitive User Models

The apparently daunting task of capturing the key characteristics of our intended users, with complex and diverse needs, using a wide range of technologies, in a multitude of different contexts and tasks, is now being tackled by research and development in user modelling and monitoring. This capturing task is critical in the emergence of the inclusive, Information Society on a global basis. User modelling and monitoring are important components of UA solutions to accessibility and inclusion problems, providing a significant contribution to inclusive design, universal design, customization, personalization, adaptation, adaptability and user augmentation. However, if user modelling is to make a difference in practice, it must relate to the emerging, accessible design methodologies and this is illustrated with reference to unified user interface design (UUID). On this basis, the future of user modelling and monitoring is portrayed as a vital part of the bigger picture of the future of universal access [1] [2].

3 The Importance of the Social Context

Social context is critically important for many reasons, not the least in this context, because it influences user behaviour in using Information Society Technologies (IST). For example, some researchers [9] found that social context and emotional tone (task-oriented vs. socio-emotional) influenced the use of emoticons in short internet chats. Equally, social intelligence is a key aspect of our everyday lives, at work, education or leisure that is often underestimated by those who might focus on cognitive aspects of users [2] [12]. Furthermore, of course, social intelligence is an unavoidable aspect of the folk psychology of today's citizens and so must be treated seriously when working within the context of the Information Society [16].

4 Relevant Types of Intelligence

Before we can focus on social intelligence, it is important to note that a number of different types intelligence has been postulated, including abstract, mechanical and social intelligence [16]. Some theorists postulate at least three types of intelligence [23]. At the extreme end of the spectrum, some authors [14] postulated at least 120 separate intellectual abilities Social intelligence is an important component of the triarchic view of intelligence, in which intelligence is made up of analytical, creative, and practical abilities [23] [24] [25]. Three components are postulated, i.e. performance components, to solve problems in various knowledge domains; executive components, to plan and evaluate problem-solving; and knowledge-acquisition components that support the learning of the first two components. He also proposes that all forms of intelligence are sensitive to the context in which they are measured. Social intelligence can be divided into two main types, declarative knowledge (knowing what to say) and procedural knowledge (knowing what to do) [16]. Clearly, the concept of social intelligence is potentially one of the most relevant forms of intelligence when considering inclusion and accessibility within the IS.

5 Social Intelligence to Extend Cognitive User Models

What is social intelligence and how can it help us with user modelling? Some researchers [13] have captured the essence of social intelligence as knowledge in co-action. They define social intelligence as “the ability of actors and agents to manage their relationships with each other.” These relationships engage us with the different agents i.e. the people, tools, artefacts and technologies in the environment. All of these are deemed to be dynamic representations of knowledge and that the appreciation of how to use that knowledge to communicate effectively, such that it becomes invisible to us, becomes knowledge in co-action [13].

If the concept of social intelligence has at least two meanings, (a) the person's ability to understand and manage other people, and to engage in adaptive social interactions and (b) to refer to the individual's fund of knowledge about the social world [16], then some cognitive user models can incorporate them within their existing architectures. For example, Simplex Two [1] [4] [5] [17] can take “to understand and manage other people” as an attribute of the executive function. “To engage in adaptive social interactions” can be taken as a function of the complex output module. The long term memory and mental models modules can be used to cover “the individual's fund of knowledge about the social world”. If so, parsimony would suggest that there is no need to postulate a distinct social intelligence module at the moment, though social intelligence may reflect a distinct domain of knowledge and skills within currently postulated cognitive modules. (This is not to imply that social intelligence is not an important concept, both theoretically and practically). However, it is possible to distinguish empirically between two perspectives of social intelligence. First, if it is a distinct set of psychological concepts, it should be completely uncorrelated with other forms of intelligence, when contaminating factors are controlled e.g. response speeds. Second, if social intelligence is based on a subset of knowledge and skills within common systems, then correlations may be low but always non-zero.

At the moment, there is no evidence for the former view. For example, in an extensive review, the authors [16] allude to Cattell's distinction between fluid and crystallized intelligence. For social intelligence, crystallized intelligence covers the person’s accumulated fund of knowledge about the social world; fluid intelligence, by contrast, involves the individual's ability to solve problems with novel social situations. Factor analyses found that crystallized social intelligence was discriminable from fluid social intelligence, but not from academic intelligence, though the correlations were not zero in any case.

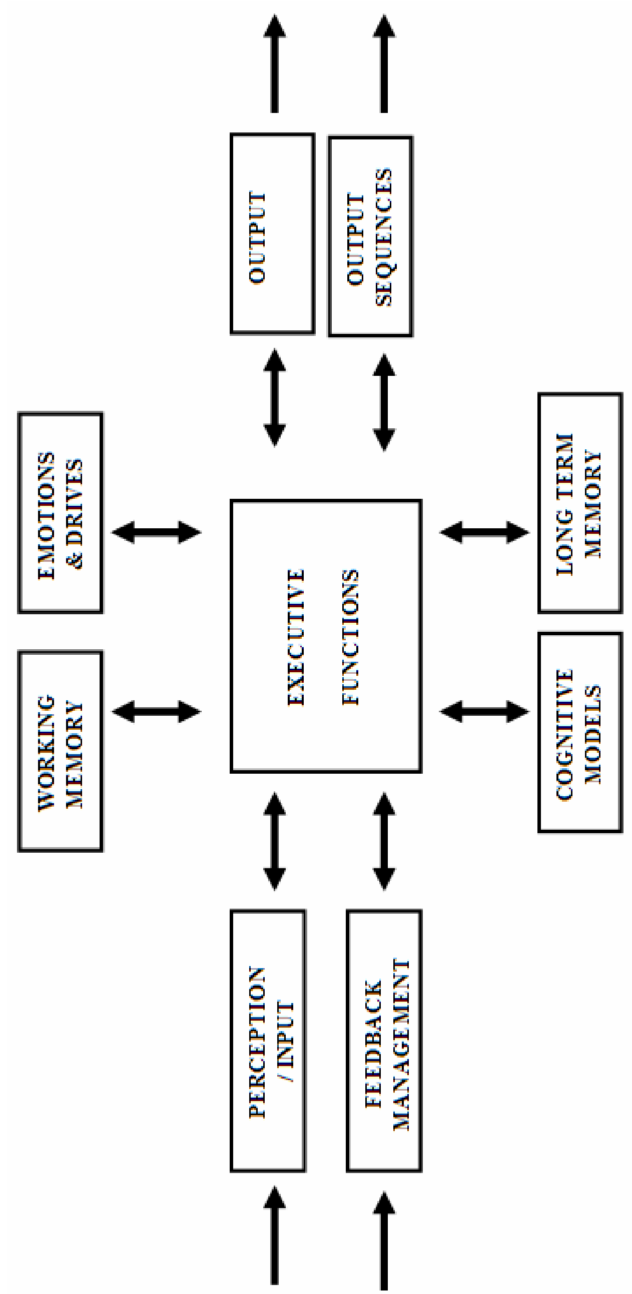

Fig. 1. Simplex two

6 Social Intelligence and Disability

If social intelligences can be associated selectively with different regions of the brain, then certain brain injuries will be associated with the impairment of aspects of social intelligence. One author [10] [11] advocates at least seven distinctly different kinds of intelligence, associated with different brain systems. If so, then brain injuries could selectively impair these different intelligences. For example some sufferers would retain their social intelligence and others would not. From neurological case studies, injuries to the prefrontal lobes of the cerebral cortex can selectively impair personal and social intelligence, leaving other abilities intact [1] [2] [3] [4] [5]. Conversely, damage to the occipital and parietal lobes can impair most of intellectual capacities, but with personal and social abilities relatively intact. Down syndrome and Alzheimer's disease have chronically impaired cognitive consequences but little influence on the person's socialisation skills. Pick's disease shows mercy to some cognitive abilities while severely impairing the person's social skills. Infantile autisms, including Kanner's syndrome and Williams' syndrome, can significantly impair the understanding of other people in social settings. According to the American Psychiatric Association, the diagnosis of mental retardation includes deficits in both social and academic intelligence. The diagnostic criteria are based on the axiom that social and academic intelligence are not highly correlated [1] [4] [5].

Autism spectrum disorder (ASD) and related conditions like Asperger's syndrome have been explained in part, to an inability to use the necessary social skills to perceive and understand the mental states of other people in their social settings, the so-called "theory of mind" explanation [18] [7]. Such children and adults face difficulties in understanding other people's beliefs, attitudes, and experiences that might be different differ from their own. Some authors have concluded that the core deficit in autism is related to social intelligence e.g. empathetic skills [7]. Another explanation is that people with ASD are very strong systematisers and this is seen as a barrier for their developing empathy, a vital social skill that is part of social intelligence (see below) [8]. In contrast, not all individuals with autistic spectrum disorder (ASD) show learning difficulties with non-social domains of knowledge. Can we really say that social intelligence is the same as general intelligence applied to the social domain? In practice, social and general intelligence draw upon different bodies of knowledge and skills.

It has been concluded by some [27] that there are three different brain systems to underpin social intelligence: a cortical subsystem which relies on long-term memory to make complex social judgments; a frontal-dominant subsystem to organize and create social behaviours; and a limbic-dominant subsystem for emotional responses. If so, different brain lesions will lead to different types of impairment of social intelligence.

From this consideration of social intelligence and disability, it is evident that a serious consideration of the inclusivity and accessibility requirements of people with disabilities will often require the involvement of social intelligence concepts.

7 Social Intelligence, Inclusive Design and Universal Access

The concept of social intelligence has been applied to show that social intelligence design methods can produce mediating interfaces that become virtually invisible in use, (i.e. become an extension of the users), in the context of graphical interaction for collaborative design tasks [13]. This could be an important factor in the design of intelligent user interfaces. Others [9] also explored the influence of social context on the deployment of emoticons in short internet chats. Social context (task-oriented vs. socio-emotional) and task tone (positive vs. negative) were varied. They found that emoticons were used more in socio-emotional contexts than in task-oriented social contexts. Positive emoticons were seen more in positive contexts and more negative emoticons in negative contexts and the two factors interacted positively. Clearly, social context and intelligence are both important aspects of any accessible ICT design.

8 Social Intelligence and Cognitive User Modelling

Social intelligence can be considered from at least two relevant perspectives within the context of universal access. First, it can be seen as an important factor in the understanding of the psychology of the intended users, as a basis for cognitive user modelling. Second, it can be seen as an important set of design considerations when developing unified user interfaces. From the first perspective, aspects of social intelligence can be viewed as sub-domains of knowledge and skills within an overall cognitive architecture of the user. From the second perspective of the system developer, as shown below, social intelligence may require a more practical approach to ensure that it is not undervalued accidentally in the design process. First, consider the theoretical perspective, as shown in the following table, which demonstrates how most, if not all the proposed components of human cognition can subsume certain aspects of social intelligence.

Table 1.

Cognitive architecture	Aspects of Social intelligence
1. Input	Effective input / perception of social cues
2. Feedback	Use of social feedback
3. Long term memory	Store social knowledge
4. Mental models	Model social setting and other people
5. Working memory	Hold relevant information in social interactions
6. Emotions	Make judgements about emotions
7. Executive function	Deploy social skills
8. Output function	Hold response in social interactions
9. Complex output	Socially skilled actions

9 Social Intelligence Interface

Second, consider the system development perspective. It is clear that social intelligence is a very important, but potentially elusive, concept when considering the requirements of all users for accessibility within the inclusive Information Society. However, it is equally clear that there is no strong evidence that social intelligence should be seen as a completely different module within any psychological architecture of the intended users of IST. There are a number of key skills and attributes that comprise social intelligence, as shown by the following list based on a major review [16]. Any socially intelligence system designer could consider the most important and relevant skills from that list when developing a system.

Table 2. Aspects of Social Intelligence

Accepts others for what they are;	On time for appointments;
Adapts well in social situations;	Open to new experiences, ideas, values;
Admits mistakes;	Empathy to other people's needs, desires;
Assesses well the relevance of information to a problem;	Displays curiosity and interest in the immediate environment;
Social appropriateness;	Social influence;
Displays interest in the world at large;	Social insight;
Extensive knowledge of rules and norms in human relations;	Understands people's thoughts, feelings, and intentions well;
Frank and honest with self and others;	Social memory;
Good at dealing with people;	Social openness;
Taking the perspective of other people;	Thinks before speaking and doing;
Applies social conscience;	Social adjustment;
Makes fair judgments;	Warm and caring.

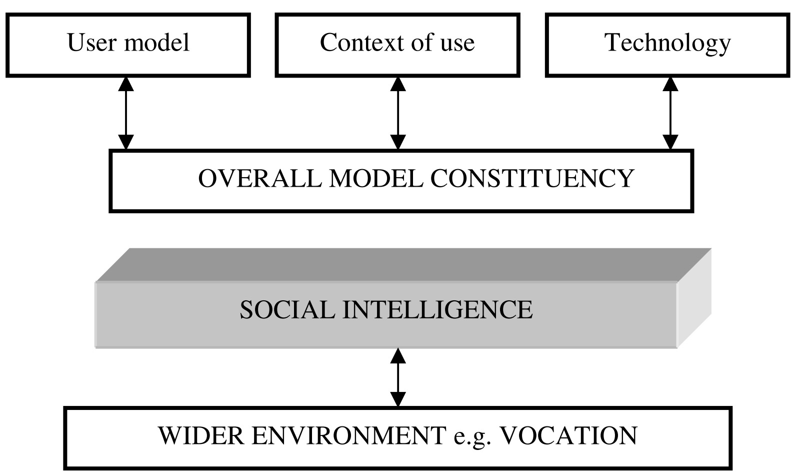

Fig. 2. Social Intelligence Interface

This listing is based on an extensive review of such factors [16]. As a design construct, it can be used by UA designers concerned about the support of social skills by IST applications. They can; select the relevant skills from the above list, build them into the user models, involve those skills in the design of the system and then use them as part of any iterative evaluation of the emerging system.

10 Discussion

Clearly, the social context is important within the modern information society. Social intelligence is of major importance when working on the needs of all users for accessible solutions within the inclusive Information Society. The development of user models is an important way to capture the challenging diversity of the intended users and social intelligence is relevant to those models. There are a number of potentially relevant types of intelligence, but social intelligence would seem to be one of the most relevant and as shown here. It is relevant, not only to the general public, but also to people with disabilities, including head injuries ands cognitive disabilities. From a theoretical perspective, there is no strong evidence that social intelligence must be considered as an entirely distinct component within the psychological architecture of the intended users of IST. It can be best seen as based upon specific domains of knowledge and skills, rather than as completely distinct. From the practical perspective of the UA designer or developer of an accessible, interactive system, there may be the concern that this theoretical perspective might underestimate the role of social intelligence of IST, particularly in those systems that are intended to support social skills e.g. negotiation through a video conferencing system. To support a greater emphasis on social intelligence, the simple developmental concept of the Social intelligence Interface is introduced. The notion is that system developers and designers will use the above list of social skills, or some subset of it, to ensure that the system supports the necessary skills. Unlike Simplex Two, it is not grounded in the psychology of the users, but is simply a conceptual, design tool that will eventually be automated. It is also being applied to social aspects of user overload [6].

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Web Navigation for Individuals with Dyslexia: An Exploratory Study

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Abstract. In this paper, we present an exploratory study of the web navigation experiences of dyslexic users. Findings indicate that dyslexics exhibit distinctive web navigation behaviour and preferences. We believe that the outcomes of this study add to our understanding of the particular needs of this web user population and have implications for the design of effective navigation structures.

1 Introduction

Dyslexic users can have problems with web pages that have heavy textual content and poorly built navigation structures. Although web sites utilise various navigation aids aimed at facilitating the navigation process, it is unclear whether these mechanisms are helpful for dyslexics. Dyslexia is a highly individual condition; it can assume several different forms, and its severity can affect people to varying degrees. In our examination of web navigation, we consider a broad view of dyslexia rather than one that concentrates solely on reading and writing difficulties. Common problems associated with dyslexia that could affect web use include weakness in working memory, visual processing, organisation, sequencing of letters and numbers, spatial awareness, motor control, and auditory processing.

Previous studies have investigated the specific needs of dyslexics in their general use of computers. The development of the personal word processing environment SeeWord involved dyslexic users in the design process and highlighted the need for a highly configurable system to meet the varying needs of different dyslexic users (Gregor, Dickinson, Maccaffer, Andreason, 2003). It also showed that using a computer for reading could reduce the severity of the difficulties experienced by dyslexics. Blankfield, Davey, Sackville's (2002) study investigated the accessibility and usability of WebCT for dyslexic students and suggested a set of guidelines for the design of course materials for dyslexics. Petrie, Weber, and Fisher's (2005) MultiReader study examined personalisation and navigation in multimedia reading systems for print-disabled users. It revealed that the readability of electronic documents can be ensured when users are involved in the iterative development process of multimedia web content.

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Research has mainly focused on interface design issues concerned with alleviating dyslexics' reading difficulties. However, dyslexics' ability to navigate the web is affected by a range of issues beyond the readability of the text such as the cognitive load of working memory, sequencing and organisation of information. Despite the existence of web design guidelines for dyslexics (BDA, 2004; Evett and Brown, 2005) and attempts to understand their needs in terms of technology to overcome their difficulties (Gregor et al., 2003; Evans and Blenkhorn, 2005), dyslexics' own reports of what they experience when browsing or searching for information on the web have not been examined. In this study, we explore the barriers that inhibit access to the web for people with dyslexia, with a focus on the strategies and personalised approaches that they employ in their web navigation.

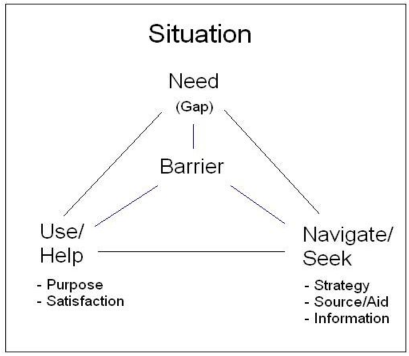

Fig. 1. Process Model of Web Navigation

This study employed Sense-Making Methodology (SMM) in the formulation of research questions and data analysis (Dervin, 2002). The SMM is a user-centred approach to studying and understanding users and designing systems to serve their needs. In our utilisation of SMM, we search for patterns in how dyslexics make sense of what is presented on web pages. Guided by the Sense-Making theory, we developed an expanded process model of sense-making in the context of web navigation (Fig. 1). Based on the main concepts in the model, the following research questions were developed:

1. In what kind of situations do dyslexics navigate/use the web? (Situation)
2. How do dyslexics describe their needs for navigating and finding information on the web? (Need)
3. How do dyslexics navigate the web? (Navigate/ Seek)
   a. What strategies of navigation and information seeking do dyslexics use? (Strategy)
   b. What navigation aids or sources of information do they use? (Source)
   c. What sense do they make of the received information? (Information/meaning)
4. How do dyslexics use navigation aids? (Use)
   d. What is the perceived purpose of the navigation element? (Purpose)
   e. To what extent does the element satisfy their needs? (Satisfaction)
5. What barriers do dyslexics experience in navigating the web? (Barrier)

2 Method

Semi-structured interviews were conducted with dyslexic web users to develop an understanding of their web navigation needs. Ten dyslexics were interviewed face-to-face about their various dyslexia-related difficulties and how these challenges have affected their use of the web. Also noted were the participants' use of assistive technology, their computer use, and their use of the Internet.

Participants. Ten participants with a confirmed diagnosis of dyslexia took part in the study, nine of whom were female and one male. Their ages ranged between 18 and 49 with a mean age of 29.7. Three of the participants reported having other Specific Learning Difficulties (SpLDs) or disabilities in addition to their dyslexia, two with dyspraxia (difficulties with fine and/or gross motor control) and one with both sensory defensiveness and dyspraxia. Participants' computer use ranged from six to twenty years, with a mean of twelve years. All participants had been online for periods ranging from five to ten years, with a mean of seven years, and all reported being online for at least six hours per week.

Materials. Interviews were audio recorded for subsequent transcription and analysis. During the interview sessions, a presentation with samples of web sites was projected on a SmartTech[1] digital whiteboard. The projected slides presented illustrative examples of web navigation approaches for discussion. Max QDA[2] qualitative analysis software was used for data coding and analysis.

Design. Interviews were conducted in the Interaction Lab of the Centre for HCI Design at City University. Interviewer and participant were seated at a computer with the presentation slides projected on the digital whiteboard. Sessions took from 50 minutes to over an hour each, depending on the amount of information given by the participant. Interview sessions began with a questionnaire designed to collect demographic information and data pertaining to the subjects' SpLDs, their computer and Internet use, their perceived difficulties in accessing web sites, and any adjustments they implement on their computers to make the web more accessible. The text was presented in the recommended font type for dyslexics, Arial 14 pt, and the questionnaire was printed on colored paper, as some dyslexics find the high contrast of black text on white paper difficult to read. Participants were assisted in filling out the form if their condition was severe or they had writing difficulties. The second part of the session was a semi-structured interview. Topics for discussion were introduced with illustrative examples of web sites projected on the whiteboard. Each slide displayed one topic for discussion; topics covered browser features, layout and presentation, web navigation aids and site structure. For each slide, the topic was introduced and participants were asked specific questions, guided by the SMM process model. Participants were encouraged to share their thoughts and personal experiences on the topic. The snapshots of web sites and different examples allowed the interviewer to explore a slide's topic in more depth than would otherwise have been possible and provided participants with visual representations and examples of elements they "liked" or "disliked" that would have been difficult to recall.

The interview sessions with the first two participants were conducted with live Internet access where suggestions of additional web sites from participants were examined in the session. The initial presentation had eleven slides covering the main topics. Analysis of data from the first two sessions revealed that interview questions related to two topics—namely search results and site structure—would benefit from

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[1] http://smarttech.com
[2] http://maxqda.com

more detailed illustrative examples. This resulted in a refined presentation of topics with fifteen slides, which was eventually used in the eight subsequent sessions in the study.

Data analysis involved a number of steps. First, we developed a code list reflecting the research questions. The codes represented the elements in the process model and the related discussion topic. Interview questions for each slide in the presentation were designed to address all elements in the model for that specific topic. The code list was kept flexible to accommodate new issues the participants might raise in the semi-structured interview session. Second, participants' responses were coded using the codes from the final list. Third, answers to the research questions were sought by examining the codes across all cases, in which the units of analysis were the web navigation contexts and elements, rather than individuals. This process was aided by the use of qualitative analysis software.

3 Findings and Discussion

The transcribed interviews produced a considerable amount of information about the problems dyslexics experienced in web navigation. Interview transcripts were examined to identify patterns in dyslexic users' information-seeking and web navigation behaviour in accordance with the SMM process model of web navigation that we developed. Recurring themes of web navigation behaviour emerged: Namely, the following:

- Navigating within a web site and finding content on a web site. Patterns emerging in the use of navigation aids such as sitemaps, site index, search box, back and forward buttons, and navigation menus were examined.
- Keeping track of websites and returning to previously visited web pages. This was examined in the utilisation of browser features such as history and bookmarks.
- Navigating within a web page and finding specific content on a web page. This involved examining patterns that emerged with difficulties in scrolling, layout and presentation of content.
- Navigating the web and finding information across web sites. This was examined in the structure of information in web directories and the use of search engines for information seeking tasks.

In this paper, we report the patterns that emerged in the first theme, navigating and finding content within a web site. Different methods can be used to move around a website. Complex navigation structures were cited as sources of 'disorientation' and frustration by participants. Under this theme we look at patterns that emerged in the use of navigation aids such as sitemaps, site index, search box, back and forward buttons, and navigation menus.

Search Box. Many web sites offer a search box on their home page and sometimes throughout the site to allow users to search for information within the site. We explored participants' utilisation and perception of the usefulness of this navigation aid and the alternative approaches they employ.

All participants reported attempting to use local search boxes in web sites. However, only two of the ten participants perceived them to be useful. One of these had severe visual processing difficulties and reported using the search box first on web pages before scanning the menus or text on the page. Eight of the ten participants cited using the search box when they are stuck in navigation; most reported using it as a last resort. Participants reported two problems with using this navigation aid, namely: (a) the quality of the results and (b) the fact that spelling mistakes were not accounted for or 'picked up' as in search engines, and especially in cases where participants reported difficulties in spelling. One participant stated, 'I usually have a Word document open at the same time, so that I can type and check spelling errors…because web page search boxes do not recognise my spelling errors.' Some users reported forgoing the site's search box after a few attempts in favour of using a search engine. As one dyslexic student stated, 'It is really frustrating in our university web page search box. I tend to use Google to search that site for information.'

Navigation Trail. Many web sites provide textual representation of navigation paths, sometimes referred to as breadcrumb trails or navigation trails, across the top of the page to situate the current page relative to its parent nodes. As this method is a textual representation and is normally displayed in a smaller font and in a linear sequence, we explored the following: dyslexic web users may have difficulties in accessing smaller fonts, therefore is the navigation trail readable? Does it add to the complexity of the page for those with visual processing difficulties? Does the linear sequence help or hinder their understanding of where they are within the site?

Four of the ten participants were not familiar with navigation trails and had not noticed them on web sites - even web sites they reported visiting quite often such as Amazon and eBay. Interestingly, all four reported - earlier in the questionnaire - difficulties in reading small fonts in their reporting of the adjustments they make to their computers to access the web.

Patterns emerged among the six participants familiar with navigation trails, depending on their key weakness or difficulty:

Not Useful. Two participants did not perceive navigation trails as useful due to lack of visibility. One participant had Meares-Irlen Syndrome (i.e. visual perceptual disorder) and reported experiencing visual stress when trying to read smaller texts. This participant described navigation trails as, '…something I would use if it [were] clear.' The other participant explained, 'It took me a long time to realise what they were. It is not easy to see… I just ignore it.'

Shortcut. Three participants found navigation trails useful in returning to previously visited pages in a single click. However, they did not perceive them helpful in understanding where they were within the site. They described their preference for alternative approaches such as using the back button or jumping back to the home page and retracing their steps, to understand their location. This was evident in comments such as '..I find being able to see the page itself makes it a lot easier to know where I am than to know from the title of the page.' and '..you don't know for sure what those pages are [pointing to the hyperlinks]. When you go back, you can see it visually and recognise it as opposed to the words.' Upon closer examination of the participants' dyslexia characteristics, it was interesting to find that all three reported difficulties in short term memory (STM), one with severe weakness in visual STM (people with this difficulty do not carry a visual image of what they saw for long). This points to the need to consider unambiguous wording of the links and clear descriptions to indicate the destination of the link in the path.

Location. Finally, only one participant found the navigation trail useful in understanding their location within the structure of web site. This participant reported having good visual-spatial skills and described it as one of many approaches used for this purpose (e.g. back button's pull-down list).

In summary, participants with reading difficulties reported having difficulties reading the small text, so they did not bother making use of this navigation aid. Those with STM weakness reported liking it, as it offers shortcut links to previously visited pages. However, when STM is a key weakness, they reported a preference for the back button as it gave them visual snapshots of the pages that they had already visited

Site Maps. Web sites often provide detailed site maps that aim to help visitors understand the site's structure and find desired locations, and as an alternative method of navigating the site. Participants were asked what they thought of sitemaps and whether they found them useful. Different types of sitemaps were displayed on the screen to probe further into what they thought of each particular design. The designs displayed were a bulleted list, a hierarchical tree structure of pages, and a categorised sitemap.

Four of the ten participants reported not noticing sitemaps on web sites, even sites they regularly visit. This is not surprising as Neilsen (2001) reports that users were aware of sitemaps on web sites only 15% of the time. Three participants reported trying them and perceived them as something that exacerbates their disorientation and frustration. Interestingly, all three confirmed difficulties in understanding maps of any kind.

Two participants found them useful only in the case when they were lost and all other search options were exhausted. Reasons cited by participants were the visual complexity, the heavy textual content, and the way information is structured on site maps. Although these problems affect the interaction with web sites for all users, dyslexia-related difficulties seem to exacerbate the problems and inhibit access to the web page content, particularly visual perception difficulties. For example, this participant explained, 'I find those [referring to types of sitemaps] difficult to look at' and had to look away from the screen shortly after each site map was displayed. In probing further, this participant had visual processing difficulties and described, 'The text gets blurred and starts moving around. Sometimes I feel a bit of anxiety coming and I need to take a break.' The one participant who perceived sitemaps to be useful explained, 'It tends to be a lot easier to use things like a site map rather than using a search box, because it can bring up a lot more irrelevant information. It can be quite frustrating to sift through what is right and what is wrong.'

As for the presentation and design of sitemaps, we continued to discuss various types of designs to see what all participants would think of their usefulness and clarity – even those that were not familiar with sitemaps at all, or with a particular design. It was interesting to note that the majority preferred the hierarchal tree structure followed by categorised/block structure for presenting pages in a site map. Most stressed the importance of how text is presented within the map, as one commented, 'I could use any of the sitemaps if the text was right.'

Site Index. Some web sites provide an alphabetical listing of topics and pages in what is generally called a site index. As difficulties in sequencing of letters and numbers are a characteristic of some dyslexics, we explored the perceived usefulness of this aid in web navigation. Nine of the ten participants reported using the index mainly in the context of information seeking in large web sites. None of them reported using it for browsing new and unfamiliar sites.

Two patterns emerged in exploring the use of this navigation aid. The first was the group of participants that experienced difficulties in the use of the index and tended to use this aid after exploring alternative methods. The difficulties reported were the alphabetic sequencing and in one case spelling and vocabulary, for example one participant stated, 'Sometimes when I am looking for something that I don't know how to spell such as xylophone, I wouldn't find the site index useful. I would give it a couple of tries before trying to find the correct spelling using my strategy of using Word and thesaurus.' It was not surprising that all four participants reporting difficulties in sequencing of letters, numbers, or both, were in this group. For example one participant stated, 'I've used the index and it always confuses me' then added, 'when you are looking for a letter such as 'J', you have to sing the alphabet, or say the alphabet to yourself even though you can spell.' Participants in this group stressed the importance of having a clear and visible alphabet key.

The second pattern was for participants that favoured the use of this aid over other navigation aids. However, they reported frustrations about not knowing which category or under which letter the information is listed under. This is illustrated in this participant's comment, 'I don't mind navigation aids with alphabetic listings. The problem would be in that I hesitate in which letter to use when I am looking for something specific. Like the street St. John, would it be S for St. or J for John?' This points to the need for categorising information to match the user's mental model and to consider listing information under different letters if various titles are applicable.

Back and Forward Buttons. Browsers have back and forward buttons to aid in navigation. The back button allows users to return to pages they have visited recently and was reported by all participants to be one of the most heavily used browser elements. The forward button allows users to move forward in their navigation path after backtracking. Duplicating browser features in web sites, such as including back and forward buttons, adds to the cognitive load of users in trying to learn new methods of navigation (Gregor and Dickinson, 2006). In our study, eight of the ten participants reported a preference for using the browser features and avoiding the duplicated web page navigation element as much as possible to avoid 'learning' the page's navigation scheme.

When asked to comment on their preference for using back and forward buttons, three patterns emerged depending on the participants' key specific difficulties.

1. The buttons are visible and consistently in the same place. As one participant explained, 'I know exactly where they are…I prefer to use things I am familiar with. I will not spend more energy searching for it [the previously visited page] if I know there is a more universal way of accessing it.' This was stressed by participants who had difficulties in reading and/or visual processing: they reported trying to avoid reading textual content in the form of links as much as possible.
2. They allow rapid return to pages recently visited. This was stressed by participants with poor eye-hand coordination who reported trying to minimize movement

across the screen and frequently clicking the wrong links and those with visual processing difficulties who find it hard to find the cursor on the screen.

3. They allow the user to retrace their navigation path visually, as one commented, 'I use them regularly and tend to navigate that way. I can retrace my steps with the back button.' This was stressed by participants with STM difficulties who preferred to see the actual pages to recall the content rather than trying to remember from a visual representation of their location such as in sitemaps or textual links describing the pages such as those in navigation trails.

Navigation Menus. The internal links of a web site generally appear consistently on every page and are called navigation bars or menus. Since the location of main navigation menus can affect the users' interaction with the site's content, participants were shown examples of different sites with left, right, top and bottom menus and asked what they think of different navigation methods.

All participants stressed the importance of having navigation that is consistent throughout the site, regardless of location within the page. Inconsistent navigation in a web site confuses users and may lead them to think they have entered another web site (Shubin and Meehan, 1997). This was confirmed by comments from most participants and illustrated in a statement by this participant explaining how inconsistent navigation causes frustration, '…because when you open up any page, you know where everything is…either on the left, top, or right hand side of the page. You have your main function there [pointing to the navigation bars in a web page]. You know something is going to be the same - it is something regular. A lot of web sites like to make themselves very individual and different and new on every page, but that is confusing.' It was noted that participants reporting difficulties with scrolling stressed the need to have the whole of the navigation bar visible at all times, as this one stated, 'I like for the navigation bar to always be there, wherever I move….I don't think I have a preference between down, side, top or both as long as it is visible.' This points to the need for employing a technique to keep navigation visible at all times, thus avoiding the scrolling issue.

Dynamic navigation elements. Recently, many web sites employ dynamic navigation schemes such as collapsible lists, menus with hover elements and multi level drop-down navigation. There was ambivalence from dyslexic participants on how they perceived the usefulness of these navigation schemes. Two trends emerged in the experiences of dyslexics with these menus.

Some participants, mainly the ones with poor eye-hand coordination, reported infuriating experiences in trying to navigate with dynamic menus, particularly when menus are sensitive to cursor movements. For instance one participant stated, 'Sometimes you scroll over something and you are still trying to read it when something else pops up or the original [menu selection] would disappear if you lose focus.' Another participant added, 'It is annoying when menus close or disappear when I lose focus. It is something that happens a lot in my case.' This was stressed by the two participants with dyspraxia as they described, '..with my dyspraxia I find it [dynamic menu] difficult to use as it is hard to hold the cursor' and '..they sort of jump and disappear you can't click over it. When you can't click over what you want, it is quite frustrating.' This points to the need to offer users some control over this type of navigation, as one participant suggested: 'The ones you can click down and stay, they are fine. It is just the ones that are very sensitive to movement are quite difficult.' It is thus important to keep the active navigation section expanded when the user is moving to another part of the menu.

On the other hand, users with reading or visual processing difficulties had positive things to say about their use of dynamic menus. Reducing the visual complexity of the page was cited as the main reason for their reported preference for this type of design. Participants commented, 'I like the idea here. It is not cluttered. If you need to navigate, you don't get a load of information that you do not need.' Another reason is that it allows them to explore navigation routes without having to actually travel that path. Thus, reducing the chance of them getting 'lost' in the web site as one described, 'It saves you having to go to different places or be so specific about what you want before seeing what else is out there… If you don't know exactly what you want, but you've got some sort of idea of what you want, then it gives you another option of exploring before you move.' This indicates that presenting information gradually and in smaller chunks (be it navigational information in this case) is a good design option if presented in a more stable way.

In both groups, two difficulties were cited by participants in their use of dynamic menus. First, the readability of the text when the menu bar is semi-transparent was cited as difficult by seven out of the ten participants because the background was perceived as a distraction while reading. Second, the readability of the text and background elements when the menu pops up over existing text, as this participant described, 'I find that [dynamic menu] helpful...you see step-by-step exactly where you are going. What I don't like is when it comes up over existing text…I have difficulty in reading and letters staying in the same place.' Comments by participants suggested that these menus exacerbated the difficulties experienced by dyslexics in tracking text on the screen.

4 Limitations and Future Research

In this study, we interviewed a relatively small group of individuals. Participants were recruited from a convenience sample of people with dyslexia in the area in which the study was conducted. Moreover, interviews produce accounts of behaviour and reported experience rather than direct observations. However, the aim of this exploratory study was to gain insight into web use by dyslexic individuals and to provide a better understanding of their needs, rather than draw strong conclusions about their web use or for generalising results. This exploratory study yielded results suggestive of the presence of patterns in navigating and scanning web pages for information by dyslexic users that may be different from typical web users. This has set our research agenda for further investigating the visual scanning of web pages by dyslexic users by examining their visual attention and web exploration through eye tracking.

5 Conclusion

This exploratory study examined web navigation experiences of dyslexic users. Using the Sense-Making Methodology to elicit user responses proved a useful approach for identifying the diverse range of navigation problems encountered by dyslexic web users that can contribute to frustration and disorientation on web sites. This study demonstrated that dyslexic individuals face considerable barriers when attempting to use the web beyond those faced by typical web users. In this paper, we report patterns in preferences and behaviour in the context of navigating within a web site. Patterns emerging in the use of navigation aids such as sitemaps, site index, search box, back and forward buttons, and navigation menus were examined. Our findings show that despite the existence of many web sites conforming to accessibility standards, the web still suffers from many deficiencies and problems in support for navigation around its information space, particularly for users with specific learning difficulties. We believe that these findings add to our understanding of dyslexic users' needs. Also, by detailing experiences of real users, we hope that the outcome of this study will encourage designers and developers to think wider than their assumed audience.

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Guidelines for the Development and Improvement of Universal Access Systems for Blind Students

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Abstract. This paper describes a study conducted to develop a set of interface design principles and guidelines that can be used to develop and improve universal access systems for the visually impaired, such as Haptic Audio Virtual Environments (HAVEs). Over the last few decades, user interface systems have advanced to allowing users to interact with computational systems physically, perceptively, and conceptually. However, this process has also left blind and partially blind users unable to access such new technologies. It is also true that there are currently only limited methods for presenting information non-visually and these do not provide an equivalent speed and ease of use to their graphical counterparts. Comprehensible design principles and guidelines addressing the needs of blind users should be helpful when developing universal access systems, such as haptic audio virtual environments that use multiple sensory modalities to present information.

Keywords: universal access, assistive technology, design principles and guidelines.

1 Introduction

Blind and partially blind users have been left behind in the technology development because of the increase of icon rich computer environments [1]. In addition, there are currently only limited methods for presenting information non-visually and these do not provide an equivalent speed and ease of use to their graphical counterparts [2]. Human computer interaction (HCI) frequently elicits the image of a fully sighted user, periodically responding to visual cues as they are presented [3], thus blind and partially blind users have not been given the proper opportunities to access these systems.

According to the American Foundation for the Blind, approximately 45% of individuals with severe visual impairment or blindness have a high school diploma, compared to 80% among fully sighted individuals. Among high school graduates, those with severe visual impairment or blindness are about as likely to have taken

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some college courses as those who were sighted, but they are less likely to have graduated. There are also about 10 million blind and partially blind people in the United States, from this number only 1.5 million use a computer. These numbers are enough evidence to start thinking of a definite way to help blind and partially blind users. Therefore, it is now important to look for ways to turn this numbers around and integrate visually impaired people into this new century full of technology.

The primary objective of this paper is to introduce design principles and guidelines for the development and improvement of universal access systems (e.g., haptic audio virtual environments) for the blind, with a main focus in developing science and engineering learning environments for visually impaired students.

2 Universal Access Systems for Blind Users

Visually impaired users have had to rely on verbal based feedback from systems such as JAWS (Job Access With Speech), ZoomText, and closed circuit televisions (CCTV). JAWS main advantage is its outputs to refreshable Braille displays, but it is limited to the use of Windows only and does not help the user interact with the actual graphical interface or its orientation within the screen. Zoomtext is a tool that helps partially blind users enlarge texts by increasing the font size. It is a very useful tool but it can only be used with texts and pictures and does not assist the user in interacting with graphics. CCTV changes the spectrum of colors of a document, assisting color blind users in interacting with texts and pictures. Although these elements are highly effective in current teaching methods, they do not contribute much in the development and understanding of some scientific and/or engineering concepts to blind students, such as Gravity or Thermodynamics which require multiple sensory modalities to present.

Some of the early research and experimentation also includes the development of the Z-Glove and DataGlove [4]. These systems allow visually impaired people to feel relieves and shapes of certain virtual simulated objects. There are not significant differences among these two systems; however their way of processing the information is different. Their main advantage is clearly the ease of sensing shapes and surfaces of objects that can be simulated, however these gloves do not assist to identify colors and pictures and there were certain hand movements that the computer could not identify. TDraw [5] has also been developed to help blind people draw pictures. Other research/experiments engage the concepts of text edition. MAGNEX is a general purpose full screen text editor which incorporates features intended to make it especially useful to individuals with a wide range of visual impairments [6]. Magnex was developed to meet two objectives: 1) to provide powerful, full screen, general purpose editing capabilities, and 2) to make these facilities available and comfortable to use for as broad a community as possible of visually impaired people. Within its options, the user is able to change the font size, background colors etc. Although this tool is a big step towards meeting visually impaired people needs, it still lacks of a variety of options that allow the user to customize the text.

Researches have been trying to implement systems and tools that satisfy visually impaired needs. However, it has always been difficult to follow a standardized set of guidelines or rules that can be used to develop systems that can meet the blind and/or partially blind user's needs.

3 Interface Design Principles and Guidelines for Blind Users

Three schools for the blind were contacted to obtain information from: Texas School for the Blind and the Visually Impaired, Oklahoma School for the Blind, and Arkansas School for the Blind.

The guidelines are divided in six major categories: GUIDING, REFERENCE, BOUNDARIES, USING SOUND, USER LEARNING SUPPORT, and INTERACTION WITH THE SYSTEM. From our previous contacts at the schools a second survey was developed to gauge the usefulness of our new guidelines. We asked our respondents to rank the effectiveness of each guideline proposed. From the survey we found that one of the methods that seem to be the most useful was the one that dealt with the system set-up. These included icon size, orientation, and reference points that the user can easily find. Some examples of the guidelines proposed are explained in more detail.

3.1 Category 1: Guiding

The Guiding guidelines address the concern of button or icon size and position within the GUI. Using these guidelines efficiently would allow the blind and partially blind user to navigate his or her way within the system.

Table 1. Examples of Guiding Guidelines and Justification

Category	Guideline	Justification
Guiding	Target points should be larger than normal	Large icons are easier to access and find than smaller ones
	Choose manipulation tool that best fits the application need	If accurate targeting is required a pen tool may be easier to use than a mouse or joystick, etc.
	Minimal # of targets/buttons used to screen at any one time	Fewer icons will result in less confusion to the user.
	Use a 'gravitational force' whenever possible to help pull the cursor into the button	Faster target acquisition will be generated.
	Use a linear set-up of icons	It is easier for a user to navigate through the icons.
	Speech activation program	It is a system similar to that used by high end cell phones to access certain programs.
	Verbal navigation system (JAWS)	It will alert the user when they are over or selecting a certain option.

With larger than normal target points blind users can locate buttons easier, because the probability of overshooting an icon or not recognizing the ‘gravitational’ force can be minimized. Choosing the proper manipulation tool is essential to the user moving around the computer interface. If more precision is needed, then a stylus type tool would be a better fit than a standard mouse. By minimizing the number of target points on the screen at any one time there will be a lower chance that the blind user will get confused or lost. A gravitational force would allow the user to be pulled into a button when he or she was within the gravity field. This force would be similar to a snap, but would be much gentler. For example, if the user was within a predetermined distance of a button then the user would feel the manipulation device being pulled into an area. With the use of a JAWS system, the user would also be prompted what icon/button they were approaching.

A linear set-up of icons would greatly improve the users targeting ability. Some systems use a circular set-up of icons because sighted users can make faster acquisition of buttons. For a blind or low vision user it would be very difficult to determine the difference of position between a button at twelve o’clock and one at one o’clock. When using force feedback studies have shown that a linear set-up will result in faster target acquisition. With a speech activation program the user would be able to pull up commonly used programs and functions easier. By activating the speech system with a key stroke the user could access a word processing program easily and then proceed to either type, or use the speech with voice recognition to type it as the user speaks. When the JAWS system is used properly the user would be alerted to the location of their pointing tool.

3.2 Category 2: Reference

The Reference guideline addresses the need to have a GUI set-up that is easy to navigate. An effective reference system will aid the blind and partially blind user in being able to use the system as effectively as possible.

Table 2. Examples of Reference Guidelines and Justification

Category	Guideline	Justification
Reference	All reference points should be easy to find	Corners and edges are well defined.
	Reference system should not be changed unnecessarily	Standard locations are easier to find.
	Pointer tool will move along a groove	A grooved path would help find targets on a grid.

Reference points pertain to common areas such as corners and boundaries of windows. By keeping things in a linear set-up these areas would be easy to find for a user using a haptic device. By using a fixed reference system the user would only need to remember the specific areas of a window. Some common areas would include an exit button, or save button [7]. It is common practice now to use a system such as this. For example Windows ® uses a system like this in all of their Microsoft Office ® programs. The exit button, minimize, and restore buttons are in the upper right corner, where the File button is always in the upper left corner. Having the pointer move along a grooved path would help the user navigate through a linear set-up of icons. The user would be restricted to moving in ninety-degree directions. This would be beneficial when using a linear set-up.

3.3 Category 3: Boundaries

The Boundaries guidelines address the need to have a system set up to restrict the blind and partially blind user to a certain area, which can help the users ‘feel’ their way within a system.

Table 3. Examples of Boundaries Guidelines and Justification

Category	Guideline	Justification
Boundaries	Manipulation on the 'mouse pad' directly corresponds to motion on the screen	This will help the user navigate to specific points on the screen.
	Instead use rounded corners and sides	Sharp edges are difficult to feel with a haptic device.
	Add ridges to the window frame.	Ridges would help to 'confine' the user to a certain area until they were ready to move into another.
	Ridges also added to icons to prevent 'over shooting' the icon	This will help in identification of acquisition.

Having a system where the movement on the surface directly correlates to movement on the screen would allow the user to find the reference points easily. By making the upper left corner of the surface correspond to the upper left corner on the screen or the center of the pad be the center of the screen, the user could find the exit button easily. Current systems do not have such a boundary system in place. Rounded corners on buttons or icons are easier to feel with current haptic devices than sharp edges. This will allow the user to determine a button or icon [8]. By adding ridges to window frames if multiple windows are on the screen at one time will help to keep the user in one area. If the user did need to cross over to a different window then the user could apply a set force to jump over the border to the adjacent window frame. If the user knows a certain window is open then an Alt-Tab function or something similar can be used to swap windows. In this case the addition of edges to open windows would help the user identify the presence of open windows. Ridges can also be added to the buttons or icons so the user will feel like they are dropping into a hole or rising up onto a button [9]. The ridges, when coupled with the gravitational force and JAWS, would help the user find buttons. It will also help the user to determine if an option is engaged. For example, if the user were to ‘fall’ into a hole then it could be understood that the option is in use.

3.4 Category 4: Using Sound

The Using Sound guidelines address the use of sound for navigation in a system. When used properly the addition of sounds can greatly enhance the blind and partially blind user's computer experience.

Table 4. Examples of Using Sound Guidelines and Justification

Category	Guideline	Justification
Using Sound	Take care in associating tones with certain options	It is recommended not to use sounds that can be mistaken for errors or other universally accepted tones.
	Use pitch only as a ranking device	Using pitch will help the user identify ranks of systems.
	Stereo sound	It will help the user determine left-to-right movement or vice versa.
	Non-Verbal sounds can be used to represent actions or information about objects	It can indicate whether an icon is un-usable or is in use.
	Use textual/verbal feedback for icons and buttons as well as menus, title bars, etc…	When used sparingly, the system will vocalize the button/icon the user is about to access.

Because certain tones can mean specific things, it is desirable when using sounds to use those that can be mistaken for something else. For example, in most systems, a simple 'ding' sound is used whenever an option is unavailable or an error has been caused. This 'ding' sound should not be used in conjunction with any other option. When using the concept of pitch, the pitch should be restricted to the soprano and bass tones. Using pitch will help the user to increase or decrease an option [10], for example if the user wishes to change the font size of text for a document being produced. A tone that gets higher in pitch would alert the user to an increase in font size, where a bass tone would alert the user to the opposite. If a low vision user needed to resize a window from left-to-right or vice versa, a stereo sound would aid the user in his or her task [10]. The stereo tones could also be used to help the user determine which side of the window he or she is in. Tones that indicate icons being usable or unusable are already in use today in computer systems. It would be beneficial to use such tones to help the user determine if a button he or she has selected is usable or if an error is caused. Using a system such as JAWS would help when the user has encountered a button or icon. The system would tell the user what button he or she is over and then they would be able to decide whether or not they wished to select the option or move on to the next one. Great care should be taken however in using sounds to help the user. If there are too many sounds, or if multiple sounds go off at once it can be confusing to the user. Therefore it is suggested that the user be able to turn off all sounds, or to choose what sounds to turn off or on.

3.5 Category 5: Interaction with System

The Interaction with System guidelines relate to the importance of what happens to the computer system if it is left idle, or if the blind and partially blind user needs to correct a mistake.

Table 5. Examples of Interaction with System Guidelines and Justification

Category	Guideline	Justification
Interaction with System	If cursor idle for set amount of time, reset to default position	If user knows starting point then it will be easier to find buttons/icons
	Make it easy to go back if mistake is made	It allows the user to have one key access to go back.
	Allow the user to turn off verbal commands or force if not desired	If sounds are not needed, they may be counter productive to the user.
	'Quick key' functions for commonly used commands	It is already in use by all computers.
	Use target crosshairs as the cursors for partially sighted users	It helps the user to accurately see where they are pointing if a typical pointer arrow is too hard to see.

By allowing the cursor to reset to a default position the user would know where he or she is starting out. If the system is using a direct manipulation model, then the user can know exactly where on the screen the pointer is. For example, the cursor may reset to the center of the screen, when this happens the user would be aware of such a move and could move back to the previous spot, or continue working on something else. If the user were to make a mistake in the process it is beneficial to allow the user to go back to a previous screen or set-up with a key stroke or key command. For low vision users this would be helpful if they realize they made a mistake in a program. By using the go-back method, the user could start over from the spot just before the mistake was made. Multiple undos could be used to undo multiple commands if needed. If the user is not completely blind and can still see a computer screen with the use of a system to enlarge the screen the ability to turn off force feedback or verbal cues may be required. Doing so would allow the user to navigate through the system without those tools. The quick key functions would allow the user to access functions such as save, exit, undo, or print easily. Although in use by all computer systems, they should be kept in the new systems to help make manipulation of the system easier. In some instances, low vision users are unable to see a regular pointer tool, or it is too large to accurately pick an option. It is recommended to use a cross hairs system so that the target is identified by two lines that intersect over an area. The cross hair system would be useful when coupled with the screen being laid out in a grid pattern and the cross hairs moving along a grooved path.

4 Discussion and Conclusions

Research and experiments that have been done during the last decade have the common goal of assisting visual impaired people; however there has not been much research to define a standardized set of guidelines that will assist in the development of new systems and tools. We believe that a strong set of design principles and guidelines can set the foundation for future researches that can assist visually impaired people interaction with technology.

4.1 Interviews and Surveys

Based on interviews and surveys with students and instructors at various blind institutions, this study showed that there is an interest in using haptic technology to help the blind and partially blind user. Most of the people interviewed felt that a 'gravitational' force would be a great benefit to target acquisition. The force should be gentle enough however as to not 'snap' the user onto the button, rather the user should feel like he or she is being guided into position. Another guideline well liked by those interviewed is a linear set-up of icons. The linear set-up would help the users navigate through the system without trying to figure out a circular set-up. With a circular set-up, depending on the number of icons, there would be a certain degree the user would have to move in an arc to find the next button. With the linear set-up the user would only need to be worried about left to right movement, or up and down. However, one area that may not be suitable for some users, or confusing to others would be the use of sounds: whether it is monophonic or stereo sounds. Those interviewed stated that it may be confusing or cause more harm than good. In dealing with sounds, the students and instructors alike did feel that keeping verbal feedback for icons in conjunction with the 'gravitational' force would be very helpful. An existing system such as JAWS would be adequate to handle this requirement.

4.2 Science Learning for Visually Impaired and Blind Students

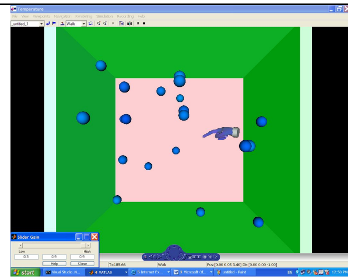
As a proof-of-concept that our interface design principles and guidelines can make a significant impact, we introduce a haptic virtual learning environment we developed to help science learning for visually impaired students, demonstrating how these principles and guidelines have been applied [11].

The Individuals with Disabilities Education Act (IDEA, 1975) require that students with disabilities receive full access to education. However, visually impaired and blind students are not adequately accommodated in science instruction [12]. For example, 38% of students with special needs hardly receive any instruction in science and 90% of science teachers who teach these special education students often employ textbook-oriented teaching [13]. Therefore, how to increase the participation of students with disabilities, especially those with visual impairments in science education is a critical issue. We suggest that haptic force/tactile perception, combined with hearing and more importantly additional thermal sense [14], can be a very important perceptual mechanism for the visually impaired and the blind, because much of the blind's world is mapped through their haptic senses [15].

A haptic virtual learning environment was developed to help science learning for visually impaired and blind students, a learning system in which science education could be made accessible to both visually impaired students and their teachers [11]. For a learning application for science concepts, the temperature concept was chosen. Figure 1 shows a part of the learning scenario on the temperature concept used to develop the application, which was adopted from the Physics-2000 Website. Based on learning scenarios, a haptic virtual learning environment was developed in which the user can control the temperature of an object, see atoms' random movements with different speed depending on the object's temperature, and feel the warmth or coolness of the object and the corresponding speed of the atoms simultaneously.

- We all know that some things feel hot, and others cold, but is there more to temperature than that?
- When an object feels hot, the atoms inside it are moving fast in random directions, and when it feels cold, they are moving slowly. Our body interprets that random atomic motion into what we feel as hot and cold.

(a) An example of learning scenario



(b) Temperature application

Fig. 1. HAVE temperature application

Atoms (represented as spheres in Figure 1b) speed up or slow down as the temperature is changed. Students can feel the atoms' speed in the form of the force as they put their tip (represented as a pointing-hand) into the box. The box's background color also becomes the darker red to indicate the temperature change. The higher the velocity of the atoms the more hits and the stronger forces are sensed. With realistic sensations (e.g., changes in color, speed, force, temperature) of the scientific concept, this application will allow students to better understand that heat energy depends on the speed, the number, and the type of particles in an object, as well as that temperature does not depend on the size or type of the object. Students will also be allowed to manipulate several variables (e.g., temperature, the number of particles, etc.), and to see and feel what is happening as they change them.

With ridges added to the area where the atoms are the user would be able to confine the search for atoms to that area. For the user to navigate outside of the box, he or she would apply a force to break over to the control panel where the JAWS system would alert them to entering the area. The user could also use a quick key function that would allow them to automatically snap to the control panel. On the control panel the buttons would be laid out in such a fashion as to adhere to the guidelines presented. With a linear set-up and sufficient size and spacing the user could change the size of the atoms, the rate at which the temperature is increasing, starting and stopping, and any other options that would be required for such a system. The linear set-up would also allow the user to navigate left-to-right or vice versa, the gravitational force would help pull the user into the adjacent button, where JAWS would tell the user what function the button related to. By using pitch the user would be able to increase the size of the atoms (a soprano sound would indicate a larger size), the user could also decrease the temperature change rate (a bass tone would indicate such a change). An easy to use quick key function could then be used to reset the pointer tool into the box where the atoms are and another key function would start the process. The user would then be free to explore the environment and feel the heat and force changes present in the program.

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From Handicap to Diversity

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Abstract. In 1980, World Health Organization defined handicap as a condition of disadvantage. Instead, since 2001, WHO considers handicap as a form of diversity, embedded in a society where anybody is diverse in his/her own way. This change in definition signals a cultural transformation both in the society at large and in its part that is composed by the "handicapped" people. Such a change in the attitudes is rooted in the fact that the assistive technologies let people to overcome limitations and allow to build an intelligent ambient that permits all to exploit their diverse potentialities. In Italy, this process of social change has been accompanied, for more than twenty years, by a Foundation (ASPHI), whose mission has been to favour the education and the inclusion in the labour market of people with disability through the use, at the beginning, of the computer-based, and, then, of the communication technologies. In the following contribution, the main characteristics, and activities, and the evolution processes of ASPHI will be presented, together with the outcomes of a survey on how the process of cultural transformation has taken place. The survey was conducted on a sample of the people that directly (they have attended course in ASPHI) or indirectly (they at least once asked ASPHI for information or help) had to do with 6h9s Foundation. The quantitative and qualitative information show a clear shift in the self-perception of "people with disability" from exclusion to inclusion, from the limitations of the handicap to the value of diversity.

1 A Brief History

In June 1979, the Director of the Bologna (Italy) IBM branch proposed a COBOL programming course for severely visually impaired people. At the time, it was first and unique in Italy, and almost without precedent the world over. By the end of the course, all sixteen participants found a job, in various work settings, such as banks, factories, private and public offices. Soon after, in the same year, the ASPHI ('Avviamento e Sviluppo di Progetti per gli Handicappati nel campo dell'Informatica' - Promotion and Development Projects in favour of Handicapped People in Informatics-) Foundation was established in Bologna.

The experience with blind people was soon extended to other disabled people (physically disabled, and deaf people, and those with psychological problems) and the field of action of ASPHI had been extended to other Italian cities and European

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countries. From 1980 onwards, programming courses for blind people, and courses for partially deaf people have been created in Greece and Russia.

In the following years, ASPHI Foundation developed as a centre of research and education, expert in using technology to reduce the impact of disability and ran numerous projects at national and international level. Soon, it became as a national centre of reference for disabled people, in particular by helping them to gain a European Computer Driving Licence (ECDL).

Since the very beginning, ASPHI Foundation has acted also a research centre for developing and evaluating assistive computer-based (and, later, communication) technologies in collaboration with many Universities.

Furthermore, the Foundation has collaborated actively with public and private companies and organisations for promoting the job placement of disabled people: It has developed a placement scheme that comprises both guidelines for smooth introduction and acceptance of the disabled people at the workplace by educating managers and co-workers, and by giving advice to the company in selecting the most appropriate assistive technologies. The objective has been not just to find jobs for disabled people, rather to help companies to set up a comfortable workplace, and a favourable social climate in order to render easy the professional and social life of the persons, with and without handicap.

The aim has been (and still is) to create, and constantly improve, the social and technological environment in order to make the work of the handicapped people profitable for the company, and let them consistent chances of a professional career, and improvement of their autonomy.

Since a number of years, numerous private companies and public agencies have adopted the ASPHI guidelines. Under its guidance and leadership, a community has been built, within which the members exchange information and identify best practices for improving workplace, technologies, and career. The community has one day face-to-face meeting at least twice a year, where themes of general interest are discussed.

Among other activities, ASPHI Foundation organizes a yearly national conference, “Handimatica”, having a number of attendees as large as six thousands in the last year.

All this means that ASPHI has played and plays a major role in research and education in the field, in change of attitude both within disadvantaged people (they are empowered to become self-confident), and by the people in general in Italy, and lobbies at the nation-wide policy decision making toward the rights of disabled people.

ASPHI strongly campaigns in favour of “diversely-able” people.

2 Changes in Work and in Attitudes Toward Handicap

The action conducted by ASPHI has taken place in a period of deep transformation in work, largely due to the widespread adoption of computer-based information, and, later, communication technologies.

Indeed, ASPHI started at the beginning of the so-called information revolution, by the end of Tayloristic era. Indeed, most of today work is very far from that of twenty-five years ago. At that time, industrial work prevailed: It was very simple, usually performed in dedicated place, permanent, repetitive, and boring. It didn't require mental effort, and was predominantly manual. Clerical work was similar, even though implies routinary mental, rather manual work.

The actual prevailing form of work shows different characteristics (National Research Council, 1999; Malone, 2004). From the demographical point of view work is heterogeneous; the diversity in human resources is growing in terms of gender, race, education, culture and status. Work is becoming more dynamic and boundaries among various jobs have become weak and permeable (Davis & Meyer, 1999). Nowadays, it is possible to work at home: Technology is everywhere, and employers expect people to have the skills required to manage this technology. Those who lack these skills are at risk of being cut off from work. This digital divide isn't limited to work but is also present in everyday life and affects people's social relations.

Work is mentally demanding and implies responsibility. It made of often quite new activities to be performed in unfamiliar settings. In these days, markets are characterised by uncertainty, consequently work goals are never clear or defined, and the value of work depends by its originality. Cooperation is deemed essential to face complexity and uncertainty.

This fundamental transformation clearly affects also the inclusion of disabled people at work. And it has not gone unnoticed by the World Health Organisation (WHO), that in twenty years has changed the basic definition of disability.

In 1980, WHO introduced a clear distinction among impairment, disability, and handicap, and for each term listed various categories, with the relating characteristics, in order to make a classification. It could be interesting to review some of these categories.

Impairments are related to the capacity of a person: intellectual, psychological, linguistic, auditory, visual, skeletal, and so on. Disability is connected with the activities performed by a person: Behaviour, communication, taking care of oneself, dexterity, and so on. Finally, handicap reveals itself as a deficiency in physical autonomy, work, social inclusion, and economic autonomy of a person.

For example, according to these definitions, a blind person is a person who suffers from a *visual* impairment, which causes a *communicative* and *locomotive* disability; it means also handicap, for example, in the *mobility* and in the *occupation*. Therefore, one type of impairment can cause various disabilities and involve different handicaps. Analogously, one type of handicap can be linked to different disabilities, which can derive from various impairments.

While the impairment is permanent for a person, disability depends on the activities that he/she has to do and the handicap expresses the disadvantage that he/she has with regard to others (so called 'normal people'). The significant aspect of the first document of the WHO was that it associated the state of a person not only to functions and structures of the human body, but also to individual activities. The key concept is 'normality'. The degree of handicap is defined with reference to the standard (the one given to "normal people"): It is the gap that must be overcome to become normal.

It is apparent that 1980 definitions of WHO were basically coherent with the work of that time. There are a lot of different jobs. Each one is executed in a standard way. Handicap underlines the gap from the "normal" mode of working caused by the disability. The inclusion of a disable person will be easier as the gap is smaller. There are even jobs where the work is not affected by an impairment at all. For the blind people, the occupation of telephonist is one of these. The new IT sector seemed to be one area where many impairments are insignificant. And ASPHI worked in that direction.

In June 2001, the WHO published "*Classification of Functioning, Disability and Health*". The title is indicative of substantial changes. The aim was no more to describe the handicap but the state of wellbeing of a person. There is no reference to any disorder, structural or functional, without linking it to the state of 'wellbeing'. The state of wellbeing is defined by the person's own physical state, by the different ways that a person interacts with the outside world, and the impact of external events on a person.

Therefore the WHO classification includes not only the physiological and cognitive functions (mental, sensorial, vocal, immunological and cardiological functions, etc.) and the physical structure of a person (the nervous, visual and auditory systems, the vocal apparatus, the cardiovascular and respiratory systems, etc.), but also the activities that guarantee inclusion and social participation (learning, communication, interaction and interpersonal relations, community life, etc.), and environmental, that is natural (the environment), artificial (technology), and social (support, attitude, services, etc.) factors.

The classification system covers every aspect of human health, arranging them in two different domains. The first is the *health domain*, which includes the action of seeing, hearing, walking, learning and remembering, etc. This is directly related to physical structure and functions. The second, the *health-related domain* which includes mobility, education, participation in social life and similar, refers to activities and environmental and social factors.

It is important to underline that it doesn't only concern persons with disability but everybody: it has a universal use and value. There are hundreds of different categories. Any person can be associated with one or more *categories* that characterise his/her 'functioning'.

For the function and structure of the body, the qualifier can assume values from zero (no impairment) to four (severe impairment, equal to 96-100%). Similar qualifiers exist for the activities that don't refer to impairment, but to *limitations,* and for *participation* it is said that there are *restrictions*. In short, concerning environmental factors there are *barriers*.

The classification is 'positive': It starts from the 'normal' level of functioning, considers if a person differs from this norm, and how far they are from it. The term 'handicap' is abandoned and the term 'disability" is extended to cover the *limitation of activity* and *restriction on participation*.

Again, it appears that new WHO definitions and classifications are strongly related with the changes in work (not to say in the attitudes of disabled people and toward them) that had had taken place during the years when ASPHI has acted. Moreover, all this had been strongly influenced by the information technology.

In summary, handicap is now seen as a form of diversity in a society where all are diverse and need some kind of assistance.

3 The Survey

Over the last 25 years, many people with disabilities have established direct (attended courses) or indirect (used ASPHI educational, and training material) relationships with ASPHI. They have also subjectively experienced the transformations in work, in attitudes, in conceptualization and language occurred over the very same period of time.

It can be of some interest try to understand through then the role that technology has had in improving their autonomy, in facilitating their inclusion in the workplace and in enriching their social lives.

In order to this aim, a survey was conducted, in 2005, making use of qualitative (focus groups, in-depth interviews, life stories), and quantitative (a questionnaire) techniques, with disabled people that had followed training courses organised by ASPHI, or used ASPHI as the test centre for the ECDL exams or made use of educational materials produced by ASPHI. The study aimed at to investigate the perceptions, needs and suggestions of this very special group of disable people.

In this contribution, the outcomes of a questionnaire, aiming at investigating their perception of the role of information and communication technology as for: (a) Autonomy in life (b) Work (c) Social relations, will be summarized.

The questionnaire was sent, either by email or by post, to 1475 disabled ASPHI related people (about half were blind and a quarter were physically disabled). The percentage of respondents was 12.5%.

In all, 184 people replied: 27.7% were physically disabled, 41.9 % blind, 18.5% visually impaired and 6.5% deaf. The large majority of respondents aged between 30 and 50 years (70%), were male (71.7%), lived the North of Italy (70.8%), having a university degree or a high school diploma (57.4%), followed an ASPHI course (65.7%). Almost all (78.4%) were at work and enjoying life contract of employment (86.1)

3.1 Technology and Autonomy

Autonomy is the mental and physical capacity of looking after ourselves and our needs and desires, and managing our free time and hobbies. It implies the chance to realise oneself ambitions. In many cases, to achieve and retain autonomy, it is vital to find tools, which may increase person's capacity. These tools are defined as 'aids' when they substitute some capacity of a person (such as an elderly or disabled person) to carry out some function, which they would otherwise be unable to do.

Since our interest was specifically directed to ICT-based aids, the use of related technologies was assessed in our questionnaire. It turned out that almost all of respondents use a personal computer, and 90% used the Internet as tools. Some of them used other aids, such as wheelchairs, or Braille bar. 94.3% of blind respondents need aids for their autonomy, and 75.8% need aids to manage their free time. Such percentages decrease, but remain still high for the physically disabled: Over half (56,5%) declare the use of aids for their autonomy, and 45.5% for their free time. Visually impaired persons are halfway between: 76% use aids for autonomy, and 53.8% for their free time. In other words, deaf people need helps for autonomy, but not for their free time.

Technology, however, hasn't brought only advantages for disabled people: For example, cash dispensers, once prevalently tactile, having now touch-screen technology have become a barrier rather than an aid. These types of difficulties were confirmed by the focus group with blind people who maintained that the shift from alpha-numeric, text based to icon based interfaces (i.e., for example, from DOS to Windows) had been seen as a severe obstacle, rather than an easy and friendly way to interact with aids. Blind people pointed out that changes in technology require much effort for disabled people. They seem to appreciate, once learnt, stable standard interfaces and routine based forms of interaction.

In summary, ICT aids are very much appreciated for improving autonomy in day life. What is questioned is too fast, continuous change in the interaction.

3.2 Work

Work has always been, and continues to be an essential element in defining the social identity of people. This statement is especially true for disable people, for whom the workplace is often the most important social group they belong to. Some authors (e.g., Uris and Tarrant, 1983) maintain that the relations established in a work setting may even be more relevant than family or friends. A similar view was supported also by Peregoy and Schliebner (1990), who, while looking at the effects of a long-term unemployment, claimed that persons think about their work place as the primary solution for social integration and as a surrogate for the family system. This tenet was also shared by the respondents to the questionnaire. Indeed, very few (12.9%) work at home (totally or partially), but almost all preferred to experience the day-to-day working dynamics.

During the 80s and 90s, the IT diffusion at workplaces has created new professions and many disable people entered the work market as programmers, data analysts and webmasters. The work experience was no more restricted (mainly, for blind people) to such jobs as telephonist and masseur. The use of information technology has also made some traditional jobs accessible for disabled people. The shift from printed material (almost impossible to handle for blind people) to digital information has turned the entrance in a new era. Blind people now have the chance to work in careers that were once precluded, such as librarians, archivists, journalists, and the most clerical jobs.

The most of respondents (89.3%) use a personal computer and (78.4%) the fixed telephone in their work. A comparatively small part of the sample use mobile phones (37%).

For the 71.1% the organisational changes brought about by the introduction of IT at work have been positive. Blind people benefited more of the changes. Indeed, the most used aids are those created for them, i. e., the screen reader with vocal synthesis (80.7%) and the Braille bar (61.5%). Almost all the respondents agree that the aids have positively or very positively contributed to enhance their ability to do their own work.

More than half (55.8%) of the respondents have participated to the purchase by the company of new aids, and played a role in fitting them to the workplace. The participatory practice is not so common, however, since 44.2% the respondents either has been forced to manage the changes by themselves, or have to face with the changes done by external technicians, without being consulted. Participation is not a general practice.

A deaf person is not able to make or receive telephone calls if the telephone does not have a text phone facility (DTS), but is perfectly able to read and reply to emails: Computers are the principal working tool for deaf people.

Professions born and die. Disabled people have made this experience too. Some remarked the demand for programmers has been reduced over the last years. Indeed, blind programmers suffer more for this, since, as they noticed, the today software is developed in a graphical and visual setting, and no existing solution enables blind programmers in overcoming this obstacle.

The sample agreed that nowadays workplace is enough inclusive, and that job evaluation is no more based on the impairment, but on the professional quality that the person is able to express in a specific contest.

In the focus groups, the participants convened that, thanks to technology, they can carry out activities, which require collaboration with colleagues, are more innovative, relevant, complex, and imply more autonomy and responsibility.

In summary, the surveyed disabled people showed a positive attitude towards the changes information technologies brought about for them in work. However, there are still standing problems, which prevent the integration of disabled people at work: The too rapid technological evolution, and the continuous, often very expensive, upgrade of aids. Disabled people have to 'run' to keep up with both the evolution of IT and with normal people. Even though 71.1% evaluate positively the introduction of information technologies in the workplace, 40.9% claim that it is hard to keep them updated, being forced to make the double effort of learning specific software and using the aid.

3.3 Social Relations

Interpersonal relations represent an interesting field in studying disability. Traditionally, disabled people were described as people with a relatively small number of social relationships, though particularly close.

Recently, the situation has changed. Three macro-phenomena, occurred in Italian society in the last three decades (though a similar dynamics has occurred earlier or later in many countries) have contributed to mitigate some prejudices about disable people and to improve their degree of social integration: By law disabled children are educated in normal schools, workplace is more inclusive and more information about disability is available to the general public. All of this is reflected in the opinions of the respondents to the questionnaire. Most of them convene that the changes arrived in the last 20 years have been positive, since they allowed to enlarge the social space for disabled.

However, they do not under-evaluate the role of ICT in socialising: Nowadays, 61.1% of respondents consider the main aid for starting and maintaining social relationships. There has been a change in the use of the technology, from using it as a tool for work to a universal instrument also capable of affecting social relations.

The introduction of mobile phones and the internet have opened up new and heretofore unimaginable channels of communication between people, and have allowed disabled people to communicate beyond and outside family, particularly for visual and hearing impaired people who have especially benefited from the spread of these technologies.

For deaf people, the mobile phone, thanks to SMS and vibration, allows to overcome many communicative barriers, and hence making possible social relations. IT aids like screen readers, enlargers, modified keyboard, vocal systems and telephone devices replace human help and allow disabled people to achieve almost a complete autonomy and a larger feeling of privacy. And for physically disabled people, autonomy is provided through wireless technology provides autonomy.

In conclusion, technology has changed the social life of disabled people. Of course, they consider such a change extremely positive: It has enriched their life

3.4 IT and Handicap: A Complex Relationship

The outcomes of the survey show that disabled people appreciate very much information technologies. They allow people to overcome handicap, and to become autonomous in the day life, both in looking after themselves, enjoying an entertainment, and participating to the public life, in learning and working. The aids help disabled people to work in different setting and to take up various jobs and professions, to pursue about any sort of carrier. Moreover, the technologies enlarge the social relationships, by allowing to communicate with much more and diverse people than before.

Disable people recognize all that, together with the positive changes in the attitudes toward them. But they have reached a level of awareness that allow them to assume a critical attitude both toward themselves and the technologies. They see the continuous change in the technologies, in the way they have to interact with them, in the skills needed to operate with them, and in the knowledge required to understand them as complex phenomenon requiring an endless effort to cope with. However, when adopting this view they reach a dramatic achievement: They exhibit the very same attitudes toward technology as the “normal” persons. The differences are quantitative, sometimes are more, sometimes are less, but no more qualitative. They are part of the same world in which anyone, no matter if disabled or not, feel more or less confident, skilled, competent, out-of-date.

Disable people realize they live in world where anyone is diverse. What is needed is transform the ambient in order to render it responsive to the persons, anyone diverse from another.

In summary, the survey suggests that disabled people are become aware that in the world of ICT their disabilities, handicaps, impairments are simply types of diversities among many others.

4 From Handicap to Diversity

The initial challenge of ASPHI was to use IT to actively include disabled people in the labour market created by advances in IT. During this period ASPHI was a “special school”, allowing disabled to take up jobs where their disability is irrelevant, that is, computer-based jobs. And ASPHI has been very successful in pursuing such an aim.

From the beginning, ASPHI moved also towards another perspective: To create instruments and aids which can reduce and remove the effect of the impairment, allowing disabled people to enter jobs in other areas of work, for example as financial analysts, teachers or entrepreneurs. The tenet was that, if disabled people use appropriate aids, they would be able to compensate for their impairment. In other words, technologies can broaden the range of possible careers.

In following this direction, it appeared more and more clearly that disabilities have to be seen as some of the forms of diversity we should take care of, since, as for technologies, difficulties and benefits concern everyone. It depends on the tool, and the context. Difficulties can arise or change at any time; it is not possible to overcome them once and for all. This perspective implies the concept of disability must be replaced by the idea of diversity.

From the point of view of diversity, people have not to be qualified as disabled but rather as more or less diverse from others with respect to their working situation and the degree of their IT competence. Everyone is, in a way, disabled with respect to digital technology; to overcome their personal digital divide (subjective and contextual), everyone needs to personalise technology. The needs of disabled people are cases in the general necessity to personalise IT. But every person, either normal or disabled, continually needs more personalised and specific solutions.

In the course of 25 years of activity, ASPHI has been able to make disabled people less different, or rather to provide them with tools and technology to overcome their disability. So, today, it is possible to claim that disabled people no longer belong to a special category, but are, instead, diverse individuals just like everyone else: Different people among different people, who require personalised technology. From this point of view, technology may be an opportunity and a problem for everyone, though greater for disabled people.

At the present time, almost all human activities involve the use of technology. We all live, more or less, in symbiosis with technology, and we have become ‘technological people’. Disabled people live in greater symbiosis with technology, and are probably the most evident case of man-machine symbiosis.

From this perspective, the solutions for accessibility for extremely severe disability might have general fallouts. Design for overcome handicaps has no more to be seen as a niche, but rather as the most challenging endeavour of widespread, general value.

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Does My Stigma Look Big in This? Considering Acceptability and Desirability in the Inclusive Design of Technology Products

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Abstract. This paper examines the relationship between stigmatic effects of design of technology products for the older and disabled and contextualizes this within wider social themes such as the functional, social, medical and technology models of disability. Inclusive design approaches are identified as unbiased methods for designing for the wider population that may accommodate the needs and desires of people with impairments, therefore reducing 'aesthetic stigma'. Two case studies illustrate stigmatic and non-stigmatic designs.

Keywords: Inclusive Design, social inclusion, stigma, aesthetic design.

1 Introduction

This paper aims to explore possible 'stigmatic' aspects of products that are designed to aid older people and people with disabilities. Its central question asks if it is possible for 'stigmatic' aspects to be identified in early stages of design and subsequently designed out. The paper will begin by addressing the importance of functional need and aesthetic quality. It will then assess the various models that can be seen to be determining certain design aspects. Using perspectives from wider social criticism the paper will illustrate how products can project wider social meaning concerning the ability of their user. Case studies of two particular products will be assessed to highlight where aspects of the design could be considered to continue stigmatising. Counter to this, another case study illustrate how an inclusive design approach eliminated such aspects.

2 Stigma

Stigma is defined in the Chambers English dictionary 'as a brand: a mark of infamy: a disgrace of reproach attached to any one'. Many disabled and older people identify their age and disability as being 'stigmatising' to the extent that they evoke negative

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responses. In his groundbreaking work *Stigma* Erving Goffman [1] proposes that stigma is not based on the functional limitations of a person's impairment, but rather the societal and social responses to disability. Recent UK legislation such as the Part 3 of the Disability Discrimination Act (DDA) attempts to target certain aspects of stigma by legally enforcing wider social inclusion of disabled people in areas such as access to the built environment. Yet whilst the act can determine the placing of a ramp, or access to suitable toilet facilities it does not include products that may be used within these public spaces. Bichard et al [2] have demonstrated that within accessible toilets, the door width may be adequate for most users of wheelchairs, but the soap dispenser maybe unusable for people with manual dexterity impairments.

For the purpose of this paper, stigma is considered an attitude brought about by a product or environment that emphasises physical, sensory or cognitive impairment as a result of birth, life course and or ageing. This impairment results in a loss of mobility and requires the use of products to assist or intervene.

3 From Stigma to Aspiration; The Case of Glasses

Pullin [3] notes that in 1930's Britain, the National Health Service (NHS) prescribed spectacles to people with visual impairments that could be assisted by this technology. Spectacles were defined as 'medical appliances', and their wearers as 'patients'. In wider social life the wearing of NHS spectacles was considered to cause social humiliation and to be stigmatising. Initially NHS glasses were, as a medical product, believed to not need to be styled, but to provide 'adequate' function. By the 1970's the importance of styling had been acknowledged by the government (financers of the NHS), yet the medical model of sight impairment, to be corrected by functional spectacles, remained the dominant design discourse. Yet within this period, the design of glasses was taken up by the private sector, which offered more fashionable choice in glasses to those who could afford them [4]. By 1991, the design press had announced that eyeglasses have become stylish' [5]. Today, eyeglasses are available on most high streets, and sales records estimate that up to 20% of some brands are purchased with clear non-prescription lenses. Pullin proposes that the wearing of glasses has become aspirational opposed to stigmatising.

4 Medical and Social Models of Disability

All people operate within a range of abilities and are able to do different things at different ages. Ability is therefore a relative concept; relative that is to the abilities considered to lie within 'normal' ranges of behaviours for a person at a particular chronological age. Set within this context, disability becomes synonymous with deviation from the normal. The World Health Organisation [6] defines 'impairment', as a loss or abnormality of psychological, physiological or bodily structure or function. 'Disability' then refers to any limitation or lack of ability resulting from impairment, when performing an activity in the manner or within the range considered normal. These definitions imply a causation, whereby impairments cause disabilities.

However, this causation is not accepted uncritically. Many disability activists take issue with the implication that the disabled body is not normal and that disabled people are either patients with a medical condition that needs to be treated or victims of personal tragedy that need to be looked after. Activists therefore offer alternative definitions of disability, based on the assertion that disability is primarily a disadvantage or restriction imposed by a society that pays little or no attention to the needs of people with impairments, resulting in disabled peoples exclusion from mainstream social life. This makes disability an issue of social justice and inclusion.

These diametrically opposed positions are associated, respectively, with the ‘medical’ and the ‘social’ model of disability. The medical model assumes that disability is caused by an impairment, which then becomes the focus of attention. The medical approach seeks to ameliorate or cure the impairment and, by so doing, to reduce or eliminate the disability. The danger in this approach is that people are reduced to stereotypes defined by their disability. At the same time, the individual becomes the focus of change and society is absolved of the responsibility to ensure that disabled people’s rights are safeguarded.

The social model asserts that whilst individuals may have impairments that may or may not require medical treatment, this need not prevent disabled people from being able to live a ‘normal’ and fulfilling life. Rather, it is society’s unwillingness to devote enough resources to ensure that they do, which is the root cause of social exclusion. The social model points to environmental barriers, poor employment protection, inadequate civil rights legislation and so on, that prevent disabled people from enjoying the same advantages as non-disabled people. This view stresses the importance of broader attitudinal and environmental factors in shaping disabled people’s lives arguing, in effect, that disability is socially produced.

Yet these two opposed models have both been criticised for selectively emphasising different aspects of disability; the medical model for ignoring social values and attitudes and the social model for denying the debilitating effects people experience as a result of impairment. A third position, the ‘bio-social’ model attempts to reconcile medical and social positions by proposing that the make up of the human body affects an individual’s ability but at the same time who or what is defined as disabled depends on social attitudes and values. Imire and Hall [7] note, “impairment is usually collapsed into a series of general and chaotic categories, such as vision, mobility and hard-of-hearing, which do little to reveal the complexities of impairment. Indeed, impairment is neither fixed nor static, or confined to any particular part of the population. It can be temporary or permanent, debilitating or not; in short, it is a contingent condition dependent on circumstances” (ibid, 2001; 35).

Bio-social perspectives therefore begin by acknowledging both the complexity of impairment - for example, there is no agreed definition of impaired vision and every vision impaired person’s experience of sight loss is unique - and the diversity of social responses to impairment, which can range from empathy and inclusion to intolerance and ostracism. The richer framework afforded by the biosocial model allows the issue of multiple disability to be addressed, thus providing a more holistic alternative to the stereotyped accounts based on single-issue disability. For example, studies of vision impaired adults found that over half of all those consulted had additional major health problems in addition to serious sight loss, and this figure approached nine out of ten among older vision impaired people [8], [9]. Multiple disability is therefore a far more challenging issue for design than that of making products and environments more accessible for people with reduced mobility as it requires a more complete understanding of the circumstances under which products and environments are experienced as disabling [9].

4.1 Case Study 1 an Example of Stigmatic Design for Impairment

In an audit of 101 accessible toilet facilities, Bichard et al [2] found that the toilet soap dispenser could be considered functionally inaccessible to users in 66% of facilities. In the majority of cases, the inaccessibility of the soap dispenser was primarily due to a choice of aesthetic over function (fig 1). In contrast, soap dispensers that provided adequate function, displayed an aesthetic in line with an object that 'would not look out of place in a hospital' and therefore reflected the medical model of disability (fig 2).

Fig. 1. Integrated soap dispenser, reflecting aesthetic over function. Bichard 2005 / Vivacity 2020.

Fig. 2. Soap dispenser reflecting a 'medical model' aesthetic. Bichard 2005 / Vivacity 2020.

5 Technology and Disabled People

Seldon, [10] argues that 'technology is not neutral… [but] is created by the same oppressive society that turns those with impairments into disabled people'. Davies [11] finds that technology is 'produced amidst conflicting social relations and thus holds the possibility of being a tool for liberation as well as for social control'.
Finkelstein[12] and Oliver [13] report that many disabled people are often excluded from mainstream technologies, which has lead to wider exclusion from the employment market. Whilst Illich [14] argues that whilst everyone is now dependant on some form of technology, the 'technological fixes' aimed at people with disabilities may discount any alternatives. Other commentators express concern that technologies specifically aimed at disabled people can be instruments of oppression as well as emancipation [13], [15].

5.1 Assistive Technology

Cowen and Turner-Smith [16] define Assistive Technologies (AT) as 'any device or system that allows an individual to perform a task that they would otherwise be unable to do, or increases the ease and safety with which the task can be performed'. Assistive technologies have a long and varied history that includes the development of the wheelchair to recent developments in electronics including sensors, robotic devices and remote controls. New developments are currently developing in the form of networked assistive technologies built into the home ('smart' technology), and tele-communications allowing medical care and health monitoring within the home. Newell [17] argues that AT and mainstream technologies are largely considered separate market segments, with AT principally directed at 'short term recuperation from injury or illness, or long-term functional support'. As such, design of AT products have similarly followed the 'market' and hence are largely 'health/ rehabilitation in flavour' and follow the medical model of disability.

Such specialised 'equipment' is usually costly to develop, especially for what is often perceived as a limited market. Newell proposes that to continue to follow a medical model within the design of AT is to miss out on a potential market of increased demographics of impaired mobility (be it from ageing or increased life spans of people with disabilities).

In an analysis of the acceptability of AT, McCredie & Tinker (2005) [18] found that many AT products were used to accomplish everyday tasks. Research participants warmly recommended a portable device for hearing impairment that amplified sound and flashed when the doorbell rang. A participant with visual impairments commented on how a magnifier had changed her life. Yet, such ATs can be considered the equivalent of the ramp outside a stepped entrance, an afterthought to the design of a product (a suitable doorbell for hearing impaired, inaccessible font size). They further [18] note that the most important aspect of AT was that it worked properly, was reliable and safe. Yet other studies of ATs have found that the aesthetic aspect plays an equally important role. Hanson [19] found that AT 'add-ons' for visually impaired users of computers tended to be aesthetically displeasing within the domestic environment. One respondent commented that they now hid their computers out of social areas to avoid visitors seeing their 'special' equipment, effectively feeling stigmatised by the need to use the AT.

Cowen and Turner-Smith [20] propose that 'the social model of disability recognises that many people may not define themselves as disabled or in need of special equipment so they may not take up a service offered with the best of intentions'. Newell [17] points to current ATs not being fashionable, but impending demographic change is likely to produce a demand and need for more aesthetically pleasing products. 'This will favour those assistive technology designers who are the fastest to respond to the true needs and wants of the user'. Newell goes on to ask: -

- Can alarm call buttons be designed as a fashion accessory?
- Would remote controlled curtains with a beautiful control panel add to everyone's home?

5.2 Assistive Technologies as Social Signifier

In order to truly understand the desirability and acceptability of assistive systems, there is a need to explore the larger social relationships and environments in which they would be placed. Most ATs are purposely designed for the home, a culturally recognised 'private' space. Yet the home as 'private' is not a neat and tidy classification as certain spaces such as the hallway, living room and kitchen maybe open to non-resident family, friends and visitors. As such spaces of the home transcend the neat binary classification of public or private being both public *and* private. In analysis of consumption at home, Silva [21] showed how her female informants sought social inclusion through acts of material consumption of mainly domestic goods and media technologies, accumulating products that signified their family's social inclusion. The home becomes the site through which goods are viewed and by extension those within the home are classified by these goods.

Miller [22] proposes that our ability to 'read' objects helps determine their social appropriateness, but that reading may differ between gender and class. Therefore, an object may signify different meaning for a man then a woman. The same object maybe revered by one subject only to be ridiculed and parodied by another. One group may find an object acceptable because it is 'bright and cheerful', whilst another 'enshrines its sense of good design'. In effect the object itself becomes the source of struggles over interests. As such an objects reading may influence it's initial purchase, where social value overrides functional considerations.

Miller proposes that through the consumption of goods some sectors of the population are able to utilise objects in their creation of a sense of self. In contrast, other groups are forced to live with objects created through images of them held by a dominant sector of the population. Goods are largely symbols of wealth and fashion that often reflect wider social differentiation. If an item has a certain specification, it will be magnified when compared with goods that do not. Miller suggests that the goods specificity becomes intertwined with the user, so that the specific nature of the user is defined by the specific nature of the object. In comparison, goods designed for mass consumption are perceived to create close social networks, provide 'equalising and normative mechanisms promoting solidarity and sociability'.

Sociological readings of objects help us to understand the wider meanings that they may hold, especially for people who use objects of a specific nature, such as ATs as external add-on devices. Coleman [23] states that 'personal surroundings communicate strong messages about identity, social position and values, which makes meeting people's aspirations as important as functionality and problem solving, if not more so'. Hence, when considering the incorporating of ATs within the home, it can be argued that it is vitally important that the design of such technologies, how they look and fit within the domestic environment, one that is both public and private be considered as not only an aspect of aesthetic pleasure but also as a wider social signifier of who the user is, and even as a possible object of wider social inclusion.

6 Inclusive Design as a Basis for Non-stigmatic Design

It is widely accepted within inclusive design discourse that a 'one size fits all' approach is implausible. People of varied ages, abilities, gender and social and cultural background, will desire products as varied as the population. Naess & Ortsland [24] recognise that current ATs can be stigmatising as they often embody a 'neutral' or 'for all' aesthetic. Such a lack of styling prevents people projecting their desired self through the objects associated with them as 'no one wants to be a product of an assistive product, which embodies aesthetics few would accept given a choice'.

Cowen and Turner-Smith [20] state that 'to ensure relevant design and uptake of technology, older people have to be given power to influence development themselves. This may be through the interested involvement of industrial designers, but most effectively it will be by the financial power older people can exert.

With the rise in an older population, namely the 'baby-boomers', it is estimated that the demand for certain aesthetic in products aimed at this demographic will also increase. Current marketing terms such as the Yo-Yo (young old) and WOOF (well off old folk) identify such groups as lucrative markets of consumers who resist age identification in their product consumption. Cassim [25] suggests that as product and technology literate consumers they will use the same work or leisure related products but will require forms of enhanced functionality. Within these products they will desire 'inclusivity by stealth', that take into consideration declining physical, sensory and cognitive capabilities, 'but lacks aesthetic stigma' found in many assistive technologies 'that would single them out as old or disabled, for they view themselves as neither'.

6.1 The "Go–Steady" Campaign

Since 1969 the universal symbol of disability has been the pictogram of a stick figure in a wheelchair. This symbol has been used to indicate access to areas of the built environment such as ramps, parking spaces and toilets. However, this 'universal' symbol can be considered to not fully represent the population of people with disabilities, of whom it is estimated only 5% use wheelchairs. Cassim (2007) [26] suggests that 'the subtlety and range of disability issues the pictogram aims to cover are ignored and the sign sets apart the population it aims to integrate. Indeed, Bichard et al (2006) [27] found that the designation of accessible toilets by the 'wheelchair' logo created tensions between users whose disability was visible and those whose disability was hidden (such as a colostomy or urostomy), yet required the facilities of the accessible cubicle.

This case study represents the output of the Design Business Association (DBA) Inclusive Design Challenge. An example of non-stigmatic design, it aims to raise awareness of problems of frailty, balance and mobility by a communications campaign based around assistance to people with mobility impairments and represented by an interlocking arrow motif (see Figure 3 below)

Fig. 3. This symbol set could be used on signage, labelling or media campaigns

The design team at Wolff Olins found that the current symbol represented the extreme consequences of mobility loss. In doing so, it failed to communicate potential hazards and risks, and did not fully encapsulate all those who may be vulnerable including older people. In addition, it was felt the current symbol for disability ‘stigmatises and isolates those to whom it currently applies’ (Cassim, 2007) [26].

The design chosen was felt to ‘speak to all’ who may experience permanent or temporary mobility impairment, and can therefore be considered more inclusive of the population who may require extra levels of vigilance.

7 Conclusion

The NHS glasses case illustrates both the tension between `functionality` and aesthetics, and the related medical and social models. Perhaps more importantly, it also illustrates how functionality and aesthetics can be combined, and how this can be understood through the inclusive `bio-social model`. However, as Pullin suggests, this fortuitous re-molding of the glasses was not user driven, but rather driven by the more amorphous pushes and pulls of the market. The case suggests that the intervention in designing out stigma has to be more direct and focused.

As a starting point it can be argued that the process itself needs to be initially understood, as illustrated with Goffman and Miller, and the AT and toilet case studies. When the biosocial model is used, and the functionality/aesthetics balance addressed, the outcome is potentially increasingly richer, and importantly, less stigmatising for the users. This is illustrated in the last case concerning the `Go-Steady` work.

This paper has highlighted the need to reconsider the relationship between functionality and aesthetics when designing products to old and disabled people. These aspects of design need not be mutually exclusive. Indeed, through the consideration of a more socially orientated model, both aspects can be successfully incorporated into the design process from the start.

This understanding will not obviously lead towards the creation of products of high functionality in popular aesthetic forms every time. It will however remind the designer of the importance of the relationship between functionality and aesthetics, and this in itself will lead to a more considered design process, and not one left to the `invisible hand` of the market.

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Effects of Mouse Tremor Smoothing Adapter on Ease of Computer Mouse Use by Individuals with Essential Tremor: A Pilot Study

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Abstract. As many as 10 million people in the United States are diagnosed with a complex neurological movement disorder called Essential Tremor (ET), with many more worldwide [1]. ET is a condition that is particularly troublesome during the use of computer programs that require good mouse control. The purpose of this study was to determine whether hardware and software versions of a smoothing filter labeled the Tremor Control Mouse (TCM) could provide short- and/or long-term benefits for individuals who have difficulty using a computer because of ET of the hands. A paired-samples *t*-test revealed significant differences ($p<.05$) between participants' responses to ease-of-use questions regarding traditional mouse use compared to TCM use. Subjective responses to survey items on TCM advantages, disadvantages, and helpfulness were very positive overall and reflected the participants' belief that the TCM was a useful device in enhancing mouse control and, consequently, computer use.

Keywords: essential tremor, disability, assistive technology, mouse control, tremor smoothing.

1 Introduction

Essential tremor is a very common but complex neurologic movement disorder. It's called "essential" because in the past, it had no known cause. ET usually affects the hands, but it may also affect the head and neck (causing shaking), face, jaw, tongue, voice (causing a shaking or quivering sound), the trunk and, rarely, the legs and feet. The tremor may be a rhythmic "back-and-forth" or "to-and-fro" movement produced by involuntary (unintentional) contractions of the muscle. Severity of the tremors can vary greatly from hour to hour and day to day.

Some people experience tremor only in certain positions – this is called postural tremor. Tremor that worsens while writing or eating is called kinetic or action-specific tremor. Most people with ET have both postural and kinetic tremor [2].

As many as 1 in 20 people older than age 40 and 1 in 5 people over 65 may have ET. There may be as many as 10 million people with ET in the United States, and

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many more worldwide. Essential tremor is much more common than most neurologic diseases, with the exception of stroke, and is more common than Parkinson's disease – a disorder characterized by resting tremor, stiffness and slowness of movement. In most cases, the incidence and severity increase after the age of 40 or so, although in some cases it begins much earlier. Many people with ET are unable to make effective use of a computer, because most contemporary programs require good mouse control.

2 Background

Several approaches to the problem of mouse use by individuals with ET have been tried with varying degrees of success. One is to reduce the physical tremor by mechanical means, such as adding mass and/or some form of damping to the mouse. Although this can be helpful for some people, such a mouse can be physically tiring to use. Furthermore, it is difficult to adjust the mass and damping to a particular individual's needs, which may vary over time and circumstance. A second approach is to use a different type of pointing device, such as a trackball, job stick, or keyboard keys. This helps some people, but not others. For example, using a trackball requires good finger dexterity, while certain types of joysticks can actually increase the tremor. A third approach, which was taken in this study, is to accept the mouse motion and apply a digital smoothing algorithm to reduce its effects.

A number of experts have written special programs for this purpose with a filter built into them. Unfortunately, adding a filter to a particular program is of limited value, as it only works for that program. What is needed is to add the filter to the computer's operating system in such a way that the mouse-motion data is smoothed, but in all other respects appears to be normal mouse data. This would allow a user to access any program needing mouse input. In general, to do so requires that the filter be incorporated into a device driver program that becomes part of the operating system. Although it is relatively easy to write the code for a filter, it is extremely difficult and demanding to write a device driver.

3 Method

Participants for this pilot study were recruited through the University of Colorado Health Sciences Center. Nine individuals agreed to participate; of these, five were female. Five individuals were retired; two held office jobs, and two were umemployed. All participants were familiar with computer use, eliminating the problem of learning to use a mouse during the trials.

4 Procedures

Initial evaluation: Subjects were first evaluated using a simple program designed by the researchers to estimate the degree of tremor. They were asked to position the mouse cursor in a target area, and the program collected the cursor positions over time and calculated the mean square positional jitter. During this test, the filter was adjusted to provide a starting point for the subsequent measurements. After studying the statistical distribution of the measured tremor, we assigned a tremor category for each subject between 1 and about 5, such that at least 5 or so subjects fell within each category.

The observers used a special program which displayed an array of buttons on the screen. The users were requested to click the buttons either in a predefined order (the buttons were numbered), or in a random and self-selected order, whichever was found in a preliminary test to provide the least stress. The times between successive clicks were recorded. There was a practice session to allow the subject to become familiar with the program, and to adjust the filter to find an optimal setting. The subjects were encouraged to re-adjust the filter during the tests as desired. The test was then repeated with the filter switched off for comparison.

Subjective evaluation: The subjects were asked to fill out a questionnaire both before and after the tests, rating the filter performance and ease of use on a scale of 0 to 5. They were asked if the filter would enable or encourage them to use a computer. We also asked if the subject would actually purchase such an adapter, and at what price. Any relevant voice comments were noted by the observer.

5 Results

Quantitative Analysis. Participant responses to the Tremor Control Mouse Questionnaire were entered and analyzed in the Statistical Package for the Social Sciences (SPSS), version 12. A frequency analysis revealed that eight of the nine participants had experienced onset of ET prior to age 40; three participants reported moderate tremor severity, while two others reported mild and severe tremor severity, respectively; and the average number of hours spent on a computer at work and at home were 7 and 1.2, respectively. Most participants had access to the Internet and e-mail at home, and all but one used a word processor. Only two individuals indicated use of computer entertainment/gaming programs. Two-thirds of the participants used a standard mouse, two used trackballs, and one did not indicate the type of mouse used. All participants claimed that the TCM had helped them and that they believed it would be useful for persons with hand tremors. See Table 1 for descriptive statistics for these variables.

The questionnaire featured four questions pertaining to ease of mouse use and four questions addressing ease of TCM use; participants were asked to indicate whether a variety of tasks (e.g., “ease of double-clicking”) were “very easy”, “somewhat easy”, or “very difficult”. Summary scores were obtained for these two sets of questions. The average score for ease of mouse use was 9 out of a possible 12, while the average score for ease of TCM use was 5.75. As lower scores reflect greater ease of use, these results indicate that, on average, the participants found the TCM to be easier to use than a standard mouse. This difference was found to be statistically significant ($p<.05$) via a paired-samples t-test. Due to the small sample size, there was insufficient power to detect a significant difference, and this result must be interpreted with caution. However, because a lack of sufficient power means that it is more difficult to detect significant group differences when they do exist, the fact that one *was* found is suggestive of a true difference in means between this study’s two groups.

Table 1. Descriptive Statistics for Tremor Control Mouse Trial

Variable	Frequency
Gender	Female = 5 Male = 4
Onset age	0-19 = 4 20-39 = 4 40-59 = 1
Tremor severity	Mild = 1 Moderate = 3 Severe = 1
Number of hours/day on computer at home	.5 hour = 2 1 hour = 1 2 hours = 2
How much do you feel the TCM helped you?	Somewhat = 5 Significantly = 4

Qualitative Analysis. Seven participants provided their opinions on the usefulness of the TCM; these were overwhelmingly positive. Comments included: “It was easier and I felt more confidence”, “Objectively it did better”, “…delay makes it go where you want it”, and “I would buy it right now!” However, one participant felt that the trackball mouse worked better while another stated, “If used to it, I think it would help more.”

Another survey item asked participants to discuss the advantages of the TCM. Most responses related to the device’s enhanced control and stability: “Offers a lot more stability with less frustration”, “Smoother”, “Not as erratic”, and “Possibly more control”. One participant stated, “Higher level of competence – could do things more efficiently”, while another commented, “Less aggravating – one you learn how you could put the arrow where you wanted and. …click”.

A final item addressed possible disadvantages to TCM use. Seven of nine participants cited no disadvantages, although one of these individuals stated, “Just need to learn to use it. Is a little slower – but that’s no big deal – have to anticipate float”. The disadvantages identified by the final two participants were, “Needs to be personally programmable. “Needs to be easily available to set up” and “Felt like it was floating away.”

6 Discussion

The purpose of this study was to determine whether hardware and software versions of a smoothing filter, the Tremor Control Mouse (TCM), could provide short- and/or long-term benefits for individuals who have difficulty using a computer because of ET of the hands. A paired-samples *t*-test revealed significant differences ($p<.05$)

between participants' responses to ease-of-use questions regarding traditional mouse use compared to TCM use. Subjective responses to survey items on TCM advantages, disadvantages, and helpfulness were very positive overall and reflected the participants' belief that the TCM was a useful device in enhancing mouse control and, consequently, computer use.

While this study clearly needs to be replicated with a much larger sample size, the impact and direct responses of our pilot subjects were promising. Most of the subjects have gone on to purchase the device since its commercialization. By conducting the user study in coordination with the development of the Tremor Control Mouse refinements and adaptation of the product design were readily incorporated within the development process leading to a very functional and adoptable design.

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Training the Elderly in the Use of Electronic Devices

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Abstract. Technical devices and software applications with an increasing number of functions are appearing on the market. With an aging population, there is a growing need to consider less experienced users. Integrating training applications in technical devices is a promising approach to close the knowledge gap of these users. But how should a training application be designed? We developed a training program which teaches the use of a mobile phone in a task oriented manner. Training versions were designed which differ in their degree of interactivity: The learner trained either with an improved paper-based manual or with an interactive e-learning application, which integrates guided exercises in the learning process. These training versions are compared experimentally. Preliminary results show that both groups learned successfully to use a mobile phone.

Keywords: older adults, training study, e-learning, interactivity, paper-based manual, mobile phone, training success.

1 Introduction

With an aging population, there is a growing recognition of the need to consider elderly users when designing products. In general, electronic devices such as mobile phones have not been designed with the elderly in mind and are usually difficult to use for them. There are different approaches to improve the matching between technical devices and elderly users.

One approach is to design special products for the elderly. This may appear to be very simple: design devices with a large display and a small selection of big buttons offering some basic functions only. These simple products often seem to be over-accommodated; this occurs when the technical device is too reliant on negative stereotypes of aging [7]. Over-accommodation poses problems such as creation of parallel technologies, growth of the gap in the use of current electronic systems and discrimination of the elderly. Nevertheless, usability of technical systems has to be

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addressed in the design process, because well-designed products support understanding and learning.

Another approach is to bridge the gap and help the elderly to learn how to handle current devices. This approach focuses on the potentials and resources of the elderly and has some benefits. Through adequate training individual resources are activated and deficits are compensated. Elderly users are able to transfer their knowledge and experience to other devices and are independent of specific products.

Our research project aims at assisting the elderly in learning to use electronic devices. But what technology training is appropriate for elderly people with little experience in the use of electronic devices? Taking the example of mobile phones, we investigated how elderly, less-experienced people can be supported in learning to use technical devices.

2 Theoretical Background

Generally, aging is associated with a decline in sensory and motor performance as well as cognitive basic capacities [18]. For instance, Freudenthal [8] found that in comparison to younger adults the elderly perform slower in an information retrieval task which required searching in a hierarchical structure. Moreover, differences between younger and older adults could often be traced back to the generation effect, i.e. elderly users having less experience with technical devices [15]. For example, handling a hierarchical structure relies on knowledge about interaction techniques - such as multiple mapping - that are unfamiliar and confusing to less experienced users. Baldi [1] found no relationship between age and training success after adjusting for trainees' knowledge of technical devices. Furthermore, elderly users differ from younger ones regarding their computer-related self-confidence [13]. Jay and Willis [10] show that the age-related lack of computer-related self-confidence can be modified by direct experience with computers.

Baltes and Baltes [2] postulate that the elderly optimize their performance by extensive practice. There is strong consensus that older adults are able and willing to learn the use of technology [14] [1] [6]. Comparing younger and older novice adults, the elderly take longer to get trained, perform less well after training, and need more help [1] [4] [6]. This decreased performance is correlated with the complexity of the technical device [20]. Computer-related self-efficacy (e.g. expectation of training success) mediates the relation between age and skill acquisition [1] [16]. Therefore, any training application should keep the initial barrier low.

Fisk et al. [6] give some recommendations about how training for elderly users should be designed. The subject matter should be divided into short lessons that motivate through immediate success. There is a favorable effect if lessons and exercises take turns [6] [9]. In contrast to young people who like exploration-based learning, the elderly prefer explicit training [15].

Further hints for designing training for the elderly could be derived from an interview study [3] which we conducted with 20 mobile phone users aged from 58 to 80 years (mean 68). It became clear that a complete step-by-step explanation of required actions is needed. To address the needs of inexperienced users, a chapter providing an easy introduction to basic functions is necessary. This is in line with

Morell et al. [14], who found that simple step-by-step instruction facilitated the elderly's skill acquisition better than expanded instructions. When reading manuals, many elderly users practice every function extensively. In doing so, they prefer task-oriented descriptions augmented by feedback from the display. Additionally, the participants suggested that cartoon illustrations might help, showing the buttons that have to be pushed and the associated changes in the display. In line with Fisk et al. [6] [5], elderly users tend to learn better when the instructions are highly structured, task-oriented and consistently organized.

3 Designing Training Applications

A task-oriented training application was designed which teaches all basic functions of a mobile phone in short lessons. The user interface of a mobile phone was simulated on the computer (Fig. 1). The simulation is as complex as current mobile phones and provides basic functions for several components such as phone book, calling lists and messages (see Fig. 2). The trainees interacted with the simulated mobile phone via a touch screen.

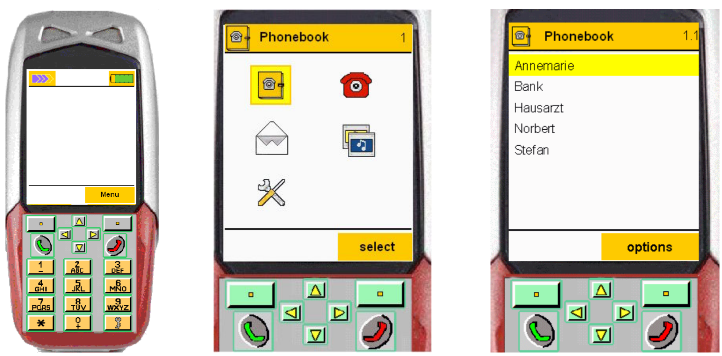

Fig. 1. Screenshots of the simulated mobile phone (menu language translated from German): complete (left), main menu (middle), phone book list (right)

Every lesson starts from the initial display of the mobile phone. The order of the lessons is based on the complexity of the training tasks. Tasks ranged from easy ones, like "dial a number ", to more complex ones, like "add a new number to your telephone list". Complexity is defined as the number of new rules that must be acquired to perform the task successfully. Following Lee et al. [12], a new rule is unique to the current task or is appearing for the first time in the training series. Every lesson has three parts: (1) Introduction to motivate the trainee and explain the goal of the lesson, (2) Step-by-step guided tour from the first display through the task and back and (3) Exercises with which to practice the task.

Two training versions were designed: an interactive e-learning application and a paper-based manual (Fig. 2). Both training versions provide the same content in 27 lessons and are based on the basic approach outlined above. The paper-based manual offers the step-by-step guided tour by text instructions, which are structured into paragraphs with coloured screenshots of the mobile phone. In the case of the interactive training, the step-by-step guided tour is realized by speech. When the trainee presses the correct button, the next step will start. The speech-based training can be fully integrated into a mobile phone.

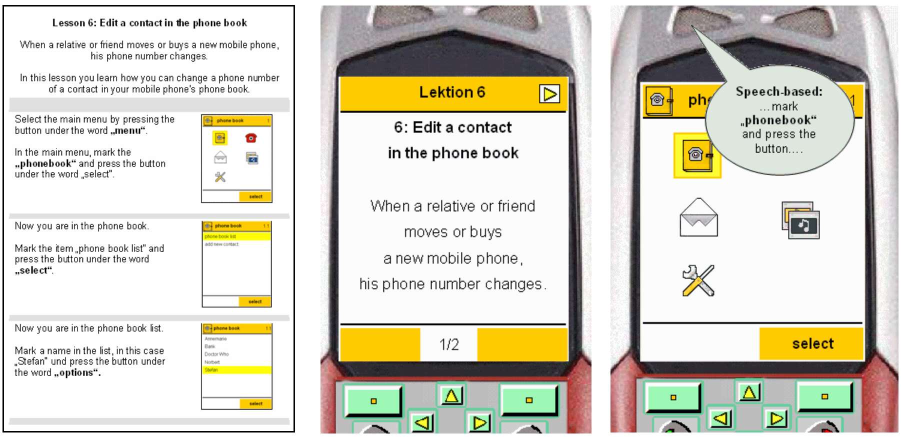

Fig. 2. Compared training versions (menu translated from German): paper-based manual (left) versus interactive e-learning application (middle and right)

Interactive training seems to have some advantages over paper-based training with manuals. Through interactive training the attention is guided to important aspects and the understanding of the link between actions, changes in display, and intended functions is supported. Ritter and Wallach [17] compared two learning environments with different activity demands on learners: an interactive and a non-interactive learning application. They found strong effects of interactivity on training success. Furthermore Morell et al. [14] as well as Kemper and Lacal [7] reported that switching between different tasks or media caused high cognitive effort for elderly users. Switching costs arise if the trainee has to alternate between paper-based manual and technical device. Since interactive training is integrated in the device, switching costs are reduced. Kelley and Charness [11] and Baldi [1] summarized that computer-based learning offers context-based feedback, which has positive effects on learning.

However, training with a manual has advantages, too. Paper offers more space than the small display of a mobile phone, so pictures can be used to visualize action sequences and the trainees can get an overview. Furthermore, paper-based instructions are available over the whole training period and the trainee can make their own notes, which may be helpful. A further advantage is assumed: paper-based training creates cognitive effort, because the trainee has to actively connect instructions and changes in the display. Active learning has positive effects on the mental effort for learning [19]. Finally, elderly people are more familiar with paper-based manuals than e-learning applications.

4 Method

An experiment was conducted to compare the effects of the training versions on the younger elderly and the older elderly.

4.1 Participants

49 individuals (eleven men), aged between 50 and 77 years (mean 65.3 years), participated in the study. Participants had no or little experience with mobile phones. They were recruited by an advertisement for free mobile phone training in a local newspaper.

4.2 Design

Two independent variables were included (Table 1). The first independent variable is the factor “training version” consisting of two treatments (“paper-based manual” and “interactive e-learning application”). Each participant accomplished 27 lessons with one of the two versions. The groups were parallel regarding the participants’ age and experience with mobile phones and other technical devices. Our hypothesis was that the interactive version and the paper-based version would differ in their effects on training success.

The second independent variable was “age” with the “younger elderly” aged between 50 and 65 and the “older elderly” aged between 66 and 80. Our hypothesis was that no differences in training success occur between the age groups.

Table 1. Design

		independent variable “training”	
		interactive	*paper-based*
independent variable “age”	*younger elderly*	X	X
	older elderly	X	X

4.3 Dependent Variables

Several methods were used to measure training success. For performance measurement, subjects had to complete operating tasks of varying difficulty. Indicators were time, number of keystrokes, and use of support. Perceived effort was measured before, during, and at the end of the training (scale from zero to 220). A cloze-test was conducted to measure subjects’ explicit knowledge of the mobile phone. Mental representation of action sequences and hierarchical structure was assessed using a card-sorting technique. Participants had to sort pictures of different states of the trained interface. A score ranging from zero (lack of representation) to twelve (deep representation) was calculated on the basis of the correctly and incorrectly sorted pictures. Additionally, participants completed a questionnaire measuring acceptance and self-efficacy.

4.4 Procedure

The experiment took place on two training days, with a four to seven day gap (see Fig. 3). Each participant was trained in a single session. Each training session lasted from 90 to 150 minutes. First, participants were interviewed about their experience with mobile phones and completed a questionnaire about experience with and attitude towards technical devices. The perceived effort after the interview was used as a baseline. The data about participants' experience with mobile phones and other technical devices were used to assign them to the training versions homogeneously. The participants practiced 14 lessons on the first training day and 13 lessons on the second training day. Performance and a rating of the perceived effort were tested at the end of the first training session (test 1), and at the beginning (test 2) and end of the second session (test 3). Every performance test consisted of eight tasks which differed in the degree of transfer needed to solve the task. After training, subjects completed a questionnaire about their self-efficacy and acceptance of training. At the end of a training session, participants solved the tests about explicit knowledge and mental representation of the trained mobile phone.

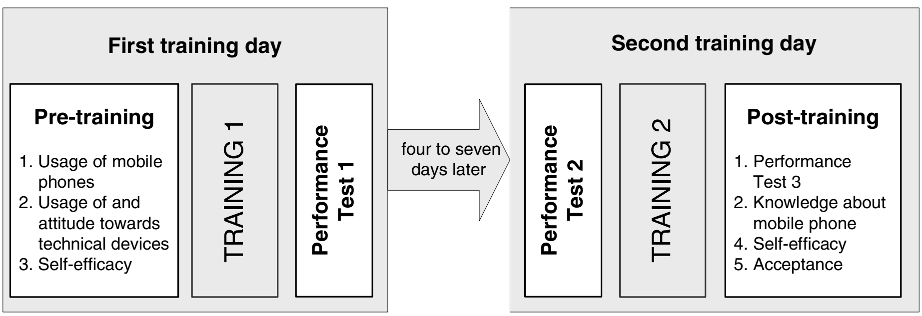

Fig. 3. Procedure and dependent variables of the experiment

5 Results

The subjects of the interactive group trained on average 92.8 minutes and the paper-based group 94.4 minutes. The older elderly needed 97.5 minutes to complete the training, and the younger elderly 89.5 minutes; differences are not significant. At the end of every lesson, exercises were offered to practice the trained functions. Participants of the interactive group practiced on average 6.6 exercises per training, the participants of the paper-based group 8.9; differences are not significant.

Both training groups rated the training as very good and rated their self-efficacy after training as good; differences were not significant. Concerning self-efficacy, significant differences were found between age groups ($Z(1)=-2.81$, $p<.01$); the older elderly rated their self-efficacy as medium and the younger elderly as high.

5.1 Performance

To assess training success, we compared the number of keystrokes, time taken, and use of help in three performance tests (see Fig. 4). The paper-based group as well as the interactive group needed less help after training (test 3) than between training days (test 1 and 2). Concerning the age groups, the younger and the older elderly completed the tasks of test 3 with less help than tasks of test 1 and test 2. Compared to the younger elderly, the older elderly used significantly more help in test 2 ($F(1,47)=4.06$, $p<.05$) which measured the performance four to seven days after the first training day.

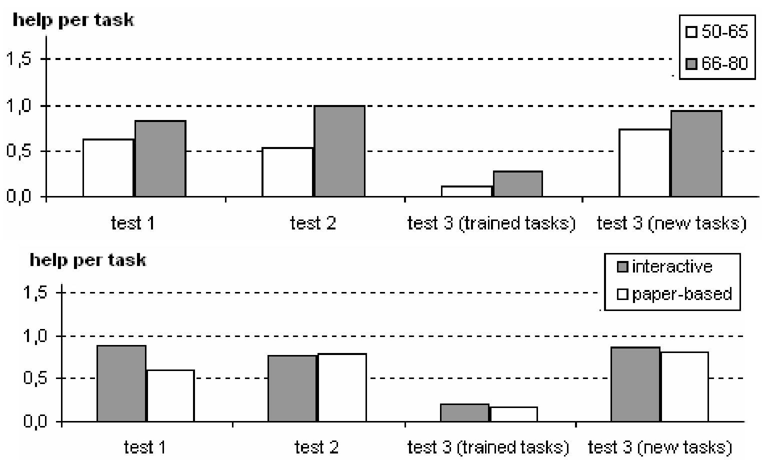

Fig. 4. Number of times help was used per task in the performance tests (test 3 divided into trained and new tasks)

In a second step, tasks of test 3 which were new, were analyzed separately from tasks which were similar to the trained tasks (see Fig. 5): no significant differences were found between groups. For the tasks which are similar to the trained tasks the subjects needed almost no help.

Concerning the number of keystrokes, no significant differences were found between training groups or age groups in the three tests. All participants completed the tasks of test 3 significantly faster ($F(2,46)=9.11$, $p<.001$) and with fewer keystrokes ($F(2,46)=8.73$, $p<.001$) than tasks of test 1 and test 2. Compared with the minimally required number of keystrokes per task, the participants needed eleven keystokes more in test 1 and test 2, but only six keystrokes more in test 3. Concerning time taken, the group of the older elderly took significantly longer to complete the tasks of test 2 ($F(1,47)=5.74$, $p<.05$) than the group of the younger elderly. No significant differences between training groups were found.

5.2 Perceived Effort

Perceived effort was measured after the interview (baseline), after the training sessions, after the performance tests, as well as after the knowledge tests (Fig. 5). The perceived effort after training did not differ significantly between the age groups. The paper-based group rated the effort after test 2 significantly higher than the interactive group (F(1,47)=7.76, p=.01). Generally, the paper-based group tended to perceive more effort before during, and after training.

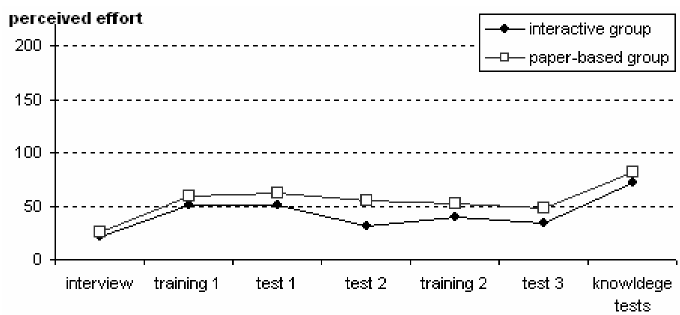

Fig. 5. Rated effort for interactive and paper-based group before, during and after training

5.3 Knowledge Tests

Explicit knowledge, measured by a cloze-test was moderate and did not differ significantly between the training groups. Concerning the age groups, the younger elderly had a significant higher score than the older elderly (F(1,47)=11.73, p<.001). The structural knowledge measured by the card-sorting technique did not differ between age groups or between training groups.

5.4 Correlations

Significant correlations were found between chronological age and the experience with technical devices measured before training (Kendall τ=-.25, p>.05). Structural knowledge is correlated with number of keystrokes (τ=-.44, p>.001) and time taken (τ=-.47, p>.001) in performance test 3. The same applies to explicit knowledge. The knowledge tests are significantly correlated (τ=.42, p>.001).

6 Discussion

Results show no significant differences for training success or self-efficacy after training between the paper-based instructions and the interactive e-learning application. The reason could be that the training versions are based on the same well designed basic concept and the same material. This conclusion is supported through the high acceptance of our mobile phone training. Many participants would like this training application to be integrated in mobile phones.

Furthermore, a ceiling effect can be observed regarding the number of keystrokes and the use of help in the performance test after training. Comparing this to the minimally required number of keystrokes, all subjects trained the usage of the mobile phone very successfully. This could be another reason for the lack of difference between training versions.

Concerning age effects, the older elderly needed more time and help in test 2. This could be a result of memory changes through aging [18]. However, after training, the older elderly used the simulated mobile phone as successfully as the younger elderly. This is in line with the findings of Morell et al. [14], Baldi [1], and Fisk et al. [6] that older adults are able to learn the use of electronic devices. However, the older elderly rated their self-efficacy lower than the younger elderly. This confirms the findings of Marquie et al. [13], who found that older adults underestimate their experience with technical devices.

7 Conclusion

The preliminary results do not prove that an interactive e-learning application is more efficient than training with printed instruction manual. But two findings suggest that the interactive version has some advantages over a paper-based version: participants rated the effort lower and trainees achieved the same training success with fewer exercises. Furthermore, stepwise training as an integrated part of a mobile phone offers some crucial advantages: it is always available, reduces situational constraints, enables users to learn when and where they want, could be an aid against forgetting, and offers training that fits the electronic devices lexically and structurally.

Training should make the learner more competent in the everyday use of a technical device in the medium and long term. Current work investigates the transfer of training success to everyday use. We are conducting a follow-up comparison of our trained groups with mobile phone users who did not participate in our training.

Currently the data regarding the trainees' behavior during training are being analyzed to obtain a deeper understanding of the relationship between learning effects and training versions. Further studies will explore which other aspects of training applications have to be considered in order to improve training for the elderly.

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Comparative Study of Disabled vs. Non-disabled Evaluators in User-Testing: Dyslexia and First Year Students Learning Computer Programming

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Abstract. User-testing is a critical activity in software development. However, eliciting appropriate test-users can be difficult. Recent work showed that (during user-testing of educational software) dyslexic final-year students identified a larger number of subtle (yet significant) issues in more detail than other students. However, final year students were not the target users of the software (designed to teach fundamental programming concepts). This paper presents preliminary results of work replicating the previous study, but with participants from the target user group (first year students). The first year students identified fewer issues and gave less detail than the final year students. The dyslexic students identified more issues in greater detail than the other students. This highlights a distinction between the perceived target user group (first year students) and the actual target user group (students who don't understand programming concepts). Dyslexia may push people deeper into the actual target user group for educational software.

Keywords: User Testing, Software Evaluation, Educational Software, Dyslexia, Learning Computer Programming.

1 Introduction

1.1 User Testing

User testing is a critical activity in the software development lifecycle. All software systems rely upon it to ensure acceptability to users. There are many examples of significant usability issues being identified and hence resolved as a result of appropriate user testing (such as [1]).

However, gaining access to appropriate test-users can be difficult due to time and resource restraints, especially where the target users are highly skilled or qualified (such as physicians, solicitors, or lecturers). Many methods have been developed as substitutes for user testing (such as expert review, and cognitive walkthrough), but they can only reduce the amount of user testing required, they cannot replace it entirely [2]. The value of user testing is especially important in education, where poor software that confuses students can have a potentially life long impact.

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1.2 Disabled Test-Users in Education

Over the last five years software has been developed to animate the changes made by individual lines of program code to variables in memory. This code-memory diagram (CMD) animation software was designed to overcome the difficulties of teaching the fundamentals of computer programming, especially the limitations of oral narratives and white boards. Evaluations suggested that this software increases understanding [3] of students in the second, first, and foundation years of university (the foundation year is an access to Higher Education course intend for mature students who do not have the nominal entry qualifications). There are two parts to the software: a viewer (which is used to display animations to students during lectures and tutorials), and an editor (which is used to create and edit animations).

Recent work [4] showed that during user-testing of this software dyslexic students identified a larger number of subtle (yet significant) issues in more detail than other students, and also significant aspects of the learning and teaching process. It was suggested that these issues were relevant to the wider target user group. The study selected four final year students on the basis of availability and used a standard protocol to ensure that the same process (in particular the same set of questions) was applied consistently to all test-users. First year students were not used as it was thought they would be reluctant to provide constructive criticism of teaching (a phenomenon know as the ‘A’ level effect [5]).

1.3 Target Users

The use of final year students in user-testing for the CMD animation software is questionable, as the software was initially targeted for first year (introduction to programming) students. Also, it has never been used to teach final year students (only second, first, and foundation year). It is intended as an aide to learning structured and object-oriented programming concepts, which should be clearly understood by final year students. Hence, the issues identified by the final year students may be significantly different to those relevant to the target users (first year students).

1.4 Comparison of Dyslexic and Non-dyslexic First Year Students as Evaluators

This paper presents the preliminary results of work that replicates the previous (final year students) study, but with participants selected from the target user group (first year undergraduate degree students). A comparison is made of the feedback given by first-year students during software user testing, which followed the same protocol as the previous study with final year students. The issues identified by dyslexic and non-dyslexic students are compared for both the first year students (in the present study) and the original four final stage students.

2 Method

A request for evaluators was sent (via email) to all students enrolled on a first year introduction to computer programming module delivered by the interviewer/researcher, where the CMD animation software (viewer) was used extensively. No financial (or other) incentive was offered for participation (as this may have biased the students in favour of the software). A total of four students were recruited. All were native English speakers, and had an established working relationship with the interviewer/researcher (via interaction during lectures and tutorials). Two of these students were reported as having dyslexia (referred to throughout this text as students Sd3, and Sd4).

The students were asked to use and evaluate two versions of the CMD Animation Viewer (Vi1 and Vi2) and two versions of the CMD Animation Editor software (Ed1 and Ed2). A single example animation was used for all pieces of software. This animation involved nine fundamental (year 1) computer programming concepts: variable declaration and assignment, array declaration and assignment, local variables, module level variables, a for loop, and a function declaration and call. All of these concepts were explicitly covered in the module attended by the students, which included the use of animation viewer (Vi2) embedded into PowerPoint slides.

The same protocol developed in the previous study was used, to ensure that the same process (in particular the same set of questions) was applied consistently to all participants, and leading questions were avoided. The evaluations were conducted independently one student at a time, outside normal teaching sessions. Participation was voluntary and started with the interviewer briefing the participant.

The students were asked some background questions regarding age, number of years programming experience, and whether they had any registered special needs. Students were invited to 'think-aloud' [1], and interrupt the process to comment on any aspects of the software's impact on their understanding of the computer programming concepts in the example animation, as well as aspects of the software that they felt were good and aspects that could be improved. The four software applications were then demonstrated, and in the case of the editors the student was invited to use the software. After each software application was demonstrated the student was asked to comment.

Audio recordings were made of each session, and transcribed. Recurrent themes were then identified, with particular attention to issues reported by the students regarding difficulties in computer programming learning and teaching, positive characteristics of the software, and criticisms/suggestions for improvement of the software. These themes/issues were emergent from the data (rather than being pre-determined), but were subsequently cross referenced against the themes identified by the four final year students in the previous study (S1, S2, Sd1, Sd2).

2.1 Animation Viewers

Figure 1 shows version 1 of the CMD animation viewer software (Vi1), which was designed as a presentation aid to support narrative explanations of code execution delivered by lecturers to students. As each line is executed a tick appears to its left, and its impact on variables is reflected in the memory diagram (right).

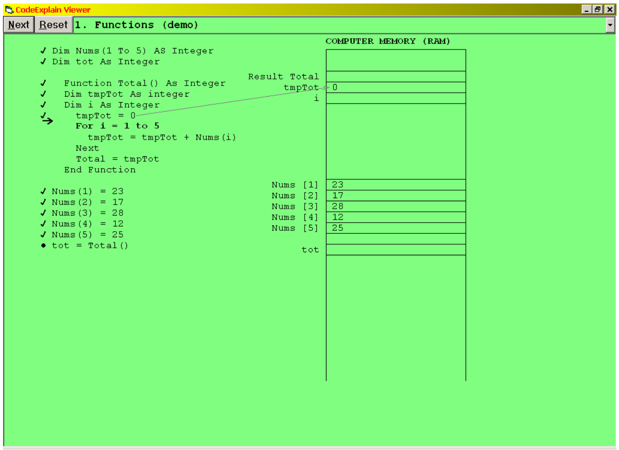

Fig. 1. CMD Animation Viewer software – version 1 (Vi1)

Figure 2 shows version 2 of the CMD animation software viewer (Vi2), which was familiar to the first years students (as it was used in their programming lectures).

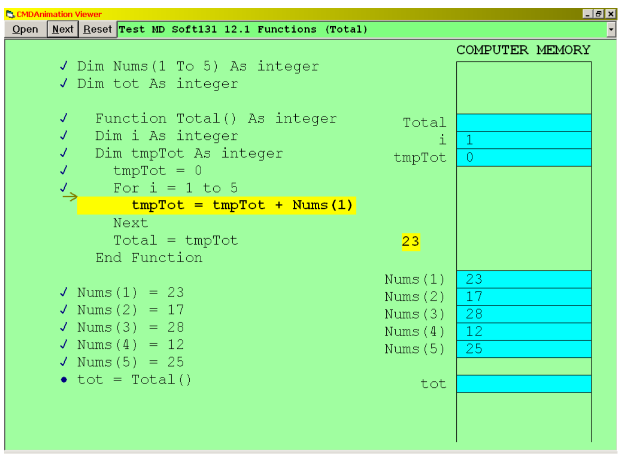

Fig. 2. CMD Animation Viewer software – version 2 (Vi2)

It incorporated additional functionality as a result of suggestions from users (both students and lecturers):

- **Variable font size** – allowed the lecturer to change the size of the font, in order to present the animations as large as possible, while still fitting on the screen.
- **Transitional animation** – animated the processes of:
  - variable creation (where the variable name flew from the line of code which created it to the position in memory which it occupied),

  - variable assignment (where the value of the expression on the right-hand side of an assignment statement flew from the line of code to the variable on the memory diagram, mentioned in the left-hand side of the assignment statement), and
  - variable removal (where as a variable went out of scope, it was removed from the memory diagram by flying from the diagram to the line that caused it to go out of scope).
- **Current line highlighted background** – The current line of program code was highlighted yellow.
- **Variable name-value substitution animation** – The process that replaces the names of variables in expressions with their current values was animated, so that the values moved from their position in the memory diagram to replace the names of their respective variables in the line of code which referred to it.

2.2 Animation Editors

Figure 3 shows version 1 of the CMD animation editor software (Ed1), which was designed to help lecturers create animations and modify animations to meet the specific needs of their student groups. It suffered from significant usability limitations, which made its use in routine teaching impractical (as creating and modifying animations was difficult and time consuming).

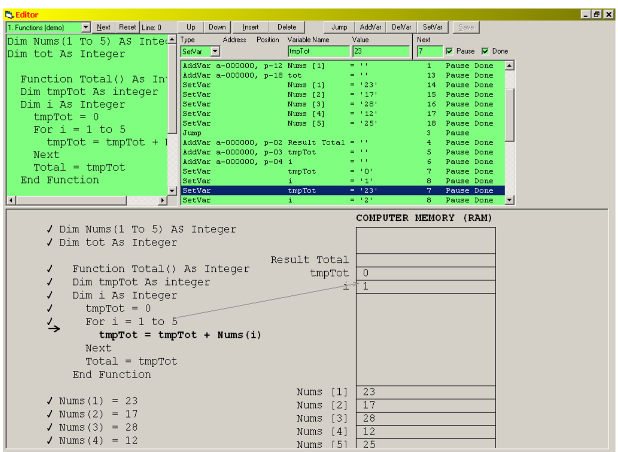

Fig. 3. CMD Animation Editor – version 1 (Ed1)

Figure 4 shows version 2 of the CMD animation editor software, which was developed as a result of limitations with the initial editor (Ed1). This employed a direct-manipulation [6] user-interface to increase usability, and hence make the process of creating animations faster and easier for lecturers. The example animation included all 6 frame types available in this version of the editor: create variable, set variable, remove variable, call, do, and substitute (not available in Vi1 or Ed1).

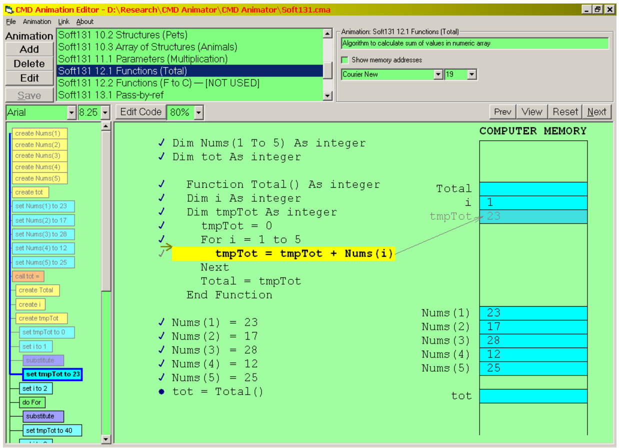

Fig. 4. CMD Animation Editor – version 2 (Ed2)

3 Results

One student (S4) was completely unfamiliar with programming (having come from an art and design background) and as a result had considerable contact with the lecturer. Two students (Sd3, Sd4) had a limited exposure to typing in scripts prior to their enrolment on the current degree course, but had not been taught computer programming formally. Student (Sd4) had very little contact with the lecturer. One student (S3) had withdrawn from a computing degree 10 years earlier.

3.1 Computer Programming Learning and Teaching Difficulties

One of the students (Sd4) described a learning and teaching difficulty. Table 1 shows this along with the data from the previous study (with final year students).

Table 1. Summary of difficulties with the learning and teaching of computer programming, reported by the student evaluators

No.	Difficulty	S1	S2	Sd1	Sd2	S3	S4	Sd3	Sd4
1	Jumping out of sequence in code		✓		✓				✓
2	Keeping track of current position in code			✓	✓				
3	Keeping up with lecturer			✓	✓				
4	Explanations on the white board don't explain things clearly			✓	✓				
5	Lecturer's don't explain variables	✓							
6	Lecturer's assume too much prior knowledge	✓							
7	Lecturer's overlook advanced aspects of programming	✓							
8	Lecturer sets pace for students who understand already		✓						
9	Students don't understand loops from oral narratives		✓						
10	Hard to keep up if pace is too fast			✓					
11	Thinking you've missed something can distract you			✓					
12	Variable name-value substitution is difficult			✓					
13	Difficulty visualising what code does from oral narratives				✓				
14	Object oriented programming is difficult because of jumping				✓				
15	Process of program development is not taught.				✓				
		3	3	6	7	0	0	0	1

The only difficulty described, involved jumping out of sequence in code. Student Sd4 commented that it was 'quite logical to go through the code' line after line, but without the animation software 'jumps' between function call and definition would be difficult to follow [741]. The number in square brackets, indicates which paragraph in the transcript the quote is taken from (i.e. paragraph seven hundred and forty one).

3.2 Software: Positive Characteristics

The first year students described 13 positive characteristics of the four software applications, which were also described by the final year students. Table 2 shows which students reported each positive characteristic, and the total number of positive characteristics reported by each student, including the original final year students (S1, S2, Sd1, and Sd2).

Table 2. Summary of positive characteristics of the four software applications (Vi1, Vi2, Ed1, and Ed2) reported by the student evaluators

No.	Positive Characteristic	S1	S2	Sd1	Sd2	S3	S4	Sd3	Sd4
1	V1: Visual element	✓	✓	✓	✓		✓	✓	✓
2	V1: Step-by-step explanation	✓	✓		✓	✓			✓
3	V1: Ticks		✓	✓	✓		✓		✓
4	V1: Contents of variables	✓							
5	V2: Yellow Highlight of Current Line	✓	✓	✓	✓	✓		✓	✓
6	V2: Transitional Animation		✓		✓	✓	✓	✓	✓
7	V2: easier to see where you are	✓		✓			✓		
8	V2: easier to keep up/catch up			✓	✓		✓		
9	V2: Substitution			✓	✓				
10	V2: Larger Font			✓	✓			✓	
11	V2: Actually doing			✓			✓	✓	✓
12	V2: Predict what happens next			✓					
13	V2: Arrows			✓					
14	V2: Memory Variable Background				✓			✓	
15	V2: Previous perception of Substitution				✓				
16	E2: Drag and drop	✓	✓	✓					
17	E2: Font Size			✓	✓				✓
18	E2: Help lecturer's understanding of students	✓	✓						
19	E2: Colour coded			✓		✓			✓
20	E2: Font used to shrink down, for large animations			✓					
21	E2: Immediate visual feedback			✓			✓	✓	✓
22	E2: Save button				✓				
23	E2: Slows delivery				✓				
	Overall Total	**7**	**7**	**15**	**13**	**4**	**7**	**7**	**9**

The following examples are representative of the type of comments made by the four first year students:

- **Yellow Highlight of Current Line:** Three of the first year students (S3, Sd3, and Sd4) commented on the yellow highlighting of the current line in version 2 of the viewer. In particular, student Sd4 indicated that it helped address the difficulty associated with the execution point jumping in function calls – 'the highlight took [animated] it up' to the function definition whereas the 'old one … just went [jumped]' straight up to the definition [777].
- **Transitional Animation:** All four first year students commented on the transitional animation. Student S4 said 'I like the fact that … the numbers physically move across the page' [286]. Student Sd4 commented that 'the [transitional] animation leads to different things … you can see where you're going with each bit of code' [775].

3.3 Software: Negative Characteristics and Suggestions for Improvement

The students described 7 negative characteristics/suggestions for improvement of the four software applications. Three of these were not mentioned in the previous (final year student) study. Table 3 shows which students reported each characteristic/ suggestion, and the total number of characteristics/suggestions reported by each student. The students with dyslexia (Sd3, and Sd4) described 2 and 6 characteristics respectively, and student (S3) described 1 characteristic.

Table 3. Summary of negative characteristics and suggestions for improvement of the four software applications (Vi1, Vi2, Ed1, and Ed2) reported by the student evaluators

No.	Negative Characteristic	S1	S2	Sd1	Sd2	S3	S4	Sd3	Sd4
1	V1: Colour Coded (Java)	✓						✓	✓
2	V2: Background colour			✓	✓				
3	V2: Arrows startling			✓					
4	V2: Colour Blindness (disability specific)			✓					
5	V2: Speed up later iterations			✓					
6	V2: Substitution confusing				✓				
7	E1: Text box too small			✓	✓				
8	E1: Buttons' Tooltips	✓							✓
9	E1: Instruction labels	✓							
10	E1: Buttons very small			✓					
11	E1: Edit boxes small			✓					
12	E1: Initially time consuming			✓					
13	E1: Prone to typing error			✓					
14	E1: Text repeated confusing			✓					
15	E1: Writing different sizes			✓					
16	E1: Data entry labels				✓			✓	✓
17	E1: Hard to follow				✓				
18	E2: Need easy Array Creation		✓	✓	✓				✓
19	E2: User training	✓		✓					
20	E2: Narratives - pop-up	✓			✓				
21	E2: Graphics on buttons	✓							
22	E2: Drag frame pane			✓					
23	E2: Font Sizes inconsistent			✓					
24	E2: Frames diagram small			✓					
25	E2: Instruction Dialogue box font			✓					
26	E2: Position of frame buttons				✓				
27	E2: Easy access to properties (lost from E1)				✓				
28	E1: New Instruction Position								✓
29	E1: Initial jump instruction confusing								✓
30	E2: No buttons, difficult to learn (lost from E1)					✓			
	Overall Total	6	1	17	9	1	0	2	6

The following examples are representative of the comments made by the students:

- **Easy array creation:** While creating the frames for animating the declaration of an array, student Sd4 asked if there was 'a way of replicating your last moves' [973], and that if there were it would save 'having to go back and forth' between the code and the memory diagram [979].

3.4 Subtle Significant Issues

Table 4 shows a summary of which students reported issues regarded by the developer as both subtle (surprising to the developer, and not considered prior to feedback from others) and significant (relevant to the general student population and would directly influence future software design and/or teaching practice).

Table 4. Summary of issues regarded by developer as both subtle and significant to the general student population, with indication of which students reported them

	No.	Positive Characteristic	S1	S2	Sd1	Sd2	S3	S4	Sd3	Sd4
Difficulties	1	Jumping out of sequence in code		✓		✓				✓
	2	Keeping track of current position in code			✓	✓				
	14	Object oriented programming is difficult because of jumping				✓				
Positive Characteristics	5	Vi2: Yellow Highlight of Current Line	✓	✓	✓	✓	✓		✓	✓
	6	Vi2: Transitional Animation		✓		✓	✓	✓	✓	✓
	7	Vi2: easier to see where	✓		✓			✓		
	8	Vi2: easier to keep up			✓	✓		✓		
	9	Vi2: Substitution			✓	✓				
	10	Vi2: Larger Font			✓	✓			✓	
	15	Vi2: Changed perception of substitution				✓				
	18	Ed2: Help lecturer's understanding of students	✓	✓						
Negative Characteristics	6	Vi2: Substitution confusing				✓				
	18	Ed2: Easy Array Creation		✓	✓	✓				✓
	22	Ed2: Drag frame pane			✓					
	27	Ed2: Easy access to properties (lost from e1)				✓				
	28	E1: New Instruction Position								✓
	29	E1: Initial jump instruction confusing								✓
	30	E2: No buttons, difficult to learn (lost from E1)					✓			
Total			**3**	**5**	**8**	**12**	**3**	**3**	**3**	**6**

4 Conclusions

4.1 Comparison of Year Groups

Overall the first year students identified fewer issues and described them in less detail than the final year students. This suggests that first year students may be reluctant to provide constructive criticism of teaching methods and tools, and that the original strategy of using final year rather than first year students was appropriate.

It is possible that the viewer software (V2) was so heavily embedded in the first year students' learning experience, that it had become tacit, which reduced their ability to criticise it (although they were unfamiliar with V1, E1, or E2). It may be that the use of the software prevented these students from experiencing many of the usual difficulties associated with learning computer programming (it worked as intended), and this made it difficult for them to articulate or be aware of these issues.

Also, final year students tend (one would hope) to be more confident, articulate, have stronger critical reasoning skills, and be more familiar with computing concepts.

4.2 Comparison of Dyslexic vs. Non-dyslexic Groups

Overall, the dyslexic students identified more issues in a greater amount of detail than the other students. However, the difference was far less distinct than with the final year students. Again, the use of the software in normal teaching may have reduced their exposure to difficulties, which they are usually more sensitive to than other students. Also, there was a marked difference between the two dyslexic students; student Sd3 behaved equivalently to the two non-dyslexic students, but student Sd4 showed a considerable difference (similar to the two dyslexic final year students). This is especially interesting as student Sd4 was the youngest evaluator, and had the least established working relationship with the lecturer (infrequent tutorial contact).

4.3 Perceived vs. Actual Target User Group

This study has highlighted a distinction between the perceived target user group (first year students) and the actual target user group (students who don't understand programming concepts). Hence, actual target user groups for educational software may be more usefully defined in terms of their (lack of) understanding of certain concepts, rather than their age or organisational grouping (class, year group, degree programme). In practice this is very difficult to achieve, requiring extensive summative assessment. A final year student who has struggled and only just grasped certain concepts, may be a more effective evaluator of educational software than a first year who has been exposed to the concepts for several years.

The first year students all indicated that they found the animation software useful during the normal teaching sessions, and that they understood the fundamental programming concepts covered by the sample animation. A perception supported by their grades (61% average for 4 students). This effectively pushes them outside the actual target user group (students who don't understand programming concepts).

It is widely accepted that the presence of dyslexia in a student who is learning computer programming makes the experience more difficult. Also, the symptoms of dyslexia are often described as being common problems for everyone, that are experienced to a much greater degree in some people (dyslexics).

A possible explanation for the results of the present work is that this additional difficulty makes the dyslexic person more aware of the learning and teaching process, especially the problems. They have to consciously consider issues that other students deal with instinctively, and these experiences therefore remain memorable for much longer. In effect, the dyslexia may push people deeper into the actual target user group (people who don't understand) for educational software.

Many avenues of further work remain unexplored. It would be interesting (but very difficult) to use the same protocol on students who fail or have withdrawn from the degree programme due to difficulties understanding computer programming. In theory they should be at the centre of the actual target user group and may provide the most insightful comments.

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GSLC: Creation and Annotation of a Greek Sign Language Corpus for HCI

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Abstract. In the framework of a research target that aims at integration of sign language technologies to human-computer interaction applications, creation and annotation of the Greek Sign Language Corpus (GSLC) involve, on the one hand, data and analysis of the phonological structure of morphemes of Greek Sign Language (GSL) and, on the other hand, collection of sentence level language samples and assignment of their respective annotations. GSLC also entails free sign narrations fully annotated at least for sentence segmentation. Simple and complex sign morpheme formation is directly relevant to development of sign recognition prototypes. In this sense, a sign language corpus intended to support sign recognition by exploitation of a language model has to entail sufficient data from simple- to complex- morpheme level. Sentence level annotation, except for sentence boundaries, focuses on phrase boundary marking and grammar information often conveyed by multi-layer markers, as is the case of e.g. topicalisation, nominal phrase formation, temporal indicators, question formation and sentential negation in GSL.

Keywords: sign language corpus, GSL, annotation, sign recognition, human-computer interaction.

1 Introduction

The existence of an annotated corpus is a prerequisite for the creation of vast linguistic resources and for the development of Natural Language Processing (NLP) applications in any natural language articulated either orally or through signing. In the case of a sign language, corpus annotation has to be performed on video sequences, since sign language utterances are expressed 3-dimensionally exploiting various combinations of spatial-temporal parameters around the signer's body. The Greek Sign Language (GSL) has developed as a minority non-written language system -in a socio-linguistic environment similar to those holding for most other known sign languages- used as the mother language of the Greek deaf community.

Video recordings of GSL have been produced for various reasons but, the development of the Greek Sign Language Corpus (GSLC) is the first systematic attempt to create a re-usable electronic language corpus organised and annotated according to principles deriving from requirements put by specific application demands [12]. Exploitation of corpus resources, in our case, has to support theoretical linguistic research as well as the extraction of a linguistic model to assist a sign

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language recognition system. The GSLC is being developed in the framework of the national project DIANOEMA (GSRT, M3.3, id 35) that aims at optical analysis and recognition of both static and dynamic signs, incorporating a GSL linguistic model for controlling robot motion. Linguistic analysis is a sufficient component for the development of NLP tools that, in the case of sign languages, support deaf accessibility to IT content and services. To effectively support this kind of language intensive operations, linguistic analysis has to derive from safe language data -defined as data commonly accepted by a specific language community- and also provide for an amount of linguistic phenomena, which allow for an adequate description of the language structure.

2 Creation of a Greek Sign Language Corpus

2.1 Language Corpus Definition

Current development of electronic corpora is connected with the «explosion» of Internet use for the exchange of either mono-lingual or multi-lingual information [12]. A definition of corpus provided by Sinclair [14] in the framework of the EAGLES (http://www.ilc.cnr.it/EAGLES) project, runs as follows: "*A corpus is a collection of pieces of language that are selected and ordered according to explicit linguistic criteria in order to be used as a sample of the language*". Furthermore, the definition of computer corpus in the same document crucially states that: "*A computer corpus is a corpus which is encoded in a standardised and homogenous way for open-ended retrieval tasks…*".

Here we will use the term corpus as always referring to an electronic collection of pieces of language, also adopting the classification by Atkins et al. in [1], which differentiates corpus from a generic library of electronic texts as a well defined subset that is designed following specific requirements to serve specific purposes. Among the most prominent purposes for which oral language (written) electronic corpora are created, lies the demand for knowledge management either in the form of information retrieval or in the form of automatic categorisation and text dispatching according to thematic category. Electronic corpora differentiate as to intended use and the design requirements that they fulfill.

2.2 GSLC Content Requirements

The design of GSLC content has been led by the demand to support sign language recognition as well as theoretical linguistic analysis. In this respect, its content organisation makes a distinction between three parts on the basis of the utterance categories to be covered.

The first part comprises a list of lemmata which are representative of the use of handshapes as a primary sign formation component. This part of the corpus is developed on the basis of measurements of handshape frequency of use in sign morpheme formation, but it has also taken into account the complete set of sign formation parameters. In this sense, in order to provide data for all sign articulation features of GSL, the corpus also includes characteristic lemmata with respect to all manual and non-manual features of the language.

The second part of GSLC is composed of sets of controlled utterances, which form paradigms capable to expose the mechanisms GSL uses to express specific core grammar phenomena. The grammar coverage that corresponds to this part of the corpus is representative enough to allow for a formal description of the main structural-semantic mechanisms of the language.

Finally, the third part of GSLC contains free narration sequences, which are intended to provide data of spontaneous language production, that may support theoretical linguistic analysis of the language and can also be used for machine learning purposes as regards sign recognition. With respect to data collection, all parts of the corpus have been performed by native signers under controlled conditions that guarantee absence of language interference from the part of the spoken language of the signers' environment. Finally, quality control mechanisms have been applied to ensure data integrity.

2.3 Selection of Representative Morphemes

The initial target of sign recognition imposed the demand for the collection of lists containing representative lemmata, capable to exhibit the articulation mechanisms of the language. These lists may provide a reliable test bed for initial recognition of single articulation units. Lemmata lists comprising the first part of the GSLC involve two categories, (i) commands related to robot motion control and (ii) simple and complex sign morphemes, representative of the basic vocabulary of GSL. Morpheme selection was based on the minimum requirement of handshape frequency of occurrence, that imposed use of at least the 15 most frequent handshapes, which are responsible for the formation of a 77% of the whole amount of lemmata met in the environment of primary school education (unpublished measurement, V. Kourbetis: personal communication). Both categories contained simple and complex signs, taking into account the use of either one, or two hand formations. Except for handshapes, all other articulation parameters have been taken into account in lemma content design. These parameters include the sets of manual and non-manual features of sign formation and involve location, palm orientation, movement of the hand as well as facial expressions and head and body movement [15].

Internal organisation of lemmata lists includes categorisation according to motion commands, location indicators, number formation, finger spelling, temporal indicators, various word families, GSL specific complex sign roots and the standard signing predicate categories.

2.4 Controlled Grammar Phenomena

The video-corpus contains parts of free signing narration, as well as a considerable amount of grouped signed phrases and sentence level utterances, reflecting those grammar phenomena of GSL that are representative for the structural organisation of the language. Theoretical linguistic analysis of such data allows for extraction of safe assumptions as regards the rule system of the language and also provides a safe ground for the use of phrase level annotation symbols.

When structuring the phenomena list that are represented by controlled sentence groups in the video-corpus, a number of GSL specific linguistic parameters were taken into account, with the target to capture the main multi-layer articulatory mechanisms the language uses to produce phrase/sentence level linguistic messages, along with distribution within utterances of a significant number of semantic markers for the expression of quantity, quality and schema related characteristics. The two parts of the video-corpus (free narration and controlled sentences per grammar phenomenon) function complementarily as regards the target of rule extraction for annotation purposes and machine learning for sign recognition.

The phenomena for which GSLC provides extensive paradigms [4] include the GSL tense system with emphasis on major temporal differentiations as regards present, past and future actions in combination with various aspectual parameters, multi-layer mechanisms of phrase enrichment for the expression of various adverbial values in phrase or sentence level, the use of classifiers, affirmation with all types of GSL predicates, formations of negation, WH- and Yes/No question formation, various control phenomena and referential index assignment.

Previous studies of GSL data have raised a number of still open major linguistic research issues, which are deliberately reflected in the content design and data collection procedure of the controlled part of GSLC. As regards, for example, constituent order of the sign sentence, it has been argued that GSL allows for two options. The one provides strings of the form [Agent-Predicate-Complement], whereas the other results in [Agent-Complement-Predicate] formations. In order to receive unbiased data, a strict procedural rule was to avoid any hint to natural signers as to preference in respect to sentence constituents ordering. In cases of deviation from neutral formations as when expressing emphasis, instructions to informants focused on the semantic dimension of the tested sentence constituent, rather than on possible structural arrangements of the relevant utterances.

Furthermore, with the general aim to eliminate external destructions (such as environment language interference), the use of written Greek was excluded from communication with the natural signers.

2.5 Video-Corpus Recording and Quality Control

In order to ensure prosodic and expressive multiplicity, it has been decided to use at least 4 signers for the production of GSLC in all three parts of the corpus content. The selection of natural signers has been based on theoretical linguistics criteria related to mother language acquisition conditions. Mother language acquisition is completed with the 10th year of age, approximately parallel to completion of development of the language centers in human brain [17], [11]. Signers chosen to participate in GSLC production should, hence, be deaf or bilingual hearing natural GSL signers, raised in an environment of deaf natural signers. This selection criterion strictly excludes the use of deaf signers that are not natural GSL signers, in order to ensure the highest degree of linguistic integrity of the data, and, at the same time, eliminate –if not completely make vanish of– the language interference effects from Greek to GSL throughout the development of the video-corpus.

Upon completion of the GSLC video recording (currently covering 18 hours of pure signing data to be annotated), uninformal quality control procedures have been followed targeting at high degrees of acceptance of the video-recorded signing material. Each part of the video-corpus had to be evaluated by natural signers, on the basis of peer review, with respect to intelligibility of the linguistic message. In case a video segment was judged poorly, the segment had to be re-collected and re-evaluated, hence, ensuring that only highly judged video segments are included in the GSLC.

3 GSL Corpus Annotation

3.1 General Aspects

The definition of annotation features assigned to a given signing string, reflects the extent of the desired description of grammatical characteristics allotted to the 3-dimensional representation of the linguistic message. The complexity of sign language message -especially as regards the use of space and time- in combination with the lack of a writing system, pose the demand for devising special annotation mechanisms, which heavily differ from the ones used for the annotation of oral languages. Nevertheless, the extensive use of grammatical descriptive models, necessary for the description of the sign message, is still lacking in the available general purpose tools that serve description of multimodal data.

Technological limitations regarding annotation tools often impeded the use of data synchronised with video. The situation has slowly started to change as, at an experimental level, open tools have been started to develop to suit the needs of sign language annotation. Research projects, as the European ECHO (http://www.nmis.isti.cnr.it/echo) (2000-2004) and the American SignStream (http://www.bu.edu/asllrp/SignStream/) of the National Center for Sign Language and Gestures Resources (Boston University, 1999-2002) [13] produced video-corpora that complied to a common set of requirements and conventions. Tools such as the iLex [8] attempt to solve issues related to convention integrity of data, arising from the lack of a writing system which follows orthographic rules. In the same context, the Nijmegen Metadata Workshop 2003 [3] proposed a common set of metadata for use by sign language video-corpora.

3.2 Selection of Annotation Features

Decisions regarding definition of the annotation feature set and related conventions have been driven by well established previous work of the sign language research community and the need to produce re-usable corpus resources.

Basic annotation fields involve glosses for Greek and English, phrase and sentence boundaries, dominant and non-dominant hand information, eye-gaze, head and body movement and facial expression information, as well as grammar information such as tags on signs and grammar phenomenon description to facilitate data retrieval for linguistic analysis.

3.3 Morpheme Level Annotation

Starting from the need for theoretical linguistic analysis of minimal grammatically meaningful sign units, as well as the description of articulation synthesis of basic signs, the term sign morpheme has been adopted to indicate the level of grammatical analysis of all simple sign lemmata. For the annotation of the video-corpus at the morpheme level, the basic phonological components of sign articulation, for both manual and non-manual features, have been marked on a set of representative simple morphemes and complex signs. For the representation of the phonological characteristics of the basic morphemes the HamNoSys (Hamburg Sign Language Notation System, http://www.sign-lang.uni-hamburg.de/projects/HamNoSys.html) annotation system is used [16].

The characteristics of sign articulation are (sometimes dramatically) modified when moving from lemma list signing to phrase construction, where prosodic parameters and various grammar/agreement markers (i.e. two-hands plural) impose rendering of lemma formation, subject to phrase articulation conditions. Hence, recognition systems have to be taught to correctly identify the semantics of lemmata incorporated in phrase formations. Furthermore, accurate morpheme level annotations serve sign synthesis systems that have to produce utterances with the highest possible level of naturalness.

3.4 Phrase and Sentence Level Annotation

Fully aligned with the phenomena list composing the controlled sentence groups of GSLC content, phrase level annotation focuses on coding the basic mechanisms of multi-layer articulation of the sign linguistic message and distribution of the most important semantic markers for the indication of qualitative, quantitative and schematic values. Both multi-layer articulation and semantic deixis are major characteristics of sign phrase articulation, whereas in the context of free narration, one major demand is the correct assignment of phrase boundaries.

Some of the most representative phrase level phenomena of GSL concern multi-layer articulation over one temporal unit that results in modification of the basic components of the sign phrase [4]. In the context of a nominal phrase, this is related to i.e. adjectival modification. The same holds for the articulation of predicative and nominal formations, which incorporate classifiers, or when providing tense indicators. A different type of phrasal annotation is adopted to indicate topicalisation of a phrase, irrespective of its grammatical category.

Sentence level annotation aims at providing for reliable extraction of sentence level structure rules, incorporating basic multi-layer prosodic articulation mechanisms, question formation and scope of quantification and negation.

For the safe use of GSLC, a subset of sentences, which are representative for all phenomena contained in the corpus, have been manually annotated. In free narration parts, sign utterance boundaries are manually marked according to generally accepted temporal criteria (segmentation boundary is set at the frame where the handshape changes from the last morpheme of the current signing string to the first morpheme of the next) and according to annotators' language feeling.

The ELAN Annotation System. The chosen annotation system is ELAN (Eudico[1] Linguistic Annotator) [5] the key characteristics of which are in a nutshell summarised

[1] Acronym "Eudico" accounts for the "European Distributed Corpus" project. The ELAN annotator has been developed at the Max Planck Institute for Psycholinguistics, Nijmegen,, the Netherlands (http://www.mpi.nl).

next. ELAN (version 2.6) is an annotation tool that allows creation, editing, visualisation and retrieval of annotations for video and audio data, aiming at providing a sound technological basis for the annotation and exploitation of multi-media recordings. ELAN is specifically designed for the analysis of language, sign language, and gesture, but it can be used by everybody who works with media corpora, i.e., with video and/or audio data, for purposes of annotation, analysis and documentation. ELAN is similar to SignStream but has certain advantages over it. It is written in the Java programming language, hence running on Windows, Macintosh and Linux computers, uses a variety of different video file formats, can annotate long texts (over an hour in length), can incorporate audio as well as video data, which can be useful for studies of contact signing, and can use up to four videos (from different cameras) of the same event. ELAN also allows annotations in Unicode, which means that annotations can be made in a wide variety of languages.

In the figures that follow, indicative instantiation examples of the GSLC annotation are depicted, with focus placed on capabilities of annotation marking on different tiers (Fig.1) as well as retrieval mechanisms in annotated signing utterances (Fig.2).

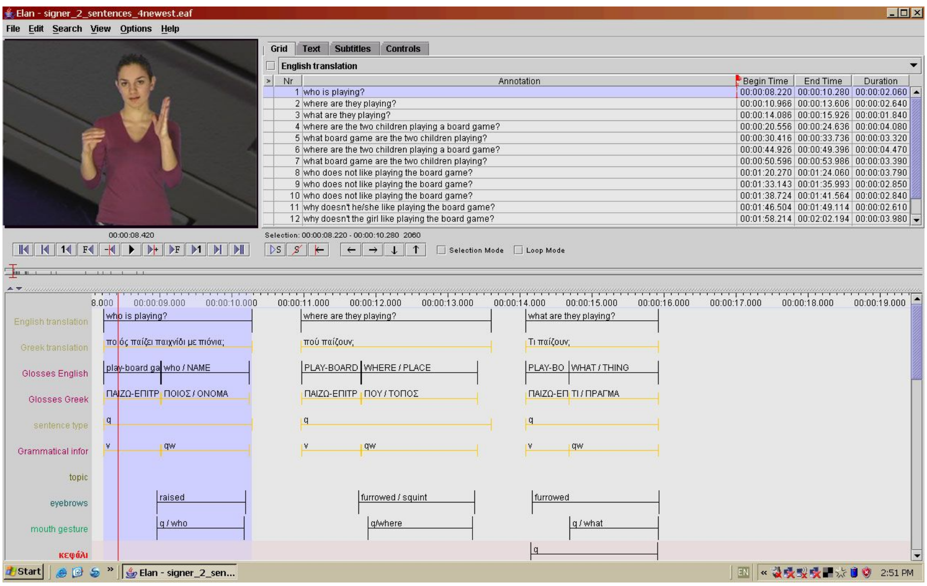

Fig. 1. The ELAN environment – multiple tiers annotation within a signing utterance boundary

3.5 Annotation Quality Control

Assignment of annotations to GSLC involves two expert GSL annotators with expertise in sign language linguistics and sign language technological issues. Both annotators are expected to annotate until the end of 2007 the majority of the controlled video-corpus consisting of representative GSL grammar phenomena (up to

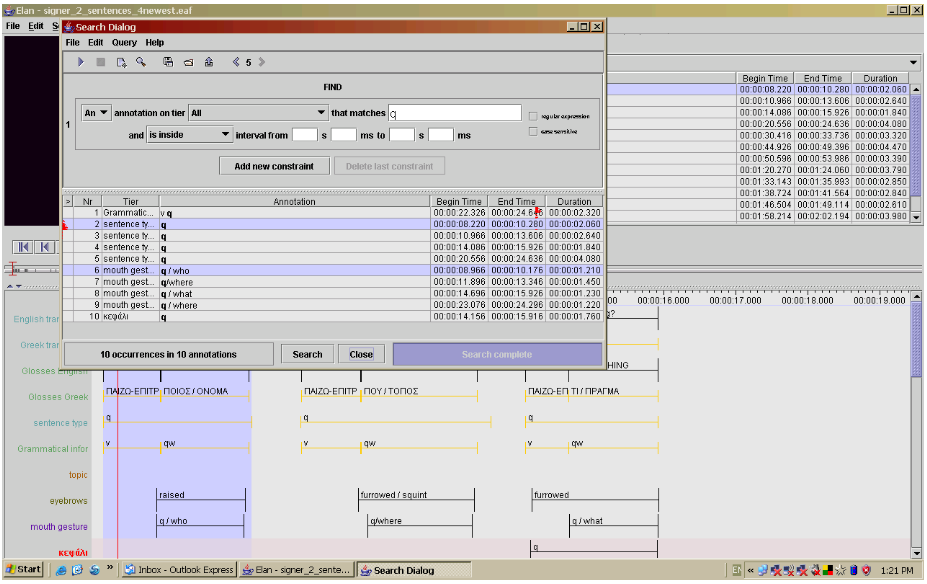

Fig. 2. The ELAN environment – retrieval mechanism

80%), while the part of free narration sequences will be annotated in full (100%) by each annotator, in order to allow for cross-linguistic analysis among the other research targets.

Annotation quality control is based on peer-review with annotation control on sample video-corpus parts, on a mutual basis by the expert annotators.

Upon completion of annotation marking, each annotator will evaluate at least 30% of the annotated by the other annotator part of the corpus. Additionally, one external GSL expert annotator will execute peer sample quality control on a part of at least 30% of the whole annotated video-corpus.

The parts of the annotated video-corpus for which conflicting evaluation reports will be provided, will be discussed among the three evaluators resulting in a commonly approved annotation string that will be finally taken into account.

4 Sign Language Corpus Exploitation – Concluding Remarks

The development of solutions to support accessibility by the Deaf to products and services of the Information Society requires maturing of technologies capable to address crucial aspects of communication and information exchange between the Deaf and/or between deaf and hearing individuals in the context of Human Computer Interaction. Sign Recognition and Sign Synthesis are leading technologies for these purposes, both requiring adequate sign language data and support by NLP based operations, in order to perform satisfactorily.

Sign recognition basically exploits knowledge and techniques from the domains of image and video processing and computer vision supported by natural language resources and NLP methodologies [2], [10]. Sign synthesis exploits virtual agent (avatar) technologies with the aim to produce dynamic signing utterances on the basis of knowledge provided through appropriately coded lexical and grammar resources of sign languages [6],[7],[9].

A properly annotated sign language corpus may be directly exploited in sign recognition systems and also serve creation of adequate language resources such as lexical databases and electronic grammars. The latter feed sign synthesis machines and also conversion tools from spoken to sign language. The current state-of-the-art on technological advances and the open scientific issues related to sign language technologies have brought about the significance of annotated corpora for decoding sign language message. GSLC design and implementation have equally focused on sign recognition support and on the extraction of a linguistic model for GSL. GSLC extensibility is intrinsically foreseen as regards both content and adopted annotation features, thus, allowing for corpus re-usability in linguistic research and HCI applications.

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Impact of Sign Language Movie and Text Layout on the Readout Time

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Abstract. In an emergency such as an earthquake, it is important to give information in different formats that permit everyone to realize rapid assimilation. In public spaces, information is presented to the hearing impaired in text as well as sign language movies. In this case, it is considered that the readout time and impression of the information depend on the layout of sign language movies and text used. However, there are no comprehensive guidelines on the proper layout of sign language movies and text. This paper focuses on optimizing the layout of text and sign language movies to decrease the readout time of the hearing impaired and the normal hearing. Tests show that the optimal spatial separation between the text and its accompanying sign language movie depends on their relative position. They also indicate that the readout time depends on the separation between the line head of text and the center line of the translator in the sign language movie.

Keywords: Public Space, Sign Language, Layout, Emergency message.

1 Introduction

In emergencies such as an earthquake, it is important for people to get information they need to deal with the emergency as soon as possible. Therefore, it is necessary to display information in the form the people can acquire easily and quickly. Also, these days, people's awareness of information displays that cater for the widest range of abilities has been rising. Especially in public spaces, text and sign language displays are being increasingly used side by side.

If we set the text and sign language movie too close together, it is possible that both will become hard to assimilate; that is, it may take more time to assimilate the message due to the collision of the disparate visual modalities. We must be carefully, however, not to separate the text and sign language movie by too much distance because this would decrease the size at which the movie and text could be displayed, and take more time for hearing impaired people to look from text to sign language movie. This suggests that when displaying emergency information by using text and sign language displays in public spaces, we need to determine that optimal separation. Unfortunately, no guidelines directly address this issue.

In this study, we assume emergencies in public spaces, and focus on optimizing the layout of text and sign language to provide the hearing impaired and the normal

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hearing with more rapid assimilation. In this paper, we use the example of trains as the public space. This is for the following two reasons;

1. Almost all subjects can imagine the scene, because many users take trains frequently, and most people have experienced emergencies, such as delay and suspension.
2. The chance of emergency information being displayed will increase, because more trains are being equipped with these displays.

Tests show that we have to vary the spatial separation between text and its accompanying sign language movie according to their relative position. Tests also suggest the readout time depends on the separation between the line head of text and the center line of the translator in the sign language movie.

2 Previous Studies

The assimilation of textual signs has been studied for a long time. The viewing area in which vision is effective is called the "effective visual field". Ikeda et al. measured the effective visual fields of Japanese reading sentences written in Japanese [1]. They showed that the effective visual field is about 10[deg]. Osaka studied the difference in eye movements when reading easy and difficult sentences, and between English and Japanese sentences; the subjects were Japanese students [2]. The results show that there are significant differences between languages but not between the different levels of difficulty.

The impact of the display style of sign language movies on message understanding has been studied. Kamata et al. conducted an experiment on sign language communication using an ISDN64kb/s TV telephone system [3]. They showed that the refresh rate of the movie has a larger influence on message understanding than display resolution. Kamata el al. showed that both display resolution and refresh rate influence message understanding but to different extents according to the image quality [4]. Shionome et al. studied the relation between display size and the take up of sign language messages [5]. They investigated the understanding and readability of sign language messages displayed using 1[inch] to 6[inch] size screens. The results show that 1 and 2[inch] screens yielded much lower take up rates than the other sizes. Screens less than 3[inch] had different levels of understanding and readability from those more than 3[inch].

No study has, however, fully examined the relation between the take up time and the layout of a display that places a sign language movie and text on the same “page”. Miyamoto et al. investigated the differences in the number of stationary gazes and eye scan strategies among hearing impaired people, sign language translators, and people in an early stage of learning a sign language [6]. They also showed that hearing impaired people look from text to sign language movie to better assimilate the message. Miyamoto et al. examined how the subjective readability of a message varies with the separation of text and sign language movie, and two text locations (test is set to the right or the bottom of the movie) [7][8]. However, for the emergency situations assumed in this study, assimilating the message quickly is more important than its subjective readability.

3 Policy for Layout

In order to give as much information to as many people as possible in public spaces at the same time, bigger and many displays are often installed. Such displays fall into three types:

A) One (big) display (ex. Fig.1)
B) Many displays working as one big display (ex. Fig.2)
C) Many displays working individually (ex. Fig.3)

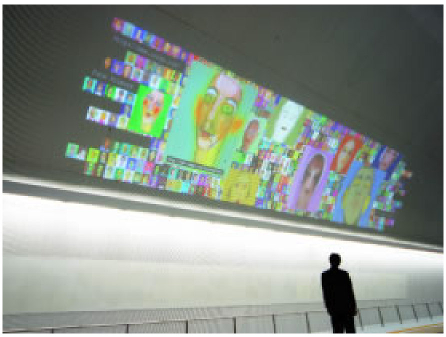


Fig. 1. Example of one (big) display

Fig. 2. Example of many displays working as one big display

Fig. 3. Example of many displays working individually

If one screen shows both text and a sign language movie simultaneously, maximizing the font size and movie size means that the separation between the two modalities is minimized. This may not be effective since there is a possibility that it will take more time to read out the message due to collision of the visual modalities. One solution is to display the text and movie on different displays, but this raises the possibility that the two messages will not be associated with each other; i.e. there is a possibility that it takes more time for hearing impaired people to look from text to sign language movie.

We examine here the case wherein a text message and corresponding sign language movie are shown on the same display at the same time; we assess the impact of

– Spatial separation of text and sign language
– Relative position of text and sign language

on the readability of the message, in particular the readout time of the message.

It is considered that this time also depends on font type, size, and color of text, size and quality of sign language movie etc. In this study, we assume that the modalities are clearly readable in their own right to focus on their interaction.

4 Experiment

4.1 Subjects

The 14 evaluators consisted of 7 Japanese men and women with ages from 26 to 45. All were hearing impaired and use sign language as the dominant communication method. The remaining 7 were Japanese men and women who had normal hearing and did not understand any sign languages.

4.2 Method of Experiment

Each message, an example is shown in Fig.4 (Left), was composed of text and the corresponding sign language movie. We used alert messages produced by Japanese railway companies. A sign language translator converted the message into sign language and his actions were videotaped. We examined eight arrangements as shown in Fig.4 (Right). We defined the center of text as the center of the minimum rectangle that bounded all text, and the center of the sign language movie as the center of the minimum rectangle that bounded the translator. Fig.5 shows the four arrangements with the text to the left of the movie. For the 8 arrangements, we measured the time taken to read each message.

– Position: Left or Right
– Separation: 22.6[deg], 11.5[deg], 8.4[deg] or 5.8[deg] (in terms of subject's view angle)

*With separations of 8.4[deg] and 5.8[deg], some text overlapped the sign language translator.

The 432[mm] * 324[mm] display used had a resolution of 1600[pixel] * 1200[pixel]. The display was placed 500[mm] from the subject. Each subject was challenged once per arrangement. The sign language movie showed the translator from the waist up [9], and movie size was adjusted so that the translator's shoulder width was 8.2[deg]. The movie was edited to show 1 second periods before and after the sign language representation, and it was played repeatedly. The screen background color was gray, i.e. no hue. The background color of the sign language movie was also gray. The text message used the font "HG-SOEIKAKU Gothic UB" and font size was 27[pixel] (0.81[deg]). Considering the occlusion of text and movie, we set the font color to aqua, a color not present in the movie. Moreover, in order to improve text visibility, we gave each character a 3[pixel] wide black drop shadow. Text language was Japanese written from left to right. Line length was set to 10 characters per line (8.6[deg]). If a text statement had more than 10 characters, the characters beyond 10 were placed on a new line.

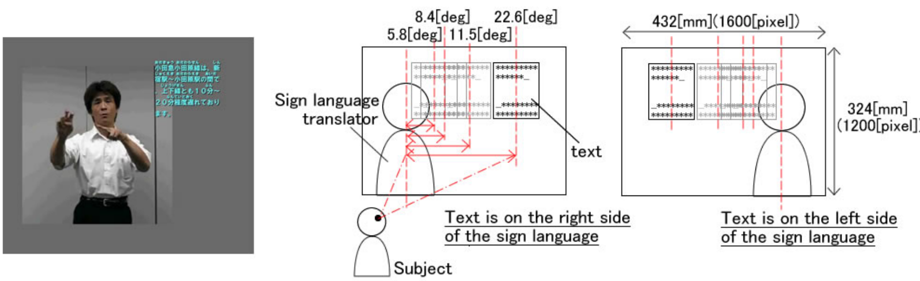
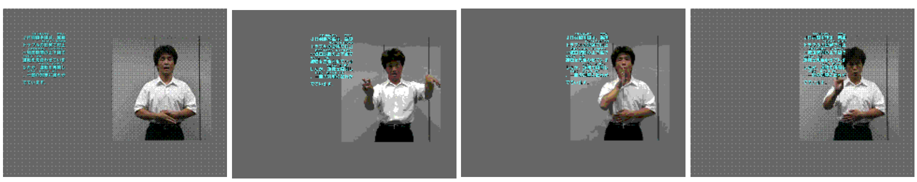


Fig. 4. Displayed message (Left), Layout pattern (Right)



22.6[deg] 11.5[deg] 8.4[deg] 5.8[deg]

Fig. 5. Examples of layout (Case text is arranged at movie's left side)

4.3 Method of Evaluation

We explained the assumed situation and how to proceed. Next, in a training phase, the subjects could read messages and answer quizzes about the messages repeatedly until they felt comfortable with the process. In the task, at first, the message, such as Fig.4 (Left), was shown to the subject. The subject read the message and then indicated the completion of reading/assimilation. At that time we stopped playing the message. Three seconds later a quiz about the displayed message was shown, and the subject answered one question. Each subject repeated this process 8 times to cover the 8 arrangements; a different message was used in each trial. The order of arrangements displayed was randomized for each subject.

Subjects were told to imagine that the train they were taking had stopped suddenly and the message was shown on a display inside the train. Moreover, we told them to read the message as quickly as possible while still understanding it. We recorded the readout time of the message and their answer to the question.

5 Result

There were differences between the amount of information in each message and the ability of each subject. Based on the number of characters in each displayed message and each subject's average readout time calculated for all 8 trials, we normalized the readout time (called hereafter "readout rate"). The readout rate of the j th message shown to subject i is given by the following expression (1).

$$R_{ij} = \frac{r_{ij}/c_{ij}}{8 \cdot \sum_{j=1}^{8} (r_{ij}/c_{ij})} \tag{1}$$

c_{ij} : The number of characters in the j th message shown to subject i

r_{ij} : The readout time for the j th message shown to subject i

Fig.6 and Fig.7 plot the readout rates for the hearing impaired and aurally competent subjects, respectively. In each graph, the horizontal axis is the spatial separation between the text and the movie, and the vertical axis is average readout rate.

We subjected results to ANOVA (Table.1). We found significant differences in the average readout rates of the hearing impaired. When the text was set to the left of the movie, there were significant differences at the 5% level between 22.6[deg] and 11.5[deg], and between 22.6[deg] and 5.8[deg]. When the text was set to the right, there ware significant differences at the 5% level between 22.6[deg] and 11.5[deg], and between 22.6[deg] and 5.8[deg]. We did not find any significant difference in the results of the aurally competent subjects at the 5% level.

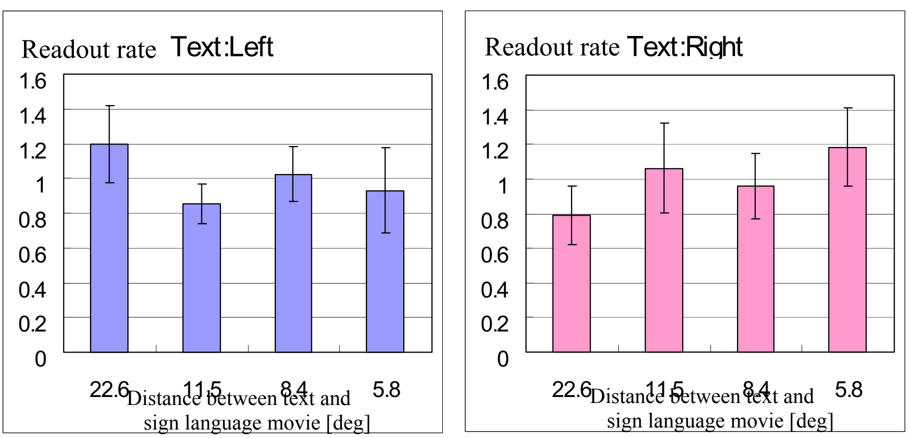


Fig. 6. Result of 7 hearing impaired subjects

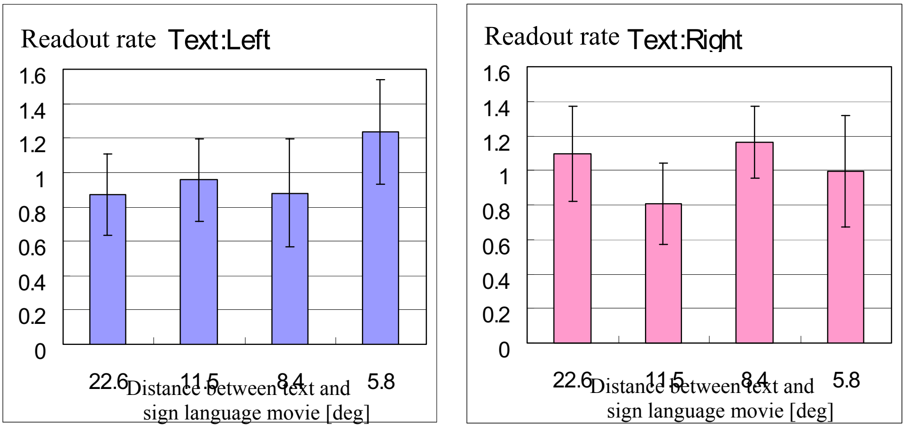


Fig. 7. Result of 7 aurally competent subjects

Table 1. Difference between average readout rates

	Hearing impaired subjects		Hearing subjects	
Text position	Left	Right	Left	Right
F-measure	3.59 (p=0.028)	3.67 (p=0.026)	2.30 (p=0.103)	2.03 (p=0.136)
5.8[deg]- 8.4[deg]	p=0.407	p=0.079		
5.8[deg]-11.5[deg]	p=0.501	p=0.329		
5.8[deg]-22.6[deg]	p=0.023	p=0.004		
8.4[deg]-11.5[deg]	p=0.140	p=0.410		
8.4[deg]-22.6[deg]	p=0.128	p=0.185		
11.5[deg]-22.6[deg]	p=0.005	p=0.037		

When the text was set to the left of the movie, 11.5[deg] and 5.8[deg] were better than 22.6[deg]. However, when the text was set to the right, 22.6[deg] was better. In order to provide information we can read quickly, we have to vary the spatial separation between the text and sign language movie according to their relative position.

6 Discussion

The trials showed that the optimal separation of text message and sign language depends on their relative position. After the experiment, we interviewed hearing impaired subjects; 3 subjects said “placing the text to the right of the movie was better,” 2 subjects had no preference. It seems that text messages are subjectively easier to read if they are set to the right of the sign language movie. We confirmed this by analyzing the trial results. For the message left arrangement, the average readout rate was 1.002 (SD = 0.2306), for the message right arrangement, the average was 0.998 (SD = 0.2584). We subjected these results to a t-test yielding p=0.97(>0.05), and this showed that relative position itself did not influence the readout time.

We read Japanese written horizontally from left to right and it seems logical to assume that one factor determining the readability of a message is the ability to rapidly identify the line head of the text. We focused on the separation between the line head of text box and the center of the translator. Fig.8 shows the relation between 7 hearing impaired subjects' average readout rate and the separation as defined above. From 1.5[deg] to 18.4[deg], as the separation became larger, the average readout time decreased. However, when the separation was 26.7[deg], the average readout time became longer. This result suggests the readout time depends on this separation and there is an optimum separation.

In this experiment, we investigated the readout time from the aspect of the separation between the center of the text and the center of the sign language movie. This implies that data is missing from 18.4[deg] to 26.7[deg], and more than 26.7[deg]. Therefore, we need to perform more detailed tests. Another task is to examine the effect of writing the Japanese text vertically.

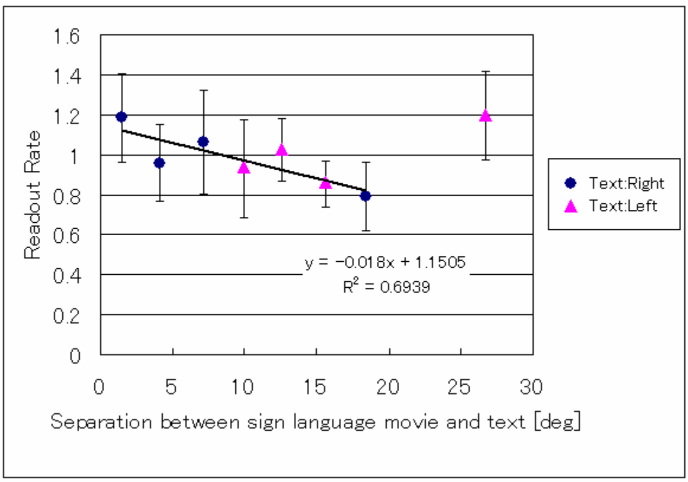


Fig. 8. 7 hearing impaired people's average readout rate from aspect of separation between line head of text and center of sign language translator

7 Conclusion

This paper focused on emergencies in public spaces, and on optimizing the layout of text and sign language movies to decrease the readout time of the hearing impaired and the normal hearing. Tests showed that we have to vary the spatial separation between text and its accompanying sign language movie according to their relative position. They also indicated that the readout time depends on the separation between the line head of text and the center line of the translator, and there is an optimum separation that minimizes the readout time.

Future work includes investigating the readout time for separations not examined in this study, and investigating the influence of the text overlapping a part of sign language translator.

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Comparative Analysis of the Accessibility of Desktop Operating Systems

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Abstract. This paper presents the results of ongoing research on methods for evaluating the accessibility conformance level of software and especially operating systems. Our approach is based on recommendations from software accessibility standards, and defines techniques for evaluating each of those recommendations. The proposed method has been applied to evaluate the accessibility features of one closed-source and one open-source desktop operating system, Microsoft Windows XP and the Ubuntu Linux distribution, respectively. Specifically, the functionality we have evaluated was task management and file system management. From the point of view of the evaluation process, we conclude that more work is needed on the development of support tools and techniques. And from the point of view of the specific comparison, we conclude that, taking into account the analysed functionality, the current version of the Ubuntu Linux distribution is slightly more accessible than the current Windows release, though neither of the systems fully conform to the accessibility standards.

1 Introduction

There is an increasing demand for accessible software, especially motivated by recent public policies on the public procurement of accessible products and services in the field of information and communication technologies (ICT). Some examples are Section 508 of the Rehabilitation Act in the United States [1] and the European Commission's Mandate M376 on standards supporting accessibility requirements for public procurement [2].

In this context it is extremely important to be able to determine the degree of accessibility of software products, including operating systems. There exist international and national standards defining the requirements and recommendations of accessible software for this purpose, such as ISO TS 16071:2003 [3] and UNE 139802:2003 [4]. But the evaluation process, techniques and tools required to assess the accessibility conformance level are not as well defined as they are in the web context [5].

Additionally, because of the current trend within public administrations of switching from closed-source to open-source software, it is important to know whether this change can be safely made from the point of view of accessibility features.

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This paper presents work in this direction. First we will present a method for performing assessments of the operating system accessibility conformance level based on the contents of the above two standards. Then we will present the initial results of the application of this method to compare the accessibility level of two desktop operating systems: Microsoft Windows XP SP2 [6] and Ubuntu Linux 6.10 [7].

2 Objectives

This paper is part of long-term research dealing with software accessibility for people with disabilities and more specifically with current desktop operating systems user interface accessibility.

The main goal of this paper is to propose a preliminary version of a method for evaluating the accessibility of operating systems based on the level of conformance to current software accessibility standards.

In the first application of the proposed method, we are particularly interested in finding out what difference (if any) there is between the accessibility of open-source versus proprietary systems. The proposed method has been applied to perform a comparative analysis of the accessibility level of relevant representatives of these two families of desktop operating systems. On the one hand, we have evaluated the accessibility of Microsoft Windows XP Service Pack 2. On the other hand, we have evaluated the accessibility of the Linux-based operating system Ubuntu 6.10 that ships with the GNOME 2.16 desktop environment. In the past Windows developers have put more effort into accessibility than the Linux community. This situation is changing rapidly and the open source community is now strongly committed to accessibility [8].

The method divides accessibility features into several functionality groups. In this research, we have applied part of the whole proposed method. Specifically we have focused on two functionality groups: task management and file system management. For each functionality group the method then defines a set of user tasks that have to be performed to evaluate the accessibility conformance level. All the accessibility features evaluated in each of these functions will be explained in section 4.

3 Significance

The results of this research are highly significant in the current context of policies concerning the inclusion of people with disabilities in the Information Society. One prominent policy is to promote accessibility in the public procurement process. Some examples follow below.

In the USA, Section 508 of the Rehabilitation Act requires the US government to purchase accessible electronic and information technology [1]. The related minimum accessibility requirements have been defined by the Access Board [9].

In Canada there exists an accessible public procurement toolkit [10], which is based on the 508 requirements with some additions. This toolkit enables public procurers to easily generate the needed procurement requirements for accessible products.

In the European Union, the European Commission has produced a Mandate on Public Procurement of accessible ICT products and services (M376) [2], and European Standards bodies are now working on the standardization of accessibility requirements for public procurement. This implies that Europe also intends to apply public procurement as a tool for the promotion of accessible products and services.

Another significant current trend is to promote open source systems in public administrations all around the world. But the administrations willing to adopt open source systems should not overlook accessibility requirements. These administrations should guarantee that the switch to open source software does not discriminate against their employees and the general public by lowering accessibility levels.

In this situation it is very important to have a rigorous method to evaluate how accessible operating systems are and to help public administrations in the process of defining accessibility requirements for public procurement. Unfortunately, there is no method based on official standards for evaluating accessibility on a single operating system, nor has any comparative analysis of the accessibility of several operating systems been published to date.

Additionally, note that most of the accessibility requirements and recommendations for software cannot be automatically evaluated and they require the participation of an expert human evaluator. This has already being demonstrated in the specific case of web content [11] but also holds true for other types of software, such as operating systems.

In this paper, we propose a preliminary version of a method for evaluating software accessibility based on international standards and with the participation of human evaluators. Then we apply this method to run a comparative analysis of the accessibility of two representative desktop operating systems.

4 Method

We have developed a method to perform a complete study of OS accessibility. This method is composed of four steps: checklist definition, definition of checkpoint evaluation methods, selection of system functionalities and evaluation.

4.1 Checklist Definition

We have created a checklist of issues to be checked to assure accessibility for people with disabilities. We have followed two main guidelines: ISO/TS 16071[2] and UNE 139802 [3] (Spanish standard which covers some issues not covered by ISO). We have chosen these standards instead of the upcoming ISO 9241-171 [12] for two reasons. Firstly, the new ISO standard is still not stable enough to be referenced as it was in the “Draft International Standard” phase at the time of writing this paper. Second, the combined content of ISO TS 16071 and UNE 139802 covers most of the recommendations of the future standard.

The chosen standards define different criteria based on accessibility impact (core, primary and secondary for ISO/TS 16071, and priority 1, 2, and 3 for UNE) and implementation responsibility (OS and/or application for both) to guide developers through the design of systems and interfaces that are as accessible as possible. In our current work we have chosen the core recommendations from ISO/TS 16071 and then we added the priority 1 requirements from UNE 139802 that were not covered by ISO/TS 16071. This generated a checklist of 39 items, which is presented in Table 1. We used the ISO DIS 9241-171 wording for the UNE checkpoints when applicable.

Table 1. Checklist of accessibility requirements

ID	Short Description
General Guidelines	
[ISO] (7.2.1.1)	Enable user input/output choice
[ISO] (7.2.2)	Enable user to perform the task effectively with any single input device
[ISO] (7.2.4)	Enable user setting of timed responses
[ISO] (7.2.10)	Avoid seizure-inducing blink rates
[UNE] (4.1.1)	Minimise the number of steps required to perform any task
[UNE] (4.1.4)	Provide accessibility services
[UNE] (4.1.5)	Accept the installation of keyboard and/or pointing device emulators
[UNE] (4.1.6)	Be compatible with speech recognition systems
[UNE] (4.10.1)	Provide accessible system start-up and restart
[UNE] (4.10.2)	Enable software-controlled media extraction
Assistive Technologies	
[ISO] (7.3.2)	Provide object labels
[ISO] (7.3.3)	Make event notification available to assistive technologies
[ISO] (7.3.4)	Make object attributes available to assistive technologies
[ISO] (7.3.5)	Present user notification in a relevant manner
Keyboard-input configuration	
[ISO] (7.4.2)	Enable sequential entry of multiple keystrokes
[ISO] (7.4.7)	Provide keyboard control of pointer functions
[ISO] (7.4.11)	Reserve accessibility key-mappings
[ISO] (7.4.13)	Separate keyboard navigation and activation
[UNE] (4.2.1)	Enable full use via keyboard
[UNE] (4.2.5)	Enable the locking of control keys
Software control of pointing devices	
[ISO] (7.5.2)	Enable the adjustment of the location of button functions
[ISO] (7.5.9)	Provide alternatives to chorded key presses
Display fonts	
[ISO] (7.6.1)	Enable font customization and legibility
Displays	
[ISO] (7.7.3)	Provide access to information displayed in “virtual” screen regions
[UNE] (4.4.5)	Provide non-animated alternatives to animations
Colour	
[ISO] (7.8.1)	Provide alternatives to the use of colour as the sole source of information.
[ISO] (7.8.6)	Provide alternatives to coding by hue
Audio Output	
[ISO] (7.9.5)	Allow users to choose visual indication of audio output
[UNE] (4.5.1)	Provide accessible alternatives to task relevant audio and video
[UNE] (4.5.3)	Provide speech output services
[UNE] (4.5.4)	Synchronise speech output of visual events
Errors and user notification	
[ISO] (7.10.1)	Allow task-relevant warning or error information to persist
[UNE] (4.6.1)	Provide understandable user notifications
On-line documentation and help	
[UNE] (4.9.1)	Provide understandable documentation

Table 1. (*Continued*)

Customization of user preferences	
[ISO] (7.12.3)	Enable cursor and pointer customization
Windows appearance and behaviour	
[ISO] (7.13.1)	Enable non-pointer navigation directly to windows
Keyboard input focus	
[ISO] (7.14.1)	Provide focus cursor
[ISO] (7.14.2)	Provide keyboard navigation
[ISO] (7.14.3)	Provide navigation to task-appropriate groups of controls

4.2 Checkpoint Evaluation Method

For each checkpoint in our checklist we have defined a method of evaluation. There are two main types of evaluations.

The most commonly used evaluation method is based on tasks performed by a human evaluator using the software. For each system functionality we have defined a set of user tasks (see below in 4.3), and the evaluator has to perform those tasks checking whether or not the software complies with the checkpoint.

In addition, there are some special checkpoints that are not evaluated by performing tasks, but by reading the software documentation (both user and developer documentation). One example of such a checkpoint is UNE 4.1.4 (provide accessibility services). Table 2 gives an example of the method of evaluation followed.

Table 2. Example of the method of evaluation

Checkpoint	Method of evaluation
[ISO] (7.14.2)	Verify whether the user can navigate through the keyboard across user interface elements during any task.
[UNE] (4.1.4)	Verify whether documentation for developers defines an accessibility API.

The result of the evaluation for each checkpoint is one of five possible values:

- *Pass*: the OS definitely meets the requirements for the checkpoint.
- *Fail*: the OS definitely does not meet the requirements for the checkpoint.
- *Partial*: the software almost fully complies with the checkpoint, but there is a minor issue to be solved.
- *Unknown*: the evaluator cannot decide whether or not the software complies with the checkpoint.
- *Not applicable*: the checkpoint is not applicable for the OS in the current context of use.

4.3 Selection of System Functionalities and User Tasks

To perform the accessibility comparison, we have restricted the OS functionality under observation: we have only evaluated the basic functionality of an OS viewed as a tool that enables the user to manage his or her files and tasks, and we have not considered additional software like media players or web browsing. The functionality groups covered are:

- *Task management*. The operating system should allow users to perform a set of actions in order to manage tasks (running applications). The user tasks that are considered for this functionality group are: get a list of the running applications (with relevant information on each one), swap tasks, start a new task (launch a new program) and finalize a task (stop program execution). We have considered window management as part of this functionality.
- *File system management*. The operating system should allow users to manage the folders and files stored in the computer storage devices. In our study we have examined the following user tasks: navigate through the file system, create, copy, rename, move and delete files or folders and, finally, delete and move multiple files.

Administrative tasks like disk formatting, disk integrity checking, new hardware installation and so on were not taken into account but will be considered in the future.

4.4 Evaluation Process

We have performed a group-based cross evaluation to enhance the objectiveness of the results. We created two evaluator groups, both of them formed by users with knowledge on both operating systems, usability and accessibility:

- In the first stage, group 1 analysed Windows XP and group 2 analysed Ubuntu. All group members worked individually and did not have access to the results of the other members of their or the other group.
- In the second stage, each group analysed the other OS.
- Then we combined the scores for each checkpoint (using the rules described in Table 3), and we conducted a basic data analysis to decide which was the more accessible operating system overall and for each main functionality.

Table 3. Accessibility evaluation combination rules. $i, j \in \{1 .. \text{number of evaluators}\}$ and $eval_i$ is the result of evaluator i. Note: N/A means "Not applicable".

Condition	Result
$\exists i, eval_i = fail$	fail
$\exists i, eval_i = partial \wedge \forall i \neq j\ eval_j \neq fail$	partial
$\exists i, eval_i = pass \wedge \forall i \neq j\ (eval_j \neq fail \wedge eval_j \neq partial)$	pass
$\exists i, eval_i = N/A \wedge \forall i \neq j\ (eval_j = N/A \wedge eval_j = unknown)$	not applicable
$\forall\ i, eval_i = unknown$	unknown

5 Results

Table 4 is a summary of the results of the evaluation. Details on the results for each operating system are shown in Table 5 (for task management) and Table 6 (for file management). Tables 5 and 6 show the final values after applying the combination rules and only contain values other than “pass” for both operating systems. Therefore, the result of the evaluation of any checkpoint not appearing in either Table 5 or 6 is positive. Some requirements in the tables are labeled “Not Applicable”. This means that they don’t make sense in that specific context.

Table 4. Summary of the evaluation results

Result	Windows XP	Ubuntu Linux
Fail	8	6
Partial	2	0
Pass	61	64
Not applicable	7	8
Unknown	0	0
TOTAL	78	78

The first and most important result is that neither of the two evaluated operating systems fully complies with the analysed checkpoints.

Table 5. Task management evaluation results

Requirement Identifier	Results	
	Windows XP	Ubuntu Linux
General Guidelines		
[ISO] (7.2.4)	***Fail***	Not applicable
[UNE] (4.10.1)	***Fail***	***Fail***
[UNE] (4.10.2)	Not applicable	Pass
Display Fonts		
[ISO] (7.6.1)	***Fail***	Pass
Displays		
[UNE] (4.4.5)	Not applicable	Not applicable
Audio Output		
[UNE] (4.5.1)	Not applicable	Not applicable
[UNE] (4.5.4)	Not applicable	Not applicable
Errors and User Notification		
[UNE] (4.6.1)	***Fail***	***Fail***
On-line Documentation and Help		
[UNE] (4.9.1)	Pass	***Fail***

Analysing the collected data and comparing both operating systems as a whole, we can say that, for the task and file management functionality groups, the current version of Ubuntu Linux with GNOME is slightly more accessible than the current version of Windows XP. Details on the failed checkpoints are given below.

Table 6. File system management evaluation results

Requirement Identifier	Results	
	Windows XP	**Ubuntu Linux**
General Guidelines		
[ISO] (7.2.4)	Not applicable	Not applicable
[UNE] (4.10.1)	***Fail***	***Fail***
Assistive Technologies		
[ISO] (7.3.5)	***Fail***	***Fail***
Displays		
[UNE] (4.4.5)	***Fail***	Not applicable
Audio Output		
[UNE] (4.5.1)	Not applicable	Not applicable
[UNE] (4.5.4)	Not applicable	Not applicable
Errors and User Notification		
[ISO] (7.10.1)	***Fail***	Pass
[UNE] (4.6.1)	Partial	***Fail***
On-line Documentation and Help		
[UNE] (4.9.1)	Partial	Pass

5.1 Task Management

- *[ISO] (7.2.4.1)*: Windows XP fails because when a user wants to kill an incomplete process or shutdown the computer and there are documents to be saved, it shows a dialog box with a time-out asking if the user wants to wait for the program to end correctly or finish immediately. In this dialog there is no way for the user to set the time limit. Linux has no timed dialog, so this requirement is not applicable.
- *[UNE] (4.10.1)*: both systems fail because start-up and restart are not fully accessible. If anything unusual happened during the last operating system execution, the start-up and restart processes will perhaps need to interact with the user, but assistive technologies are not activated until later. This checkpoint is common for both functionality groups (task management and file system management).
- *[ISO] (7.6.1)*: Windows XP fails because the font of some texts in the task manager cannot be modified by the user.
- *[UNE] (4.6.1)*: Windows XP fails because it displays a message like “Error 0x53: ask your administrator” for some application errors and some cases when the operating system returns a fatal error. Also Ubuntu Linux displays messages like this.
- *[UNE] (4.9.1):* Ubuntu Linux fails because some help documents contain sections written in different languages (i.e. a mixture of English and Spanish).

5.2 File System Management

- *[UNE] (4.10.1)*: Common checkpoint, see “5.1. Task management” for details.
- *[ISO] (7.3.5)*: Both operating systems fail. In Windows some informative (non-error) messages are shown in a “Dialog Box” and others are shown inside a “Bubble” (i.e.

renaming a file with a non-allowed character). In Ubuntu Linux, a lot of informative messages do not have a title.

- *[UNE] (4.4.5)*: There is an animation in the progress dialog that cannot be deactivated when copying a large set of files in Windows.
- *[ISO] (7.10.1)*: There is one case in Windows that does not comply with the requirement. When the user renames a file or directory and types a non-allowed character (i.e. “:”, “/”,”*”), the system shows the message ‘A file cannot contain any of the following characters: \ / : * ? “ < > |’. But if the user switches to another window or task, the message will no longer be there when he or she goes back to the original window or task.
- *[UNE] (4.6.1)*: Windows XP fails because it displays a message like “Error 0x53: ask your administrator” for some application errors and some cases when the operating system returns a fatal error. Also Ubuntu Linux displays messages like this.

6 Conclusions and Future Work

Today, software accessibility is a relevant issue concerning both the public administrations and the private sector. In particular, public administrations all around the world are starting to require accessibility compliance for the public procurement of products and services.

For this to be possible there is a need for reliable methods to assess the accessibility conformance level of software products. In this paper we have presented a preliminary version of such a method and we have applied it to two desktop operating systems —Microsoft Windows XP SP2 and Ubuntu Linux 6.10— to compare their accessibility level.

We observed some variability in the results obtained by different evaluators when applying the method. This variability cannot be explained either by their previous knowledge of the two systems or by the order in which they performed the assessment. This leads us to suspect that we need to refine and clarify the evaluation method for the checkpoints so that the results are more objective and reliable. This is the main goal of our future research. In addition we will need to develop tools to support the evaluation process.

Concerning the comparison between the analysed systems, neither fully complies with the evaluated checkpoints, but they are nearly there. Ubuntu is slightly more accessible but there are no big differences. And the results may have been different if we had been able to evaluate the latest version of Windows (Vista) which appeared recently. This would have been a fairer comparison in view of the fact that Windows XP is 5 years old and Ubuntu 6.10 was not released until last November.

Finally, as regards the debate between open-source and proprietary software, given the small differences that we identified, we do not expect accessibility to be a key factor at present or in the near future.

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DfA Implementations for People with Vision and Hearing Disabilities: Application and Development for Information Society

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Abstract. This paper presents activities and challenges when implementing information processing technologies for people with hearing and visual impairments. Other than keyboard based input and monitor based for output modalities should be employed for this category of users. More important is that these modalities are crucial element for successful implementation of complex systems designed for disabled people. Some activities carried on in Lithuania implementing applications oriented for disabled people or using speech technologies and targeted to impaired people are presented too.

Keywords: design for all, impaired people, information technologies, speech technologies, voice user interface, information infrastructure.

1 Introduction

Technology can help to lower many of barriers that people with disabilities faces to accessing information services. Barriers can be grouped into three functional categories: barriers to providing computer input, interpreting output, and reading supporting textual data. Using computing technology and particularly the voice processing technology tasks such as reading and writing documents, communicating with others, and searching information on the internet, people with disabilities are capable to perform independently [1]. These technologies could be important component trying to achieve higher quality of life for many categories of impaired people.

One of the major advances of the human-machine interfaces in the recent decades was the advent of the graphical-user interfaces (GUI). But GUI left behind the blind and vision impaired people. It is noted that prior to the GUI era it was easier for impaired people to work with the computer using a Braille reader. Similar story was

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observed looking at the Internet development. When the World Wide Web (WWW) became a common way to access Internet for majority of people blind and vision impaired were left even in the more difficult situation. It is well known fact that speech is the preferable modality for the majority of the disabled people. Speech recognition and text-to-speech synthesis are the two main components enabling the use of many information technologies and different gadgets for impaired people.

The aim of this paper is to present the activities carried on to provide people with disabilities possibilities to access modern information technologies and tools in Lithuania

2 Current Situation with Informational Infrastructure for Impaired People in Lithuania

Situation with information accessibility for impaired people in Lithuania is improving, but still require high attention and efforts. In recent years Government of the Republic of Lithuania has done first steps due to Information environment adaptation for disabled. State institute of information technologies has participated in most of the government initiated projects. In recent years attention was focused to provide information to society about problems of disabled, but not to adapt information environment to the disabled. Currently information environment for disabled is adopted by subtitling or translation to sign language various TV programs, partially adaptation of education programs, books, and non government institutions support (providing technical and other means for information accessibility). There are libraries for blind persons (books in Braille, voice books, e-books), translation centres to sign language, etc.

Government of Lithuania has started more important projects aiming to adapt information environment for disabled. In the Government program (2004-2008) were foreseen measures for integration of disabled into information society, labor-market, rehabilitation, etc. Various governmental institutions, such as Department of disabled affairs under the Ministry of social security and labor, Information society development committee are responsible for implementation of programs regarding information environment adaptation for disabled persons. State institute of information technology together with these institutions has executed various projects in this field.

First project was the analysis and concept preparation of “The Adjustment of the Information Environment to the Needs of the Disabled” (2001). In this study current situation in Lithuania and disabled persons needs, world experience and good practices were analyzed. Also was provided plan and future steps of information environment adaptation in Lithuania. With the aim to develop information society, the pilot process of implementing the most promising technologies in the society on the basis of “Design for all” principle is being modeled [2].

Later there were prepared guidelines for web pages design, development, implementation, evaluation and testing according to W3C and other relative guidelines. These guidelines were prepared and issued and now they are mandatory for web pages of state institutions.

The next step was adaptation of several governmental web pages for disabled people according to the issued guidelines and other requirements (especially W3C).

Information society development committee is responsible for supervision how governmental institutions follow the Web content accessibility requirements. Once per year there are executed tests of web pages accessibility. Results are not very satisfactory, but they are improving each year. In the beginning of 2006 only 20 government institutions web sites (from 90 tested) conform to 1 priority (A) WCAG 1.0 W3C requirements. The main unconformities are absence of alternative description for video, audio information; row and column headers for data tables are not identified.

Next project was “Guidelines for information environment, used for education and adaptation for disabled people”. During this project we prepared guidelines for information environment adaptation for disabled. These guidelines explain how to develop information environment, content, educational applications accessible for all users. Guidelines provide information about disabilities, functional limitations, and assistive technologies. Applications accessibility can be improved by several means:

1. During applications design stage attention should be paid to how to made application accessible for all without usage of additional hardware and software (direct accessibility).
2. During applications design stage attention should be paid to how to made application accessible with assistive technologies usage (for several disabilities).
3. It is necessary to ensure accessibility of additional documentation (help documentation, support documentation, etc.).

Guidelines explains how to ensure text, graphical, audio, video information accessibility, how to provide information in alternative ways. Also there is provided recommendation for specific content adaptation, i.e. mathematic, diagrams, charts, schemes, maps, geographical information, etc.

Consequent project was “Requirements and guidelines for e-learning environment and education materials formats”. Educational materials can be provided in various ways, i.e. paper, audio/video, e-books, TV broadcasting, e-learning, etc. On-line learning has a lot of advantages, i.e. flexibility, speed, new technologies usage, interactivity. Attention should be paid to educational materials formats.

It was also implemented “Rehabilitation and integration information system for people with disabilities”. The purpose of this project is to develop and implement information system, which will be able to provide on-line detailed and comprehensive information for disabled people, including assistive technology products, services, events, descriptions, images, technical data, social, education information, etc. The main goal of the system is to provide latest and periodically updated information, related to disabled persons. Information system is developed according to accessibility guidelines. SIIT, together with Lithuanian deaf and hearing impaired education center, prepared Lithuanian-sign language vocabularies and web based online sign language learning program.

Now Lithuania has good chances to improve information environment adaptation for disabled persons using European Union Structural funds, 7 Framework program and other national and European Union funding.

3 Voice Technologies for Impaired People

Voice technologies have potentially enormous benefit for people with various kinds of physical disabilities. The richness of human speech communication gives the user many degrees of freedom for control and information input or output. Applications using spoken language technologies can be grouped in the areas of access, control, communication and rehabilitation and therapy. For people with different kinds of disabilities different types of speech technologies are more important or valuable: for people with visual impairments speech synthesis is essential as a way to access necessary information, for people with hearing impairments perceptual speech processing and amplification are essential as a way to gain information got when communicating with other people, for people with motor-handicapped impairments speech recognition could be essential technology as a way to control different devices and environment in the general sense. Anyway it is very difficult to find person with some kind of impairment that can't benefit from voice technologies and these benefits often are very significant. But it is well known that to develop successful application using voice technologies oriented to disabled people it is necessary effectively take into account the specific needs of user groups and preferably to have the ability to adapt to the needs of individual [3].

For a long type impaired people benefited from a various specialized devices (e.g. wheelchairs or other assistive devices) designed to fulfill their specific needs. These devices most often could be supplemented with voice processing capabilities and get additional and important functionality. In this case assistive devices could provide new level for independent living since impaired people could perform independently tasks that required help from other persons before. Environmental control systems or smart home interfaces becoming available which address many aspects of home management such as control of audio-visual equipment, telephones, household appliances, doors and curtains as well as the ability to summon assistance.

In recent decades also emerged new group of tools and technologies that are common for modern living. First of all computers and internet are such tools. People with disabilities require access to new technical devices and information on the equal basis with other people. However typical input modalities used in modern control and communication devices – keyboard input and visual output – are often not suitable for disabled people due to the physical disorder. Voice technologies are the most preferable way for these persons: speech recognition serves as a substitute for the computer keyboard or mouse based control and speech synthesis used to read information presented on screen as a substitute of typical eye reading [4]. Below we will briefly mention some obstacles that people with impairments faces when using computers and internet and we will try to show possible solutions and the ways to integrate voice processing technologies.

3.1 Voice Technologies for Visually Impaired People

The recent advent and widespread use of computers and internet gave new challenges for the visually impaired people and developers of assistive devices [1]. The major obstacle is the inability to use computer screen – the main source to provide computerized information for the rest of people. One of the popular ways to avoid this limitation is to use screen readers – software tools that could read information by voice from screen using text-to-speech technology. In earlier console-based operating systems screen reading was relatively straightforward task since the screen was memory mapped in character/attribute pairs. In modern GUI based environments the relatively simple mechanisms of mapping are no longer appropriate and require more sophistication to determine information about screen's content. Additional difficulties arise from the widespread use of a mouse pointing device. Those difficulties are common to the users throughout the world. But there are some difficulties that are less important for the visually impaired people that are native speakers of more widespread languages such as English but which are important to the native speakers of less spoken languages such as Lithuanian. Those speakers more often tend to get information in different languages (e.g. to get access to popular foreign based web pages) and multilinguality arises as a key issue designing screen reading system. Well developed system must possess good language recognition system and will activate necessary speech synthesizer. Another important and popular feature of screen is variable speaking rate. Screen reading by voice is essentially more time consuming process than screen reading by eyes. Many visually impaired persons feels uncomfortable when listening read information from computer screen since this do not provide useful information for them up to the some point of interest. Many of the users prefer to speed up reading in this case even at the cost of loosing speech quality.

There are various available screen readers at moment. Many of them employs synthesizers as the separate independent engine which is significant advantage to Lithuanian visually impaired users since potentially allows to implement Lithuanian speech synthesis engines. The most popular screen reader in Lithuanian visually impaired computer user's community is Jaws screen reader. It allows implement any SAPI5 compatible speech synthesis engine. It means that Lithuanian speech synthesizer together with widely used other languages speech synthesis engines could be used with Jaws without any significant or costly changes. Important step in the more successful utilization of speech synthesis for visually impaired people was the requirements of Lithuanian state for web page designers. Many of the state institutions and state run organization rearranged their web servers according to those requirements. Unfortunately since requirements are not obligatory majority of commercial web servers neglects them and reduces the benefits of speech synthesis and screen readers for impaired people.

3.2 Voice Technologies for Motor-Handicapped People

As well as visually impaired persons motor-handicapped people are especially keen to use voice technology. This is especially true for people hand movement restraints. In this situation emphasis will be placed on speech recognition technologies while speech synthesis is of relatively lower importance. Even more often the use of voice recognition is the only mode to transfer a computer or other device control commands independently. Our main interest at this stage is devoted to the computer control and information access with computer tasks (such as web browsing) as well as the control of some home equipment using computer and standard controller tasks. While such tasks as autonomous control of wheelchair by Lithuanian voice commands does not differ in principle from mentioned above tasks it arouses some additional technical obstacles.

The major requirements for software tools that aim to enable information access for motor-handicapped people could be expressed in following terms:

- User input is given by spoken commands
- Output is unaltered visual rendering with so-called Saycons ("sayable icons" which informs the user how to activate the various links by voice) and optionally combined with speech synthesis for eyes-free browsing if necessary.
- No deep parsing of web-pages is deployed due to the complexity of the task.

While there are few examples of web-browsers oriented to the motor-handicapped persons (e.g. such browsers as Converse Voice Surfer, Hands Free Browser or Indtal [5] as well as add-ons shipped with some versions of IBM's Via Voice and Dragon Naturally-speaking commercial speech recognition software) none of them does not support commands in Lithuanian language or does not have possibilities to implement separate Lithuanian speech recognition engine. Other criteria that must be taken into account are such requirements as independency of the language on the websites being browsed, support for different web standards, minimal need for maintenance since often these tools are developed as targeted projects rather than commercial projects and their post-development support is often uncertain.

Those requirements serves as the basis for the development of information access tools with voice user interface oriented to motor-handicapped people or people with other types of impairments that may benefit from them as well. It is important that disabled people can often use speaker-dependent recognition and train speech engine to achieve highest possible recognition accuracy.

4 Development and Implementation of Voice Technologies in Lithuania

This chapter briefly summarizes research activities in the area of speech processing in Lithuania. Also there are presented several speech applications that could be used by disabled people also. It must be noted that these demonstrations serves for the demonstrational purposes and it needs to be adapted for the particular requirements and environments. That's why standardization and compatibility issues are discussed also.

4.1 Lithuanian Speech Synthesis Development

Activities in the area of Lithuanian speech synthesis area are underway for several decades. Here we will try to summarize briefly major achievements and current state-of-the-art.

At moment there are two Lithuanian speech synthesis engines – diphone-based synthesizer called Aistis and it's further development - MBROLA based synthesizer called LtMBR. Both synthesizers were mainly developed at the Vilnius University as a result of long term research projects. First version of diphone based synthesizer Aistis dates back to the year 1997. Later this engine was improved using larger number of synthesis units (most recent engine uses nearly 10000 diphones), improved concatenation methods, better stress selection algorithms and better grammar modeling. It may be important to note that Lithuanian language has three different types of stresses and any syllable in the word can be under stress. So in opposite than in many languages correct stressing in Lithuanian is not straightforward task. Aistis synthesizer has relatively good level of intelligibility but suffers from relatively low naturalness of synthetic speech.

Consecutive development of Aistis synthesizer was MBROLA based synthesizer LtMBR developed in recent years. It employs improved synthesis units base, some developments in grammar and stressing but the most important changes are related with the use of MBROLA algorithm to select and concatenate speech synthesis units. This synthesizer achieves significantly higher synthetic speech quality comparing with Aistis engine both in the term of intelligibility and naturalness.

From the application perspective it is important that both Lithuanian speech synthesis engines are compatible with Microsoft SAPI specification and this facilitates the implementation of various applications using speech synthesis. This is significant also since Microsoft Windows operated computers has nearly heaped all computer market in this country.

4.2 Lithuanian Speech Recognition Development

Activities in the area of speech recognition were carried on in Lithuania right from the beginning of 70's. During this period various methods and areas for speech recognition were under consideration. Particular attention was paid to phoneme based speech recognition both in the sense of seeking better ways to describe phoneme and to find methods with stronger discriminant capabilities. These activities resulted in the proposed projection based speech recognition algorithm which could be characterized as the modification of well-known DTW algorithm, speaker dependent fully phonetic recognition of 200 words with very high accuracy level, improved recognition of acoustically similar phonemic units (e.g. nasals in different acoustical contexts) and other achievements. All these achievements are particularly useful for isolated word speaker-dependent recognition. This mode may be viewed as restricted but often is enough to enable impaired people to use many IT tools.

Together with the research of various recognition methods and phoneme discrimination peculiarities a lot of attention has been devoted to implementational issues of speech processing technologies. A decade ago we proposed and implemented a computer-assisted stenography system for Lithuanian parliament. Despite the fact that this system does not utilize speech recognition for transcription of spoken language to written text it had a lot of innovative elements for the time it was developed. Telephony system of inter-city bus timetables using recognition of speech commands has been developed for the telecomm companies for the demonstrational purposes.

4.3 Some Applications of Lithuanian Voice User Interfaces

In recent years a lot of attention we paid to the development of demonstrations that uses speech technologies and have potential for the use by impaired people. All these applications use Lithuanian speech processing engines. Significant interest was paid to the standardization issues. There we see distinction between two approaches for speech enabled applications for impaired people. One approach is based on SAPI and TAPI interfaces. For telephony based applications SAPI interface dramatically reduces the code overhead required for an application to use speech recognition and synthesis, making speech technology more accessible and robust for a wide range of applications. SAPI provides a high-level interface between an application and speech engine. It also provides such tools as speech grammar compiler, which enables to design voice dialogues in XML grammar format without changing the program source code. TAPI interface provides developers with a standardized interface for a wide range of telephony hardware. TAPI eliminates the need to wrestle with device specific APIs and enables well-behaved device sharing between applications. Unfortunately TAPI is very complex and does not include direct support for speech technologies.

Another approach integrates together telephony, speech and internet. So far there are two kits to develop applications using this approach. IBM Web Sphere Voice Server is a VoiceXML enabled speech environment. From other side Microsoft is using SALT specification within its speech server. Each of the specifications has own advantages and disadvantages that were for example analyzed in. The selection of particular kit for the application depends both on the requirements for the application and on the habits of the developer.

One of tasks was the navigation of internet by voice (access to internet information by voice). Preliminary attempts to combine recognition of voice commands, reading of text from internet and text-to-speech synthesis were performed.

Demo version of program, which reads the text from internet and reports the weather forecast by voice after the appropriate voice command, was prepared [6]. The main obstacle for this program development is the problem of useful text extraction from all text presented in the internet pa ge. The removal of HTML tags is not complicated, because the special functions are prepared for such task. The one way to extract the useful text from all text is to use the HTML comments. Such comments point to the beginning and to the end of articles in the internet editions of newspapers "Lietuvos Rytas", "Lietuvos Žinios", but not in all internet pages are supporting comments. This program enables to select the text that will be synthesized: the beginning and the end of selected text are indicated in the special areas for edit. It is adapted to read by voice two internet pages ("www.lrytas.lt" and "www.lzinios.lt"). After pressing, for example, the button "L.Rytas", Microsoft Internet Explorer opens the internet page www.lrytas.lt (old version of page design), the user selects the desirable article, the program analyzes HTML codes, finds the comments, which points to the beginning ant to the end of desirable article, extracts the text without HTML tags and passes this text to Lithuanian text-to-speech synthesizer AISTIS. This synthesizer is realized as ActiveX component.

Another application "Form filling by voice" was created to demonstrate Lithuanian voice dialog possibilities [7] and could be used in such areas, as internet banking, e-shops, data acquisition and registration systems, etc. Without doubts such type of application could be useful for visually impaired or motor-handicapped persons since in a number of situations could improve limits of self-service and independent living. Presented scenario serves only for demonstrational issues and needs to be adapted for particular situation and environment. Speech can be implemented in two ways: using *"Voice Web Studio"* toolkit for *"Macromedia Dreamweaver MX"* as regular speech-enabled HTML webpage or using Microsoft's SASDK as telephony speech-enabled web application. Scenario of voice dialogue in this application: computer (either via computer speakers or telephone) greets user and asks to what company he would like to make the transaction (possible answers: shops "Minima" or "Maxima"). After user's response computer shows the recognized input. In case of incorrect recognition or silence, computer asks to repeat (giving possible answers) or to speak up more loudly (e.g., "I'm sorry I can't hear you, could you speak up more loudly please"), otherwise executes the second part of the voice dialog asking user how much he would like to pay (e.g., one or two Litas). Once all required information is gathered, program asks for confirmation (e.g., "would you like to transfer one Litas to Maxima's account?"). This sample is hosted on Speech Research Lab's website (http://www.speech.itpi.ktu.lt/demo/eb/default.html). Speech-enabled "voice only" telephony application with the same scenario was developed with SASDK. In this section we'll describe main steps of this application creation. First step is opening of *Visual Studio* and creation of *Speech Web Application* project. Second step is buildup of grammar rules. Grammar is a representation of everything the user can be expected to say, with certain selections tagged with semantic properties and values. Grammars are built in grammar editor using *List* and *Phrase* (recognizable words) elements. Each rule in the grammar specifies semantic information in *Semantic Markup Language*. Third step is creation of dialog framework. *Speech QA* (Question-Answer) controls prompt user for information and can also recognize user answers. Properties on the *QA* control also assign information to semantic items for use in responding to the recognized responses.

Next step is to record voice prompts. All the prompts are kept in a prompt database. Prompt transcriptions and recordings are done with *Speech Prompt Editor*. When all transcripts and extractions are ready, it is possible to record the audio data for each transcription. Speech recognition engine processes recorded audio data and creates alignments (marks the end of each word in the audio data). Speech recognition engine processes user input and returns semantic information to *SemanticMap* control. The *SemanticMap* control specifies semantic items to be used throughout the application to contain the semantic information. In order to make voice dialog more effective, application should confirm the responses that it has recognized to ensure that it has not recognized some phrases incorrectly, and to give user a chance to correct the error. To play back the user's responses as a prompt, it is necessary to create a prompt function, which extracts the text from the semantic items that were filled with user's answers to previous questions. This telephony application could be used calling to Speech Research Laboratory by telephone and with prior agreement with group personal.

5 Conclusion

Current situation with the situation of information infrastructure for disabled people in Lithuania is analyzed and presented. Activities of Lithuanian research and development institutions in issuing requirements and adapting environment are shown. Importance of voice user interfaces to impaired people is emphasized. Activities and achievements of Lithuanian research groups in the area of speech processing are presented. Also we presented several demo applications with voice interface that have a potential to be adapted for the use by disabled people. Now Lithuania has good chances to improve information environment for disabled persons using European Union Structural funds, 7 Framework program and other national and European Union funding. It is important to initiate more projects of this kind, particularly implementing voice based interface.

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Mobile Computing in Maintenance Activities: A 'Situational Induced Impairments and Disabilities' Perspective

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Abstract. This paper examines the context of mobile computing within facilities maintenance activities on the basis of an analysis of cursor movement and point and click disruptions that may occur when a number of perturbations are induced by the computing environment. An analysis based on context-aware computing distinguishes between situational induced impairments and disabilities (SIID) whose properties are related to Health Induced Impairments and Disabilities (HIID) such as motion impairment, tremor or spasm. A number of technology solutions based on Assistive Technology interventions for motion impaired cursor movement stabilization are possible approaches to counter SIID in Mobile computing for maintenance environments. A software based cursor movement smoothing method based on statistical state space filtering is presented as an example of a new development of one such approach.

Keywords: maintenance activities, situationally-induced impairments and disabilities, context-aware computing, state-space filtering, kalman filters.

1 Introduction

The development of mobile computing devices that are capable of accessing and capturing information during maintenance activities is a growing concern in research. In both construction and aerospace sectors existing technology supports a range of engineers and maintenance technicians conducting different tasks across different sites. For example, in the field, mobile computing enables technicians and engineers to log onto a Website using a personal digital assistant (PDA) or cell phone and search for preventive maintenance work orders whilst also taking new incoming corrective maintenance orders. Other types of knowledge and information management occurring directly at site during maintenance also typically includes: accessing maintenance manuals, part and component data, recording project data, and using systems hosted on the internet that facilitate rapid communication and collaboration [6, 7, 8].

Supporting information accessibility and capture is necessary across a range of service scenarios and within widely varying site conditions. Context is a continually

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evolving and highly situation-dependent construct [1] and developing technology-based adaptations that can support contextually aware computing requires a different approach to "anytime/ anyplace universality" [2]. Whilst it is helpful to consider context as being recurrent, the dimensions of a situation (and the interactions of those dimensions) result in variability and consequently impact upon human-computer interaction (HCI). Accordingly, consideration of situational variability raises issues of the usability of mobile computing devices whilst conducting maintenance tasks. The complexity of issues surrounding usability emphasises a situated perspective [3] – where it is not only the recursive processes between the individual, environment and computing application that play an important role –but also the notion that "where you are, when you do what you do, matters" [4].

For many mobile computing applications a "point and click" interaction is a key feature of Graphical User Interfaces (GUIs) and such typing and controlling pointing devices are likely mobile computing interface requirements in maintenance scenarios where information retrieval and capture is essential to service operations and efficacy. This interaction is based on the activation of 2D regions of the display screen such that if the cursor enters this area and a mouse click event is recorded a specific function can be triggered. This basic interaction is the primary focus in conventional HCI approaches and corresponds, for example, to button pushes, hypertext link activation or to simply to select a position point. However, accurate tracking cursor control is often also required in modern program interfaces where the 2D position of the cursor is constantly updated and controlled by movements of the input device whether a mouse or touch screen stylus. This is the case for using scrollbars and dragging regions of text or cells of spreadsheets but also plays an important role in drawing or image manipulation. In maintenance tasks such interaction with 2D representations can be important in referencing complex physical and functional interdependencies of component parts whilst onsite.

Clearly, this can be difficult for somebody with movement impairment, as in Health Induced Impairments and Disabilities (HIID). For example, motion-impaired users with conditions such as Cerebral Palsy, MS, and the results of head injury or stroke have various symptoms such as tremor, spasm, coordination difficulties, weakness, and reduced dexterity ensuring that certain aspects of computer use can be difficult. However, these motion difficulties or their functional analogues are also likely to occur as a result of situational effects arising from the use of mobile devices in harsh or sub-optimal maintenance environments. Sears et al. [5] outline the basis of SIID using the International Classification of Functioning, Disability and Health (ICIDH-2) classification of impairment: -

> "…impairment refers to a loss or abnormality of body structure or function and disability refers to difficulties an individual may have in executing a task or action."

This applies in HCI, when environmental factors are considered and illustrates how hands-busy situations can result in similar disabilities, depending on the input technology. Both environment and the nature of an activity can lead to SIID. For example, environmental factors such as accelerations, vibration, noise, temperature and lighting. Sears et al. [5] also distinguish cognitive factors including attentional demands resulting from multiple perceptual and reasoning tasks; working memory overload resulting from time and perceptual limitations during a control task such as driving a car. This suggests that SIIDs may be temporary and dynamic which itself is problematic due to the complexity of developing strategies to overcome these kinds of impairments. That is, unlike those individuals who develop strategies to overcome health-related disabilities, the temporary and dynamic nature of the situation makes it more difficult to overcome SIID with mobile computing. In fact, it is possible that SIIDs may, at times, be impossible to overcome due to their cognitive demand in a control context, as in the case of use of a mobile phone whilst driving, known to be statistically associated with motor vehicle collisions [13]. Motion based SIID, such as the availability of only one hand or imposed body motion raise the further possibility of physical compensations strategies. We address three related issues-:

i. what characterises interactions between the individual, environment and computing applications?
ii. what type of situationally induced impairments and disabilities (SIID) may be encountered?
iii. how can technology-based adaptations support context-aware computing and facilitate effective solutions to SIID?

The remainder of this paper is divided into three main parts. Section 2 presents an example scenario from building maintenance. Section 3 then examines the characteristics of– and interactions between– individual, environment and application dimensions so as to explore aspects of SIID in maintenance environments. Section 4 looks at an effective solution to SIID based on technology-based adaptations of cursor movement interaction, whereby a method based on trajectory estimation and filtering is presented. The paper closes with a discussion of our key considerations and long term objectives of this research.

2 Facilities Management and Mobile Computing

Maintenance tasks are dispersed throughout buildings, across complexes, estates and cities. As a result engineers and maintenance technicians need to access and capture information at the site of the task. Such information is varied and can include work orders, service manuals and visual representations of component parts. Sophisticated facilities management (FM) services now utilise mobile computing devices so as to carry out a range of knowledge and information management activities, including logging and tracking corrective, preventative and predictive maintenance, recording data for root cause analysis and updating maintenance databases – all whilst being at site.

The ability to retrieve and capture information whilst onsite is becoming increasingly crucial for the competitive advantage of FM via increasing accuracy and decreasing time and costs that might have otherwise been incurred as a result of having to return to base. As a result the past decade has seen the introduction of mobile computing devices in FM. However, a significant barrier in using mobile computing devices for onsite maintenance lie in the fact that the conditions of maintenance activities are often subject to noise, dust, poor light, vibration, and temperature. Compared with other industries, this has proved a disadvantage in giving maintenance technicians' adequate information technology (IT) support. Mobile computing devices in maintenance environments require devices with interfaces which are durable, efficient and usable when subject to a range of harsh environmental conditions. As a result, this has in part reduced the impact of IT on the way the maintenance tasks actually work. However, the personal digital assistant (PDA) has recently reached advanced levels of maturity and usability. The PDA's memory capacity, speed, wireless networking, size and long power independence, as well as its degree of hardware and software standardisation, provides a powerful tool that can potentially meet the requirements of knowledge and information management during the day-to-day maintenance activities of engineers and technicians. It presents an integrated and systematic approach, whereby connections of PDAs make wireless data transmission and network-based document management a reality for the use of maintenance technicians. Ruggedised cases and designs make touch screen, stylus interactions feasible permitting both "point and click" and cursor movement interactions.

2.1 Maintenance Tasks and PDAs

Handheld (i.e., PDAs with keyboards), and palmtop, (i.e., PDAs without keyboards) devices are capable of supporting the wide range of FM-oriented software utilised during maintenance tasks covering wireless web-based communication, text and spreadsheet processing, database access, drafting and design, and image processing.

The following description portrays a typical building maintenance scenario as observed in the field. The task commences once the facilities manager has uploaded daily work orders to the Internet. The mechanical engineer/ maintenance technician is informed by an SMS message of a new daily plan and acquires all relevant information regarding the maintenance task from a web file system. Once the maintenance task is complete, these files are uploaded to a web file system and the facilities manager is informed. As such this scenario is characterised by: (i) the need to retrieve of capture information at site; (ii) user interaction using cursor point and click and/or cursor movement via a stylus, and (iii) harsh conditions:

Corrective and Preventative Maintenance Scenario. Inspection and analysis of the condition of building's heating system so as to correct operating efficiency and avoid future maintenance problems and breakdowns.

- *Technician's Task*: Maintenance technician evaluates current performance of the system, compares this to the original specifications, measures air system discharge quantities, static pressures and sequencing of heating and cooling valves. This data is recorded and then used to verify control operation and ensure compliance with latest Standards and Guidelines.
- *Work Conditions*: Distinct vibration characteristics from machinery of heating systems, confined and restricted space, and poor lighting. The technician must also maneuver between hazardous mechanical equipment and interact with measurement and scanning equipment.
- *Computing Applications*: A Palmtop PDA and a range of software is utilised during this service task including Internet Explorer; Pocket Word; Pocket Excel; and Autodesk OnSite View (for viewing drawings). This software requires the user to

interact using cursor point and click and cursor movement via a stylus as the input device.

2.2 Maintenance Tasks, Interaction and SIID

The interfaces of commercially available PDA's used in onsite maintenance tasks are currently unsuitable under conditions such as dust, strong light, humidity, vibration and acceleration, occurring through normal handling by engineers and technicians at a building site. Users can recognise certain aspects of the context and adapt. Maintenance technicians can stop walking if motion causes difficulties entering information, mute their phone if the conversation hinders speech-based input, or even switch to a different input device. The user may be able to turn on additional lights, turn off a radio, or move position, if necessary. However, the context may also limit the user-based adaptations that are feasible. For example, a maintenance technician must continue with their primary task of providing servicing even if this interferes to with their record keeping activities, as in the case of restricted access environments or when maintenance requires considerable environmental exposure. Such situations may lead to an inability to use both arms or hands, preventing two handed use of a PDA and stylus, as illustrated in Figure 1, or may render screen displays unreadable due to the angle or brightness of the display. Vibration or body movement may prevent accurate stylus positioning and hence cursor use.

Fig. 1. Stylus input requires two handed use in a static environment where the screen is visible

3 The Context of Interactions

A model of 'Context Space' proposed by Sears *et al.* [5] is used here to represent and understand the interactions between: (i) maintenance technicians, (ii) supporting mobile computing devices and (iii) maintenance situations so as to explore how they adapt to environmental factors. In this section we utilise this model to represent the interactions of the maintenance scenarios highlighted in the previous section.
Figure 2 represents the Sears et al. Context Space model which is based on a combination of the 3D model proposed by Schmidt et al. [24] and the definition proposed by Dey et al., [25] that separate contextual information into three categories: human, environment, and application.

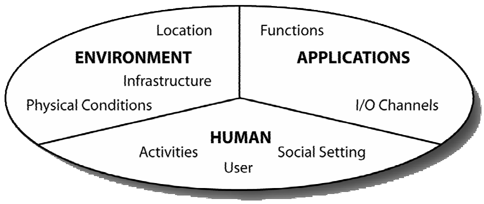

Fig. 2. The Three Dimensions of Context Space

Sears *et al.* [5] enumerate the importance of understanding variability using the interaction of three dimensions of the situation. While most research continues to focus on a single dimension, the concept of SIID can only be addressed if the cumulative effects of all three dimensions are considered. Sears et al. describe this model:-

> "The human dimension addresses the characteristics of the user, […] current social issues, […] and users' current activities. The environment dimension includes location, […] physical conditions, […] and the infrastructure. The application dimension includes the available functions, […] and input/output channels."

3.1 Cumulative Effects of Human, Environmental and Application Dimensions

Using the example maintenance scenario in Section 2 we examine characteristics and interactions of the human, environmental and application dimensions. Applied here, when the maintenance technician is attempting to complete the maintenance task, the *application dimension*, i.e., PDA, software and input device, defines how the task can be completed due to information requirements. Specifically, in this case we examine the stylus input. The *environmental dimension* may make this input technique more or less attractive, i.e., stylus input is not effective in this confined or dynamic environment which is subject to vibration. Similarly, the *human dimension* alters the efficacy of various solutions, i.e., physical disruption and movement caused by interacting with mechanical equipment as well as measurement and scanning devices hinder the use of stylus-based input; whereby special purpose interface adaptations based on assistive technology may be seen as undesirable or stigmatic.

The SIID that may be suffered during the example maintenance scenario can only be addressed if all three dimensions are considered and, more importantly, the interactions among these dimensions are understood. For full and effective interaction with the necessary application, functions and I/O channels in both cursor movement control and point and click interfaces are necessary.

4 Effective Solutions

Performance in pointing tasks is most commonly evaluated using speed and accuracy. Although traditional measures may show that a difference exists between conditions for impaired movement, establishing why they exist is more likely to be accomplished by analysing the path of movement throughout a trial in conjunction with conventional measures [11], [9]. Users may trade speed against accuracy, achieving an optimised number of sub-movements that is often about two with able-bodied subjects [16]. Such a model may also be applicable to the analysis of cursor movement [17] where impaired motion can be characterised as consisting of multiple slow trajectory jumps separated by breaks during which users assess their own performance under conditions of perturbation from their motor system.

Most academic theory in HCI and user modelling concentrates on alternative input options for able-bodied users. There are a number of original input approaches such as head movement input [14], eye-gaze and EEG scanning [15], but these are often expensive and frequently do not match the typical actions required to interact with a mobile GUI [5]. An approach that is matched to the mobile user's preferred input device may be more productive. One approach that offers significant potential is haptic feedback, particularly force feedback for modification and damping of perturbed movement [10], [9]. However in the context of mobile computing in a construction and maintenance environment, fixed input devices such as mice are unusable and haptic control of input devices on PDA's currently unavailable.

Another related possibility, however, is the modification of input cursor position and visual feedback resulting from software assisted real-time cursor smoothing. This approach could be tested with data from HIID motion-impaired movement. We have analysed some motion-impaired cursor movement data from previous Assistive Technology studies using state space filtering. Cursor movement data derived from motion impaired users' point and click trials were utilised to test the effectiveness of advanced techniques for enhancement, namely state-space filtering. The aim was to develop and evaluate software methods of enhancing SIID motion-impaired movement, such as those found in maintenance environments, for dissemination to the motion-impaired and software development communities.

4.1 Trajectory Estimation and Filtering

For several decades researchers have studied the estimation of state trajectories in state-space or dynamical models ('filtering'), by means of Bayesian filtering methodologies using such classical methods as the Kalman filter. In recent years, the massive increases in available computational power have led to rapid advances in both tracking methodology and applications; in particular, the development of Sequential Monto Carlo (SMC) methods that are readily able to handle non-linear, non-Gaussian models in a vast range of applications from audio signal processing, through to computer vision and robotics [18], [19], [20]. These methods are particularly strong candidates for the cursor movement application, since they automatically store a randomised range of hypotheses about the tracking parameters when the data are ambiguous

This approach is an innovation in enabling access to computers for motion-impaired users that has not been researched in depth before. Previous work with able-bodied interface use has looked at trajectory analysis for prediction of the users' intended target [21] and trajectory prediction for telepointers under conditions of network latency delays [22]. In the former approach, able-bodied trajectories proved to be essentially linear and velocity predictable while in the latter, trajectories for writing-like gestures were successful predicted up to delays of 80 msec and could be smoothed using Kalman filter predictors. Both able-bodied physiological tremor and pathological tremor, which may have an analogue in SIID resulting from vibration, have been addressed using Fourier software methods [23] with success, indicating that software approaches are feasible for predictable motion-impairments with a repetitive oscillatory nature. By addressing a fundamental element of the human-computer interaction; cursor movement in SIID represents an original and novel approach to enabling computer access in mobile contexts. The increased use of mobile computing systems has generated a need for vibration-insensitive input interfaces. The recently matured status of methodology in efficient, on-line filtering, using methods such as particle filters and their approximations, combined with readily accessible computational power, means that it is a highly appropriate time to adapt these methods into interface systems in new ways.

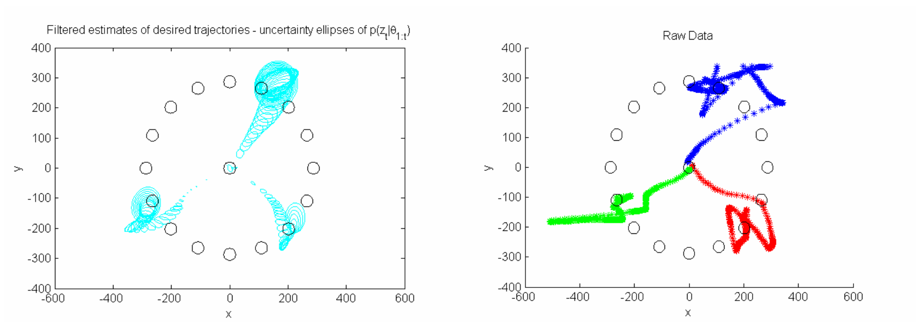

Fig. 3. The right hand traces show erratic cursor movements aimed at point and click on circular targets; left hand traces show the results of sequential monte-carlo filtered smoothing of the same data as confidence ellipses

We present in Figure 3 some results from preliminary analysis of a range of motion impaired cursor movement traces under different conditions and assess the effectiveness of the technique. On the left hand side: filtered traces, showing confidence ellipses obtained from a sequential Monte Carlo filter of cursor inputs. While on the right hand side: the corresponding original noisy trace data with excessive deviation, overshoot and perturbation is shown. The filter has successfully 'smoothed' much of the erratic trajectory behaviour and quite clearly identified the user's intended destination, despite the ambiguity of the data.

5 Discussion

New developments in mobile computing are finding applications in the use of PDA to support facilities maintenance activities. A context-aware computing environment can, in principle, support the networking, application and I/O requirements of the hostile environments that may involve vibration, humidity, variability in lighting and physical motion restrictions. Following a SIID analysis, applications may be devised to match their functionality and input requirements to the context, including the structure of maintenance tasks and onsite networking infrastructure. Adaptive behaviour can compensate for poor lighting, attentional demands and stress. However, cursor-based point and click and cursor movement needed to operate mobile touch screen interfaces with, or without, a stylus are very susceptible to SIID perturbation from movement, hands busy situations and dynamic changes of position. This is analogous to the motion impairments produced by motion-impairment resulting from health induced impairment and disability. Addressing this we explored how technology-based adaptations surrounding cursor movement interactions can facilitate effective solutions that reduce errors and increase the efficiency as well as efficacy of interaction. We discuss the benefits of statistical state space filtering techniques [11] to situationally induced factors, such as movement perturbations, that impair the usability of point and click devices and show that they are in principle capable of filtering highly perturbed cursor movements from HIID motion impaired computer users. Further, accelerometers may be used to sense the environmental context of a mobile interaction both from the users body, vehicle or the device itself [6]. If the user is moving, stylus-based input can be modified. If the movement becomes such that filtering or smoothing is no longer effective, alternative forms of input could be provided. The long term objective is to develop and evaluate methods that can counter mobile device SIID for dissemination to service and maintenance as well as software development communities. The case study presented in the first section, examined in conjunction with the reviewed cursor filtering techniques, indicated that this is a possible basis for context-aware support of mobile SIID interactions in a facilities maintenance environment.

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Establishing Design Best Practices for Users with Cognitive and Learning Difficulties

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Abstract. In many respects, cognitive difficulties and learning impairments are the poor relation of Universal Access (UA) research. Research into emotional impairments is even less common. A simple review of almost any general UA or Assistive Technology conference proceedings will typically show a strong bias towards sensory (vision and hearing) impairment, with a strong minority addressing motor impairment issues. This is an improvement on the situation a few years ago where the vast majority of the papers would be based solely on blindness, despite that particularly impairment constituting only 14% of people with a vision impairment and 2% of the overall prevalence of functional impairment in the general population [7]. This paper discusses the reasons why such a disparity exists and summarises the outcome of an International Symposium, hosted by the IBM Human Ability and Accessibility Center, to establish the state-of-the-art in research and best practices for supporting access for users with cognitive difficulties and learning impairments.

Keywords: cognitive impairment, learning difficulties, design best practices.

1 Introduction

In October 2005, the IBM Human Ability and Accessibility Center and T.J. Watson Research Center hosted an International Symposium on “Cognitive and Learning Difficulties and how they affect access to IT systems”. The central premise of the symposium was the recognition that Cognitive and Learning Difficulties have a profound impact on a person’s ability to interact with information technology (IT) systems, but that little support is currently being offered by those systems.

By bringing together internationally renowned experts from a variety of different, but complementary, research fields, the Symposium aimed to provide a complete overview of the issues related to this topic, including:

- the symptoms and causes of cognitive impairments from a medical perspective;
- the effects of aging on the process of learning and acquiring new skills – a particularly relevant topic when considering the use of IT;

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- the level of cognitive demand placed on people by the modern information society and how those with cognitive disabilities should be accommodated by IT systems;
- cognitive user models and how these can be used to highlight the different cognitive functions that need support when using IT;
- a practitioner-oriented view of how cognitive impairments have a direct impact on the workplace, in particular highlighting the comparatively high proportion of people with such impairments that are unemployed;
- the potential for Universal Design in education by addressing the process of learning and the challenges of structuring IT to maximize its support of that process;
- the educational divide, with an emphasis on the social and societal factors that also play a role in a child's educational development;
- the IT available for adult learning;
- how an interaction design process can be modified to be more responsive to the needs of users with cognitive disabilities; and finally,
- examples of e-Learning tools that have been developed using a philosophy that the learning should be structured as a game to support users with learning difficulties in acquiring practical skills.

2 Defining "Cognitive and Learning Difficulties"

The term "cognitive and learning difficulties" is not a standard phrase in the universal access vocabulary. It was a term that was adopted by the organisers of the Symposium precisely because it did not have a specific set of definitions, and thus preconceptions, associated with it. This was very important for the success of the Symposium, because it was deliberately neutral and non-judgemental. The aim was to tease out the differences in assumptions and presumptions about this topic prevalent in the different research fields. Therefore, a good starting place is to examine the different interpretations of this topic.

It was quite clear that there are no uniform definitions of many commonly-used terms. "Learning difficulty" and "cognitive impairment" have different meanings not only between different research communities (such as educational, medical, design, etc.), but also between different cultures and geographies. Even supposedly basic concepts, such as "cognition" or "thinking", do not have universally accepted definitions.

Among the medical community in the US, a cognitive disability is generally accepted as arising from an impairment that affects IQ, invariably lowering it. IQ is a well-recognised concept, but also has no universal definition. For the purposes of this paper, it can be best regarded as an indicator of overall "cognitive capacity" or even "thinking power" – the analogous cognitive equivalent of the horsepower and torque of an automobile engine. Under this framework, a learning difficulty (or disability) is one that affects a person's capability to acquire, process or utilise knowledge such that any of these capabilities are not performing at the level that would be ordinarily expected for that person's IQ. However, this definition results from the way that different medical conditions are diagnosed and treated.

Elsewhere, both geographically and by discipline, the two concepts (learning disability and cognitive disability) are considered to be more interrelated. Indeed, some researchers argue that the terms are so loosely defined that the differences between them are difficult to substantiate. As far as access to IT systems is concerned, the exact classification of a difficulty as "cognitive-" or "learning-" based is not of that much interest, or even use, for designers. Instead, what really matters is a definition of what the user is capable of achieving. In other words, what is of most value to designers is a functional description of the user's capabilities. This functional description approach is very similar to that taken by the International Classification of Functioning, Disability and Health [6]. Note that the emphasis here is on what the user can do. There are two principal reasons for this:

1. By focusing on what a user can do, the user is not described in terms of a capability deficit. This distinction is important. Firstly, thinking of users in terms of deficits is not socially acceptable or respectful. Secondly, the negative connotation of regarding someone with an impairment as being somehow less than the "mainstream" users (itself a doubtful semantic classification) tends to relegate the needs of that user in the mind of the designer and typically moves accessibility to the sidelines of the design process.
2. Knowing what a user cannot do is not actually that useful for designers. For example, if a product is designed such that it places greater demands on the user than the user's own capabilities can meet, then a deficit model simply tells the designer that the user cannot use the product. However, it provides no further information than that, whereas a capability model provides the designer with detailed information about how the product demands relate to what the user can do. This provides much more useful information, as it indicates the magnitude of reduction in product demands required to allow a user to use it successfully.

This focus on the user capabilities also resolves other semantic issues. For example, the question of whether behavioural issues should be addressed can be answered by identifying whether the specific behavioural issue has a direct impact on the user's ability to use the particular IT system under consideration. Similarly, societal factors, such as a user's economic status, culture, language, ethnicity, etc., can also be recast in terms of the direct impact on the user's capabilities with respect to their ability to access and use the particular IT system. The corollary of this is that any aspect of those factors that does not affect how the user accesses a particular IT system in some way can be trimmed from the data that the designer needs to consider. This ability to provide only the relevant data is also important, as it allows designers to focus on what it truly important in terms of ensuring accessibility, rather than simply overwhelming them with masses of data and challenging them to identify what is important and relevant for themselves.

In terms of this paper, the umbrella term "cognitive and learning difficulties" (C&LDs) is used to represent the set of cognitive functions relevant to the design of a nominal IT system.

3 Prevalence of Cognitive and Learning Difficulties

Cognitive and learning difficulties are remarkably prevalent. However, they are not as immediately observable as many other functional impairments. Someone using a wheelchair clearly has a motor impairment, be it temporary or long-term. Similarly, someone using a white cane is highly likely to either be blind or have very low vision. Someone who has difficulty reading, though, is a lot harder to identify, short of asking them to perform a reading task, or asking them directly if they have such a difficulty. In that respect, cognitive and learning difficulties can be considered something of a "hidden" disability.

The US Census Bureau's 1999-2004 American Community Survey [12] asked respondents if they had any kind of disability, defined here as "*a long-lasting sensory, physical, mental or emotional condition*" [1]. From this survey, when asked if they had "*a physical, mental or emotional condition lasting 6 months or more that made it difficult to learn, remember or concentrate*" 5.2% of all US adults agreed with this statement [1].

In Great Britain (GB), the Disability Follow-up Survey (DFS) [4] to the 1996/97 Family Resources Survey [10] was designed to update information collected by the earlier Survey of Disability in Great Britain [8]. The DFS collected data through interviewing 7500 adult respondents who had been selected to be representative of the adult GB population. The respondents were asked to self-report a range of impairments and difficulties and then rate them on a scale of severity.

From the DFS it can be seen that 5.6% of the GB adult population self-reported some kind of cognitive impairment. It should be noted that this figure has been derived from the aggregation of two separate criteria from the DFS, namely Communication and Intellectual Functioning. Both of these criteria were assessed through a series of questions or statements.

For example, the statements for the Communication criteria ranged from "*Other people have difficulty understanding him/her / Has some difficulty understanding what other people say or what they mean*" (severity score = 1.0) through to the most severe case (severity score = 12.0) "*Is impossible for people who know him/her well to understand / Finds it impossible to understand people who know him/her well*".

For the Intellectual Functioning criteria, the respondents were asked to agree or disagree with a series of 11 statements such as "*Often forgets what was supposed to be doing in the middle of something*" and "*Cannot read a short article in a newspaper*". The sum of the positive responses were converted into the corresponding severity score (sum = 1.0, severity score = 1.0; sum = 11, severity score = 13.0). The full set of questions asked and data analysis can be found in [7].

The figure of 5.6% from the DFS is most likely conservative, as cognitive impairments can be difficult to self-diagnose and report. It is worth noting, however, that the 5.6% of GB adults who self-reported a cognitive impairment is very similar to the 5.2% of US adults who self-reported a "mental disability" from the 1999-0224 American Community Survey.

4 Why C&LDs Are Not Widely Researched in Universal Access

For many years blindness was the most commonly research functional impairment in terms of Universal Access and human-computer interaction. It still is a very common focus. For example, one of the most famous sets of accessibility guidelines available is the Web Content Accessibility Guidelines (WCAG) promoted by the Web Accessibility Initiative (WAI) of the Worldwide Web Consortium (W3C) – [13]. The WCAG 1.0 guidelines offer fourteen specific guidelines for web page authors to help them ensure that their pages are accessible. Of those 14 guidelines, 11 are relevant to vision impairment, and blindness in particular, whereas only two – Guideline 13: "Provide clear navigation mechanisms" and Guideline 14: "Ensure that documents are clear and simple" – explicitly address the need to consider the cognitive processes involved in accessing, navigating and understanding the content of web pages.

The comparative lack of priority on addressing the needs of users with cognitive and learning difficulties with WCAG 1.0 is representative of UA research generally, with the notable exception of Education. There are several likely explanations for this, such as:

1. **C&LDs are often difficult to diagnose** – while someone who has very restricted vision or hearing can be diagnosed via a veritable battery of tests, many of them very straightforward to administer and interpret, C&LDs often do not, partly because,
2. **many C&LDs do not have a universal diagnosis** – debate still rages about what constitutes conditions such as dyslexia, attention deficit disorder (ADD), attention deficit hyperactive disorder (ADHD), etc.
3. **many people with C&LDs are reluctant to admit to having them** – while the general population is usually understanding towards companies that make an effort to employ wheelchair users, older adults, etc., there is still an innate suspicion of people with C&LDs that their ability to perform the tasks necessary to complete the job are deficient somehow.
4. **designing for C&LDs is not easy** – not having a clear, unambiguous statement of the condition that is being designed for makes it very difficult to design effective solutions.

This is extremely unfortunate given the central role that cognition plays in all human-computer interaction.

5 The Role of Cognition in HCI

IT systems are often quite complex and the underlying model of interaction is often "virtual". In other words, there is often no inherently observable physical connection between action and reaction. The users have to infer the connection and establishing this inference can be problematic, especially for novice users. Even where the interface provides a clearly elaborated cause-and-effect representation, the poor bandwidth of sensory communication between the IT system and the user often degrades the observable quality of the interaction.

For example, many people find it is much more difficult to drive a car in a racing game using a mouse and/or keyboard, than it is to drive one for real. The racing game provides basic and very low-resolution visual feedback – especially when compared with the rich feedback experienced when actually sitting in a car. This limited feedback is often supplemented by exaggerated sound effects, and maybe force feedback through a specially-enabled joystick or steering. In these cases, the designers are relying on the user's meta-knowledge to help the user successfully interpret what these cues are meant to represent. In the case of racing games, this is sometimes sufficiently successful that a large number of the intended users are able to understand what the game is trying to convey. However, whether or not they succeed is dependent on the user having an accurate model of the interaction and the ability to infer meaning from artificially generated feedback.

If the user does not have an accurate mental model of the interaction, or if the ability to infer additional meaning is impaired in some way, then the user can end up lost and confused by the interaction. Interface designers have been aware of this disconnect for some time and often try to imbue an interface with an equivalent to a causal property by using real-world metaphors to provide affordances [9] to the user.

This approach works to a certain extent, but is not infallible. For example, not all computer processes have a real-world equivalent. Even when suitable real world equivalents ("metaphors") are available for individual elements of the interface, those metaphors are not always consistent with each other, e.g., opening a file via a menu in a window on a desktop [10]. Many experienced computer users are comfortable with these metaphors, but many novices find these concepts very difficult to comprehend. Thus, developing a mental model of the interaction based on observations of how the system behaves is complex – especially for novices and for users with cognitive and learning difficulties.

5.1 Models of Cognition

In "The Psychology of Human-Computer Interaction" Card, Moran and Newell [3] proposed that all interaction with a computer consists of three basic components:

- **Perception** – "sensing" that an event has occurred
- **Cognition** – "thinking" about the event that has been perceived and deciding on an appropriate response
- **Motor** – "acting" on the result of the cognitive process

Once the motor action is complete (or even during its completion), the user is already perceiving the system response to that action and thus the cycle repeats ad infinitum. This description of human-computer interaction was succinctly described in the Model Human Processor [3].

More sophisticated models of human-computer interaction decompose this umbrella "cognitive" function into its functional components. Adams' Simplex II model replaces "cognition" with 9 separate functions [2]:

- Working memory;
- Emotions and drives;

- Perception;
- Output;
- Feedback;
- Complex output sequences;
- Cognitive models;
- Long-term memory; and, tying them all together
- Executive functions.

Each of these functions can be further subdivided into components and this it is easy to see how complex cognition is and why designing effective methods of assistance for users with C&LDs can be so difficult. In an attempt to help designers, the Symposium focused on identifying current best practices in this area.

6 Best Practices When Designing for Users with C&LDs

During the discussion sessions of the Symposium, the participants were asked to propose specific recommendations for designers and examples of what they considered to be best practice. This section of the paper summarises those discussions.

- **Find the required set of demands to complete the task compared with what the IT system demands.** When designing any IT system, it should not place any additional functional demands on the user beyond those that are required for the completion of the task itself.
- **Involve users with cognitive and learning difficulties in the design process.** It is well known that adopting user-centred design practices leads to more usable products and by including users with a diverse range of capabilities in the user panels, the resultant product should also be more accessible.
- **Use clear language.** For users with cognitive or learning difficulties, the use of clear, unambiguous language, reinforced with clear images where appropriate, is essential.
- **Use "scaffolding" techniques.** For many people with cognitive or learning difficulties, rote learning presents significant difficulties as it requires the memorisation and recall of comparatively unrelated and complex facts. Instead, it is much more effective to use "scaffolding" techniques that build a support structure beneath each new concept, which consists of strong links to other, already learned, bits of knowledge and links to alternative explanations of the new concept or fact.
- **Use positive reinforcement and provide feedback.** Users with cognitive or learning difficulties often have low self-esteem, and so frequent positive reinforcement, using encouraging language to tell them how they are doing, not only improves their self-esteem, but also makes them more willing to stick to a task and see it through.

- **Recognise the use of coping strategies by users and try to complement, support and augment these wherever possible.** Most people with some form of functional impairment or difficulty develop coping strategies for adjusting a task so that they complete it. They are a terrific source of potential inspiration for designers, because they indicate possible alternative mechanisms for completing a task by reducing the demands placed upon the user. The designers can simply re-design the IT system to include the coping strategy as a supported option.
- **Design for people's learning strengths, not for their weaknesses.** Just because someone has a C&LD, this does not mean that all of their cognitive or learning capabilities are affected. It is best to find out which ones are affected and which ones are not and then design IT systems to utilise the latter. For example, older adults often have excellent crystalline intelligence, but poorer dynamic intelligence. Similarly, dyslexics have difficulty reading, but often respond well to visual or auditory learning.
- **Design for flexibility.** Providing information in multiple formats means that someone who has difficulty processing one format may be able to find a more accessible format to meet their capabilities. Work by Shneiderman [11] indicates how interfaces can potentially be developed with sliding levels of complexity, by strategic hiding and uncovering of varying levels of functionality. This is an idea that is worth researching further.
- **"Chunk" information.** Many people with C&LDs find it difficult to process long reams of text or other information sources. Instead, information that is broken down into "bite-size" chunks is considerably more accessible to them.
- **Keep hierarchy depths to a minimum.** Trying to remember multiple levels of hierarchy in menu structures, help pages, etc., presents a significant challenge to many people with cognitive or learning difficulties. As a general rule, try to restrict hierarchy depths to less than 2.
- **"Help" needs to be concrete, repeatable, focused and consistent.** Help systems need to provide alternative and flexible forms of explanation, and ideally be grounded in concrete examples, e.g., "Give me an example of this done." Using actively linked text and images to reinforce each other can help. Finally, the help also needs to be context sensitive, wherever possible, and chunked.
- **Present assistance options carefully.** The "range effect" implies that people will typically prefer to choose options in the middle of a range of choices. This illustrates that there is an effect of how options are presented on the likelihood of them being selected. In the case of assistance options, users will often be focused on not wanting to appear to be "different" from what they consider to be the "norm". Thus, if the assistance options look to be different from the "norm", then users will often be reluctant to select them. However, if they are presented as a neutral, non-judgemental range of options, then users are more likely to choose them.
- **Avoid "feature creep".** The continual addition of new, and often unnecessary functions to an existing IT system, is particularly bad for older adults. Their reliance on "crystalline" intelligence makes the continual

re-learning required by feature creep particularly time-consuming and potentially annoying.

- **Try to be consistent.** Use of, for example, a universal "exit" button across different applications [5] makes it easier for users to learn and, later, trust systems.

7 Conclusion

This paper has presented the argument that cognitive and learning difficulties are remarkably prevalent and also can have a significant impact on a user's ability to interact successfully with information technology systems.

To provide immediate assistance to designers, a series of current best practices have been presented. These represent the collected knowledge of several internationally renowned researchers in this area and have been designed to be as accessible to designers as possible while avoiding the need for in-depth knowledge of the different conditions that can lead to C&LDs.

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Technology and Regional Social Structures: Evaluation of Remote Sign Language Interpretation in Finland

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Abstract. During the years 2001–2004 STAKES implemented a national development project VETURI - networking interpreter services -. Its objective was to improve the preconditions for the availability and quality of interpreter services. The starting point for this development work was to provide a service with a sufficiently large population base, in the form of regionally co-ordinated network co-operation of a variety of stakeholders. A part of the service in the project was given as remote videophone service. Remote interpreting made an interpreter's work easier because she did not need to travel and was able to work from a familiar work location. New ways to produce services enabled the growth of remote interpretation service. Larger population base and service resources made it possible to bring service also there where it has not been earlier.

Keywords: Disability, Interpretation service, hard of hearing people, ICT.

1 Introduction

The aims of Finland's disability policy are equitable treatment and support for life management, working capacity, functional capacity and independence. Measures include services, rehabilitation and removal of barriers. The aim is for all general services to be appropriate and sufficient for all citizens; special services such as housing, assistive devices, transportation and interpreter services are never a first resort.

A personal service plan is drawn up for each disabled person to clarify the services and support he or she requires. Officials of the municipality together with the client and his or her carer or relatives prepare the plan. The service plan is designed to improve the clients' autonomy and their possibilities to influence their situation. A counsellor, who is tasked to accommodate the various services together and call meetings of other relevant officials, checks the plan within specified timeframes [6].

1.2 Interpretation Services

People whose hearing is severely impaired, who are deaf and blind or who suffer speech disabilities are entitled to free interpretation services arranged by their municipality. Interpretation services are provided in sigh language or, for example, using new technology [6].

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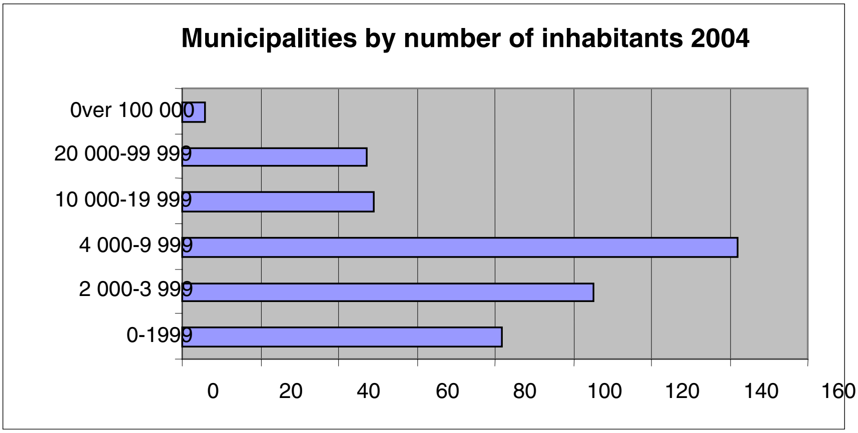

Fig. 1. Municipalities by number of inhabitants 2004 in Finland

The responsibility for the arranging of interpreter services lies with municipalities, which must arrange a minimum of 120 hours of interpreting per year for deaf sign language users (1.1.2007 180 hours). There were 432 municipalities year 2005 (417 year 2007) in Finland. Most of municipalities are rather small, the number of inhabitants is under 10 000 [1]. The population is concentrated in South-Western Finland and eastern and northern parts of Finland are sparsely populated, 2-7 persons per km^2. Also the distances are rather long. About 30 % of all municipalities did not give interpretation services in 2005 [5]. This means that usually small municipalities don't have the skill.

Table 1. Interpreter service recipients during the year [5]

1994	2000	2003	2004
2716	3137	3351	3398
% of the population			
0,05	0,06	0,06	0,06

2 Development Project

During the years 2001–2004 National Research and Development Centre for Welfare and Health (STAKES) implemented a development project VETURI - networking interpreter servioces - commissioned by the Finnish Ministry of Social Affairs and Health. Its objective was to improve the preconditions for the availability and quality of interpreter services set by the Act on Services and Assistance for the Disabled, throughout Finland. The starting point for this development work was to provide a service with a sufficiently large population base, in the form of regionally co-ordinated network co-operation of a variety of stakeholders [4].

A part of the service in the project was given as remote videophone service. In the project videophone consisted of pc-computer, video camera, ISDN or IP connection and videophone software. In the beginning there were more ISDN connections but later most of them were changed to IP connections. The project did not provide any new equipment but both the customers and services centres used their own equipment.

Fig. 2. Videophone workstation [3]

Interpreter was using one workstation and user contacted her/him from another workstation. Usually hard of hearing or death person uses her/his own workstation to order interpretation service. Workstation can be also in some other place for instance in social office. Then often social worker takes connection to interpreter and dialog between hard of hearing customer and social worker begins via interpreter. This is called a two point service.

A multipoint service started during the project and this is a goal. There all three persons can be in the different places. The service centre takes all the calls. The interpretation service is decentralized to different interpretation organisations and locations in the country. A duty list is prepared for interpreters. The caller can see the list of available interpreters and can connect to the first in the list or someone familiar. In some cases the server in the service centre has software for invoicing. It has records of clients, interpreters and the municipalities which pay the service. According to time used and other circumstances program calculates the bill and sends it to responsible municipality.

Requirements to equipments and software are: basic pc or laptop computer, video camera, ISDN (2x3x124 Kb) or Internet connection (2x 384 Kb, recommended 1 Mb), videophone software with voice communication facility (recommended also text) (frame rate minimum 18 p/sec, recommended 25 p/sec).

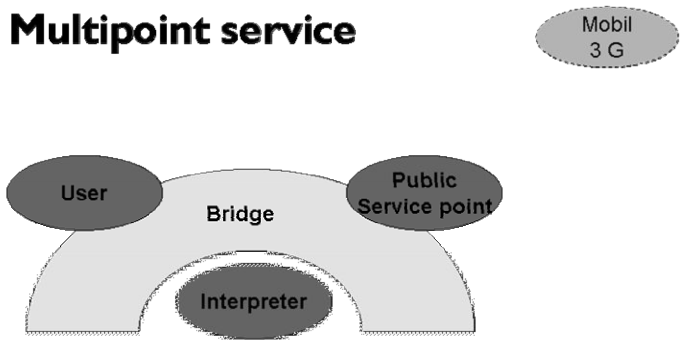

Fig. 3. Multipoint remote interpretation service

There have been technical problems especially with firewalls. Some programs change all the time ports for communication. This means that several ports ought to be open through the firewall during connection. Certain software requires fast IP address, but home users have it rarely. Compatible problems occur also quite often. But all the same technology has been working pretty well. To get a reasonable video picture a user needs 384 Kb connections to both directions. In practice the speed ought to be bigger rather 512 Kb to both directions. Selected software seems to work well also in wireless (wlan) environments [2].

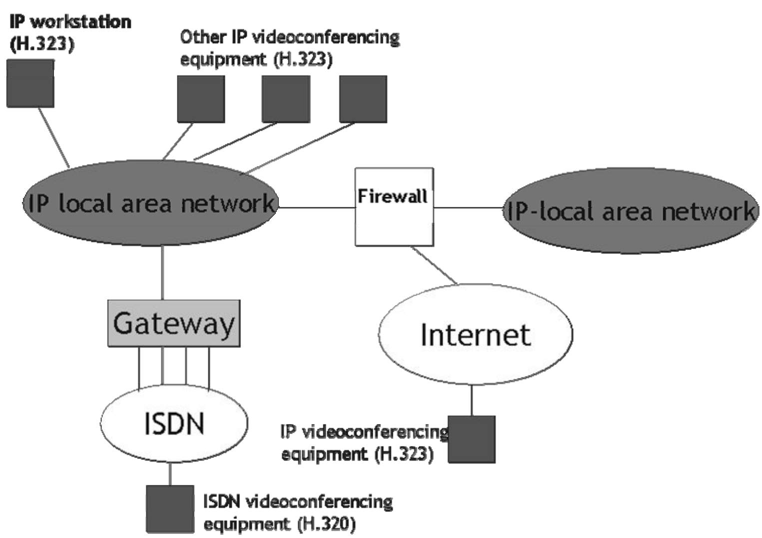

Fig. 4. Remote interpretation network [2]

3 Evaluation

The goal of the evaluation was to define the efficiency of the network project and its impacts on the regional development work of the interpreter service. The main source of information was the response data obtained from a thematic survey addressed to the regional presidents of the VETURI groups. Additional source material included project feedback from 2005, obtained from STAKES Information Services, as well as documentation and interim reports of the project. This material was related to the organisation and co-ordination of the project and contained descriptions and analyses of information systematically collected during the project from the presidents of the regional groups.

According to the impact evaluation, VETURI project generated the expected benefits. Positive outcomes include strengthening regional thinking with regard to organising and providing interpreter services. The utilisation of regional resources and their channelling in support of municipalities has been improved. The project set significant regional change processes in motion. New service structures, working and operating methods were developed out in different parts of Finland. Some of these are now established as permanent activities in the service structure, and some results will be further developed in new development projects. Concrete decisions have been made and confirmed by agreements, on the regionally organised provision and sourcing of interpreter services, and more decisions are to be expected. Rising trends in demand for, and the supply of, interpreter services were confirmed in all project areas that answered the survey. Hidden demand in the regions is in the process of being identified. None of the groups using interpreter services faced a decrease in the provision of these services. The deployment of new technology showed progress in the regions, but differences existed in the speed of such development.

The preconditions for the availability and quality of interpreter services appear to be improving in different parts of Finland, in the intended direction. An interpreter service cannot be replaced with other services. Users of interpreter services need them during their entire lives, or the rest of their lives, after the initial need has arisen. An interpreter service is essential to the person needing it, in terms of the realisation of equality and social inclusion. There are ways and various alternatives for improving the irregular service situation for different regions and disability groups. In VETURI project, progress was made in finding solutions for many essential issues concerning regional co-operation. In the future, interpreter services will enjoy the support of expert resources organised into regional networks, newly launched projects and high-level interpreter training.

Despite this progress, mutual co-operation between municipalities in organising the services seems very challenging. It will also be necessary to continue finding solutions to issues concerning the division of work between, and specialisations of, regional providers. Much remains to be done regarding the use of information and communication technologies and their integration into service provision, as well as ensuring professional know-how and communication on the municipal level. The need for information within various disabled groups remains extensive.

The development of regional networks for one service type designed for the disabled has opened up horizons for the regional development of other services. In the future, a possible and natural step will be to develop services for the disabled further, according to the customers' individual needs. This can be achieved by developing a particular service or by integrating services into a larger entity, necessitating agreement on how to ensure a sufficiently strong structural and economic base for them [4].

Remote interpreting made an interpreter's work easier because she did not need to travel and was able to work from a familiar work location. On the other hand, remote interpreting posed new challenges to an interpreter's work, because interpreting assignments came unexpectedly with a variety of topics and without a chance to prepare in advance. The use of technology also contributed to the challenging nature of the work [3].

New forms to produce services enabled the growth of remote interpretation service. Bigger population base and service resources made it possible to bring service also there where it has not been earlier. In some areas like in Northern-Carelia which is rather sparsely populated the amount interpretation service given as remote service raised to 12 %. Introduce of new technology can help in the strained economic situation of municipalities [4].

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Cognitive Ability Measures for Accessible Web Content

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Abstract. Accessible design for World Wide Web content has been a significant focus for many years. Guidelines, such as the W3C Web Content Accessibility Guidelines (WCAG), give designers a list of checkpoints to be used to help ensure that web content will be accessible to users with deficits. Of these deficits, however, far less attention has been paid to designing for users with cognitive deficits. In order to address this, we present an orthogonal set of cognitive ability dimensions based in modern neuroscience, the SCEMA model, which designers may use to characterize an individual user and help better inform accessible design.

Keywords: Accessibility, Design, World Wide Web, Cognitive Deficits.

1 Introduction

It is no longer controversial to assert that the World Wide Web is an important part of modern society. Web sites provide access to a broad array of day-to-day activities, including education, entertainment, commerce, and social interaction. For people with deficits, if the web content can be appropriately designed so as to be more accommodating of their individual needs, then the freedom and flexibility provided by web-based access can materially improve their quality of life.

1.1 Web Access in Today's World

The World Wide Web provides designers a rich and flexible palette. Through the HTML language, Cascading Style Sheets, and scripting, web content providers deliver information and functional applications to a large and growing population of web users. Recent studies have estimated that 73% of American adults use the internet [4], with over 1 billion users worldwide [13]. Affordable computers and high speed internet access help fuel this growth. Businesses provide services via the web in order to differentiate themselves from competitors, reach an expanded customer base, and reduce costs. Likewise, governments and other public service organizations offer their constituents improved service and do so more efficiently. Finally, E-mail, instant messaging, and blogging can bridge time zones and geographical distance in order to bring people together. All of these factors combine to make access to the web increasingly important in today's society.

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1.2 Web Content Accessibility Guidelines

Given the broad-reaching penetration of web information and applications, reaching people in all walks of life, it is easy to imagine in the near future that access to the web will be a prerequisite for participation in society. It is important, therefore, to examine the implications of web access for people with deficits. Initially, web content was typically simple stylized text and hypertext links. Modern web content, however, is a rich, multi-sensory, animated experience designed to convey information, attract attention, and convey complex linkage and structure behind the scenes. Deficits in vision, hearing, or motor control can limit an individual's ability to access one or more aspects of the information. Unless the content designer has built in redundancy, important information may be obscured or lost.

The web community is generally sensitive to the difficulties which may be encountered by users with deficits. The Web Content Accessibility Guidelines (WCAG), published by the World Wide Web Consortium (W3C), seek to explain to web page designers and providers how to make their content accessible to people with deficits. The goal is to promote accessibility and to make content available to a wider audience. Version 1.0 of the WCAG was issued in May of 1999 [10], and contains fourteen separate recommendations intended to explain to web content developers on how to make that content accessible to people with deficits. WCAG 1.0 is about to be replaced by updated guidelines, WCAG 2.0[11], which sets forth four design principles and thirteen guidelines intended to more accurately reflect current web content technology and usage (see figure 1).

Each guideline in WCAG 2.0 is further defined by levels of success criteria, described by fairly specific rules. For example, one of the success criteria for Guideline 1.1, "Provide text alternatives for all non-text content" is met:

> If non-text content is pure decoration, or used only for visual formatting, or if it is not presented to users, it is implemented such that it can be ignored by assistive technology.[11]

Thus, by following these principles, adherence to these guidelines, and validating the resulting design against the success criteria the designer may be able to ensure an accessible design. There is, however, an ongoing discussion in the accessibility community whether or not WCAG 2.0 can be successful.[2][9]

1.3 WCAG and Cognitive Deficits

While WCAG 1.0 and 2.0 are intended to foster Universal Accessibility [8], some reviewers have concluded that cognitive deficits are not sufficiently considered.[5] Of all the individuals with deficits, as estimated in 2005, some 11.6 million people in the US (age 5 or over) are considered to have a sensory deficit ("blindness, deafness, severe vision, or hearing impairment,"), another 14.7 million people have a cognitive deficit (a physical, mental, or emotional condition lasting 6 months or more that made it difficult to "learn, remember, or concentrate.")[7]. If cognitive deficits resulting from brain injury, Alzheimer's Disease and other dementias, severe and persistent mental illness, and, some cases of stroke are included, the estimate grows to over 20 million people [1]. We feel that this population represents a significant challenge to

Universal Accessibility design, and has thus far been under-represented and under-analyzed in the creation of accessibility scenarios and solutions.

*** Principle 1: Content must be perceivable.**
- Guideline 1.1 Provide text alternatives for all non-text content
- Guideline 1.2 Provide synchronized alternatives for multimedia
- Guideline 1.3 Ensure that information and structure can be separated from presentation
- Guideline 1.4 Make it easy to distinguish foreground information from its background

*** Principle 2: Interface components in the content must be operable**
- Guideline 2.1 Make all functionality operable via a keyboard interface
- Guideline 2.2 Allow users to control time limits on their reading or interaction
- Guideline 2.3 Allow users to avoid content that could cause seizures due to photosensitivity
- Guideline 2.4 Provide mechanisms to help users find content, orient themselves within it, and navigate through it
- Guideline 2.5 Help users avoid mistakes and make it easy to correct mistakes that do occur

*** Principle 3: Content and controls must be understandable**
- Guideline 3.1 Make text content readable and understandable.
- Guideline 3.2 Make the placement and functionality of content predictable.

*** Principle 4: Content should be robust enough to work with current and future user agents (including assistive technologies)**
- Guideline 4.1 Support compatibility with current and future user agents (including assistive technologies)
- Guideline 4.2 Ensure that content is accessible or provide an accessible alternative

Fig. 1. Web Content Accessibility Guidelines (WCAG) - Draft Version 2.0, April 2006

2 Cognitive Deficits

To begin with, it is clear that the characterization "cognitive deficit" is not at all informative for the designer considering the abilities and limitations of a prospective user. Medical diagnoses related to cognitive deficits include: autism, Down Syndrome, traumatic brain injury (TBI), and dementia. Less severe cognitive conditions include attention deficit disorder (ADD), dyslexia (difficulty reading), dyscalculia (difficulty with math), and learning disabilities in general.[12] The problem is that a given medical diagnosis may result in one or more functional (e.g. memory, language, problem solving, etc.) deficits and, further, may result in different functional deficits in different individuals. For example, in the case of TBI, the functional deficit will depend on which area of the brain was injured. We feel that in order to create accessible web content it is crucial that the designer be able to understand what there is about a specific disability that contributes to or detracts from the accessibility of a given web page. We will now develop a functional model of cognition based in modern neuroscience which we will be able to apply later to the accessible design problem.

2.1 The SCEMA Model

SCEMA[6] is a neuroscientific model that provides a coherent framework for understanding individual differences in intellectual and emotional functioning. It identifies five separate and interactive information-processing systems, each of which may be an area of relative strength or weakness for the individual. This model provides an appealing alternative to using psychiatric or educational diagnostic categories, such as "dyslexia" or "attention deficit disorder," to describe difficulties an end-user may have in accessing information on a website. The diagnostic categories are problematic in being behaviorally descriptive, rather than referencing to particular functional system, the breakdown of which explains the problem.

In this model, the *Sensory system* gets information into the brain; the *Cognitive system* make sense of the information; the *Executive system* selects or retrieves information for processing; the *Motor system* determines a response and the *Affective* (emotional) *system* prioritizes information, putting a positive or negative spin on it. Table 1 lists the subsystems of each of the five processing systems in the SCEMA model.

As an example of a popular but nonspecific and misleading label, "dyslexia" means only a problem with reading, not a specific disorder or cause of a problem with reading. Reading problems may be due to a deficit in the Executive (attentional) system or to a deficit in the Cognitive system. Depending on the source of the problem, which system it is in, the supportive design tool will be very different.

People with deficits in the Executive system (including people with attention deficit/hyperactivity disorder, or ADHD), will tend to miss words, word-parts, punctuation or even entire lines of text due to difficulty sustaining their focus or to inefficient visual scanning. As a result, the passage will not make sense, and they will have to re-read it. Comprehension of material may also suffer secondary to difficulty holding information in mind (a process called "working memory") – such as keeping the first part of a long sentence in mind until we have read the whole sentence, in order to put it together to get the meaning.

Another person may have difficulty with reading due to a deficit in the Cognitive system, either with the processing of auditory verbal information – the sounds and order of sounds in spoken language, or the processing of visual spatial information – the location of things in space, whether left-right or up-down. Listening to the text being read will not be helpful if the problem is with auditory verbal processing, whereas it may be helpful to the person whose difficulty is with visual spatial processing. On the other hand, color-coding of directionality – green for the left hand margin (for "go" or "start here") and red for the right hand margin, may be helpful. Visually simplifying the information, with larger, simple font, wider spacing of words and lines, and alternating the highlighting of lines to aide in scanning, will be helpful for people with scanning difficulty whether due to an Executive or Cognitive deficit.

Table 1. The SCEMA model

Processing Systems	Subsystems
Sensory	**vision**
	audition - hearing
	olfaction - smell
	gustation - taste
	touch - pain, pressure, temperature
	proprioception - knowing the position of one's body/limbs in space
	vestibular - balance and movement
	visceral - body organ sensation, such as heart palpitations, intestinal cramping, hunger pangs
	basic emotion - fear, anger, pleasure, loss, disgust
Cognitive	**visual spatial perception**
	auditory verbal perception
	spatial abstract reasoning
	verbal abstract reasoning
	social/emotional perception
	social reasoning
Executive	**vigilance** - sustained attention
	working memory - as in mental calculations, holding information in mind and operating on it
	retrieval fluency - finding and making available stored information when needed
	response inhibition
	processing speed control
Motor	**fine motor coordination**
	gross motor coordination
	oral motor coordination
	response selection - thought and action, initiation and inhibition
Affective	**positivity** - an active state of mind in which ideas flow readily and initiative of responses is high
	curiosity - in which seeking or exploratory behavior is high and attention is facilitated; includes sociability and emotional modulation
	anxiety
	sadness - loss, depression
	anger - aggression

While color-coding spatial information may be helpful to some people, it may be distracting to others. People with problems in the Affective system, with anxious or depressed moods, or with problems in the Sensory system, such as a hypersensitivity to color or high visual contrast, may experience it as a distracting or upsetting feature of the website.

3 Applying the SCEMA Model

The SCEMA model provides a web content designer with a powerful thought-tool for accessible design. A simple test, “If a user has decreased efficiency in this particular subsystem, will my web page be accessible?" may be performed for each of the subsystems in the model. Based on the answer, the web design can be refined, or perhaps an alternate page may be offered presenting the same information content in a more appropriate way. For example, providing pictorial menu choices instead of text, or presenting a two-page information structure rather than a single, denser page. Further, by considering deficits in two or more of the subsystems, the designer can validate the accessibility of their content in a more realistic yet still controlled scenario where more than one deficit exists, as is often the case in traditional cognitive deficit diagnoses.

3.1 A Design Exercise – Navigating an E-Mail Inbox

In order to illustrate the application of the SCEMA model to the design process, we would like to consider a common web function: navigating an e-mail inbox. Of all the online internet activities, e-mail is by far the most common (52%).[3] E-mail is a powerful tool for commerce, information gathering, and social connectivity. Clearly, there is great value in ensuring the design of an e-mail application is accessible to all, and in our case to users with cognitive deficits.

Figure 2 shows a sample web e-mail inbox (AOL Mail, in this case). A list of mail folders are gathered on the left, a set of application-selection buttons across the top

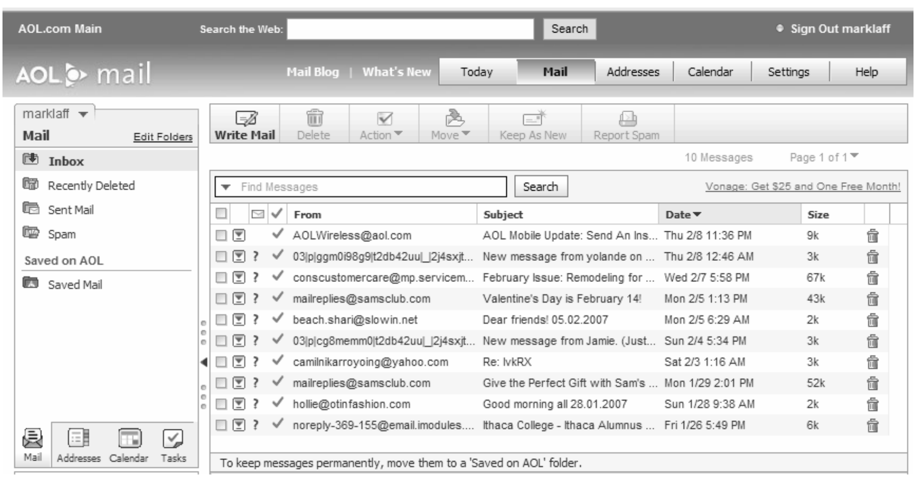

Fig. 2. Example Web E-mail Application – AOL Mail (© 2007 AOL LLC)

(Today, Mail, Addresses, etc). Just below the application selection buttons is located a row of mail message operation buttons (Write Mail, Delete, etc.). A vertical list of the current mail messages occupies the bulk of the display. Each mail message is represented by a row of text and iconic items, including the name of the sender, the subject of the message, and the date it was sent. Iconic buttons enable various functions, including "Delete" (represented by the trash can), a "Select" checkbox (preparing for later operations which effect only the selected mail messages), and a drop-down menu handle (the downward-pointing triangle). When the drop-down menu handle is clicked, a textual list pops up showing more available operations (search, reply, forward, delete, etc.).

Simply by inspection we can guess that this interface was designed for users with typical cognitive ability. There is a lot of information represented here, using a combination of textual representation, icons (trashcan, dropdown menu handle), layout (columns for the email list; border around the folder section), and graphical appearance (the "Mail" function, since it is selected, looks like a physical button that has been pressed). Suppose we were the designer assigned to modify this interface to be accessible to users with cognitive deficits. Where would we start? Would we simplify the screen, change the layout, choose different modalities for representing the state, or use temporal expansion (step-by-step information disclosure)?

Consider a user, Sam, who has a visual/spatial processing deficit which makes it more difficult for him to scan horizontally. He has difficulty associating the various columns of information about an e-mail. In order to facilitate the scanning process, we could make the background of each line in the e-mail list a contrasting color (for example, yellow and green instead of the light-grey background in Figure 2).

Would that design change in fact reduce the efficiency of another user, say Pat, who has a sensory integration deficit and so would experience a very strong, confounding reaction to the high-contrast color scheme?

These design tradeoffs, optimizing the experience for users with different cognitive abilities and deficits, are often very hard. This leads web content designers to offer users alternative representations, such as "All Text" vs. "Text plus Graphics", or "No Frames" vs. "Multiple Coordinated Frames".

We would like to suggest that in some cases no single design will suffice. By employing the SCEMA model, however, there are a finite number of combinations of disabilities that the web designer will need to accommodate. By reflecting on the design from the perspective of a prototypical user with a deficit in each one of the SCEMA subsystems (or perhaps two subsystems simultaneously) one can at least predict how accessible the web content is for all users and thereby make the content more accessible if not ideal.

4 User Modeling and Dynamic Adaptation

The previous examples demonstrate how the SCEMA model may be applied to the design process. The web content designer examines the accessibility of the design for a user with a particular sub-system deficit and then modifies the design. This will lead towards "accessible to all" web content. However, one can easily imagine the case where an improvement for one cognitive-ability profile will actually degrade the accessibility for another user. In this case, "accessible to all" would seem to be impossible.

If, however, we allow for dynamic adaptation of the web content, and if we employ the SCEMA model to describe each individual user, then the web content can be maximally accessible for each user. At run-time, as the web content is being displayed, the cognitive ability relative to each subsystem in the SCEMA model can be used to select among different design options.

A user profile database would, for each user, store an "efficiency level" for each of the SCEMA subsystems quantifying that user's ability / deficit from that perspective. By tracking the efficiency level separately for each subsystem, it would allow the user's abilities to be completely described, and as a result the dynamic web content would have available all the information necessary to make the web page maximally accessible.

Further, it is important to recognize that there are time- and situation-dependent components to each user's subsystem efficiency levels, for example, during a long web browsing session where the user's efficiency declines as they begins to tire, or when a user first takes their medication vs. after a period of time as the medication begins to wear off. Either under user control or based on automatic system measurements, each component of the user model could be updated to reflect the changes over time, triggering the web application to adapt and modify the user interface accordingly.

5 Conclusion

Access to the World Wide Web, with its wealth of information and applications, is an important part of life today. Activities such as education, entertainment, commerce, and social interaction are all moving online. If users with disabilities are to have benefit, web content designers must consider a range of user abilities much as architects and civil engineers do designing in real life spaces. The W3C Web Content Accessibility Guidelines are meant to address this challenge. For users with cognitive deficits, however these guidelines are not sufficiently informative. As a first step towards accessibility for these users, we present a more in-depth, neuroscientific decomposition of cognitive processing definitions: the SCEMA (Sensory; Cognitive; Executive; Motor; Affective) model. Only by looking at individual SCEMA subsystems can we profile the cognitive abilities and disabilities of an individual user. The ability profile may then be used to assess the accessibility of a particular web content design. This tool, then, can inform the iterative design process, leading to more accessible designs. Finally, in some cases the goal of "universal design" may not be achievable. Given two users with different cognitive ability profiles, design features which improve the accessibility for one user may degrade the usability for another user. This would lead us to advocate dynamic web content designs configured "on the fly" based on a cognitive ability model of the current user. The systems and sub-systems of the SCEMA model seem, to us, to provide a powerful basis for this cognitive ability profile.

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Cognitive Aspects of Ageing and Product Interfaces: Interface Type

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Abstract. Twelve users with a range of ages between 20 and 70, were assessed for their cognitive capabilities and degree of experience with microwave cooker features and then trialled with two microwaves, one with a dials interface and the other with a buttons interface. The users were provided with a set of tasks to complete with each microwave. It was hypothesised that all users would perform better with the dials model but that the difference in performance between dials and buttons would become more pronounced as age increased. This was found to be the case in comparing the performance from the trials, with the strongest correlation occurring between the users age and the time taken to complete the tasks.

Keywords: inclusive design, product design, cognition, learning, product experience.

1 Introduction

A previous study examined the effects of ageing, generation, cognitive ability and previous experience on their ability to use both a motor car and a digital camera [1]. The products were deliberately chosen to be significantly different. Performance of the products was measured by the time taken and errors produced by a sample of users completing set tasks. There was evidence to support the theories of deterioration with ageing and step changes for generational effects but the strongest evidence indicated a relationship between degree of previous experience and performance.

The experiment discussed in this paper addresses the conclusions reached from this previous study [1] as well as a background understanding of inclusive design and cognitive psychology to examine the age-related effect of type of user interface.

1.1 Inclusive Design

In 2020, more than half the population of the UK will be over the age of 50 and the over-80 range will be growing the most rapidly [2]. In order to meet the ideals of inclusive design, a designer must create a product that minimises the number of people excluded or who experience difficulty with a product [3]. Whilst inclusive products reduce the difficulties suffered by the elderly and those users with

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disabilities, the products often attract those without either. Work from similar fields to inclusive design has characterised specific impairments as well as produced guidelines for specific product types [4], [5]. However evidence exists that product designers will ignore this form of guidance in favour of more concise advice [6].

Researchers in inclusive design have found helpful the use of simulation kits in conveying the effects of physical and sensory impairments to designers [7]. However, by their nature, cognitive impairments are significantly more difficult to accurately simulate than motor or sensory impairments. A primary area of concern, for example, is how the properties of memory affect the learning of a products use and the ability of individual users to transfer learning from prior experience. Inclusive design theory promotes consideration of both the properties of the products' interfaces and the users' capabilities, when seeking design improvements.

1.2 Memory and Learning

The development of the knowledge a user brings to a new product is provided by their ability to acquire, store and retrieve past experience. An overview model based on the human information processing approach to cognition would include memory functions such as Sensory memory; Short term memory (STM), Working Memory (WM); Long Term Memory (LTM), as well as LTM memory models implying organising processes, such as Schema; Semantic, Episodic, and Prospective Memory. Following current models, such as that of [8], it would also assume an Executive function as part of working memory. According to generally accepted theory, [8] the WM has a duration of between 10-15 seconds, has a limited capacity for information of around five to seven items and is organised by different modalities of storage such as visual-spatial and auditory-verbal. The WM can hold sufficient, separate items for further consideration from either perception, memory or other input sources. It is thought to consist of three components:-

- a central executive to divide attention amongst the required tasks
- a phonological store and articulatory loop for verbally based information
- a visuospatial sketch pad for organised, visual information.

1.3 Previous Experience and Training Transfer

New products rarely are designed that make no reference to products that have gone before and of which users will have no experience. The more experience a user has of similar products, the quicker they will learn the operation of a new product.

Training transfer research has looked at the relationship between the similarity of a user's training to the actual task to effectiveness of training. For example, a flight simulation will provide an improved training performance over studying a video of a pilot at work [9]. This can be counter productive if the training product is too similar to the actual product and acquired accepted behaviour on the training product represents an error on the actual product. In the product design world, the designer may change the function of a button on an interface from one model to another causing experienced users proactive interference, or failure to learn the function of that button when using the later model.

1.4 Generational Effects

Previous work has shown that ubiquitous, existing symbolgies across product families are only noticed by some generations [10]. Studies in the Netherlands have explored this further by outlining technological generations. These consist of the time era during which one was born and the interface technology that was experienced untill the age of around 25 [11]. The electro-mechanical era can be considered for people born pre-1928, 1928-1964 sees the remote control era, 1964-1990 is dominated by displays and post 1990 layered menu systems are generally prevalent and popular.

1.5 Past Work and Research Questions

Furthering the work of the previous study [1], individual interface elements were to be examined in anticipation of further evidence of ageing and generational effects. Two functionally equivalent microwave interfaces were chosen to be examined; one with a dials interface and the other with a display-button interface (fig. 1). It was anticipated that all age ranges would perform better with the dials interface due to the reduced complexity offered by this model. However, the difference in performance between the two models would increase with age with a possible generational effect in the over 70 age group.

Capability variation with task difficulty was expected to be subject to the following influences:-

- An experience effect: The degree of previous experience with the same and similar products;
- A generation effect: The age of the users and specific technology generations;
- An ageing effect: The gradual decline of learning and cognitive abilities with age;
- A cognitive capability effect: The ability of users as measured by a variety of tests of individuals' general and specific cognitive capabilities.

Fig. 1. The interfaces of the microwaves tested (a) dials and (b) buttons

2 Method

The users were selected to cover the age spectrum with a representation in each age decade band. Six male users and six female users ranging from 21 to 68 were tested. Users were informed throughout the trial that it was the purpose was to test the products' performance through different age categories and not to comparatively measure their personal performance. They were also informed of their entitlement to stop the trial at any stage and have any records deleted. The detailed methodology followed the codes of practice of the British Psychological Society [12].

2.2 Cognitive Assessment

The users each completed a short, 15-minute cognitive test [13] that provided sub scale scores for: Verbal, Mathematical ability, Spatial, Logic, Pattern Recognition, General Knowledge, STM, Visualisation and Classification. For convenience these were amalgamated into five categories: Perceptual, Reasoning, STM and LTM and a Combined-Cognitive-Score (CCS). Users were informed that should they not know the answer to a question they could either pass on it or guess at a solution. The assessment contained a normalising age correction factor on the sub-scales. Since one of the factors under investigation was ageing, this factor was deemed inappropriate and each solution set was calculated without correction. This combined, uncorrected scale is denoted by the acronym CCS20.

2.3 Experience Testing

Users also completed a short experience test to quantify their microwave knowledge. The test comprised five questions on symbol recognition with symbols taken from the both the microwaves tested and also other products. This was followed by 10

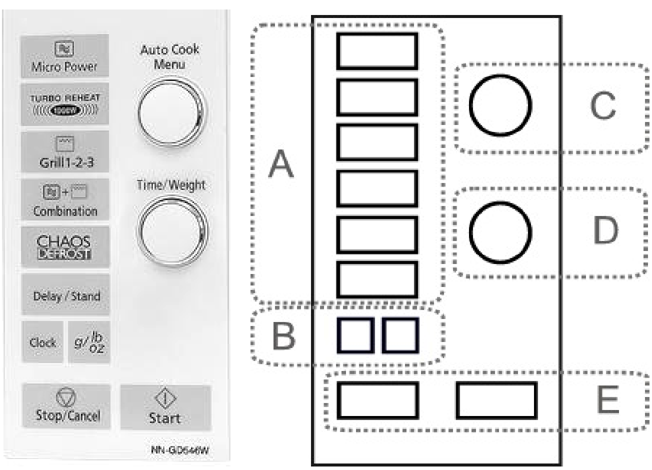

Fig. 2. Sample from Microwave Experience Test showing Interface and schematic

questions relating to button position and symbol recognition combined. A picture of a microwave was shown alongside a schematic diagram of the button layout (fig. 2). The schematic diagram grouped the buttons into lettered regions and five questions were asked relating to which button group the user would select for a particular task. This was repeated for a second microwave, both different from those tested. The test was not under timed conditions and the different sections were completed separately.

2.4 Products

The microwaves tested were both Goodmans, models; M20S and ME20S. They were essentially the same microwave with the exception of the control panel interface that for the former was two circular dials and for the latter, a buttons interface with ten numbered buttons, three function buttons and two further buttons representing activate and cancel (fig. 1). They were priced at the lower end of the range offered by a UK chain electrical retailer, with the buttons model slightly more expensive.

2.5 Segmentation and Errors

The time required for each user action was recorded by studying the video recording and managed on the basis of: retrospective protocols; observation of the video recording; observation of evident task boundaries. Users were provided with the different tasks on different pages of a paper folder. The tasks times were easily determined by recording the times upon which the pages were turned. Further information was gained from comments in the retrospective protocols.

Additionally each user action was assessed as to whether it constituted an error. An ideal sequence of events was created and users' actions were compared to this. Actions that changed the state of the microwave further away from a status than that requested by the current task were deemed errors. Unnecessary actions were also recorded as errors.

2.7 Trials

The task list supplied to the users is shown in fig. 6. The users were asked to complete the two written tests before the trials. The order of the testing microwaves was alternated to avoid any ordering effect. Task 1 was the only task that had an identical procedure for successful completion as it relied upon the user noticing the handle which is true for both microwaves. After the completion of the trial the users were shown the video recording of their trial. They were asked to provide a spoken protocol describing their performance and explaining their interpretation of their mental process during the task. The researcher remained silent during this but asked follow-up questions relating to anything that remained unclear. The users were debriefed after the follow-up period and offered to opportunity to discuss the study.

3 Results

3.1 Cognitive Ability Analysis

Figure 3 shows the relationship of CCS20 with Age. As anticipated CCS20 declines with increasing age, this is more prominent as the age correction factor had been removed.

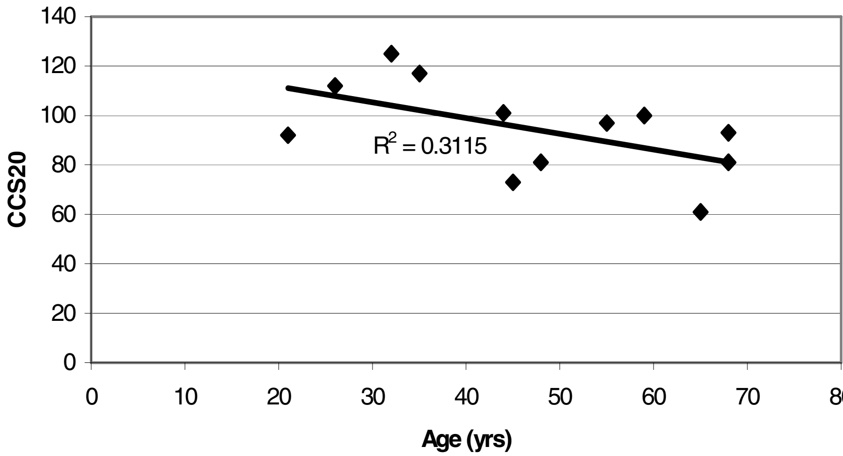

Fig. 3. CCS20 Distribution with Age

3.2 Experience Analysis

The Experience scores were weighted so that the results from the symbol recognition were worth twice the value of the combined symbol recognition and position questions. There was no significant correlation with either Age (R= 0.405) or CCS20 (R=0.286).

3.3 User Performance

The users' performances were analysed by examining the completion times and the number of errors for the trial. Users were limited to 3 minutes per task and in the situation when a user gave up, this resulted in them being awarded the full 3 minutes as their time taken. This penalty was not added where the user had falsely assumed they had completed the task. Completion of tasks was also recorded as a separate measure.

Time taken and age produced good correlations with both microwaves (fig. 4) as indeed was the case for time taken and CCS20 correlation (Dials R=-0.539, buttons R=-0.626). Errors produced no significant correlation with either age (Dials R=0.306, buttons R=0.235) or CCS (Dials R=-0.424, buttons R=-0.014).

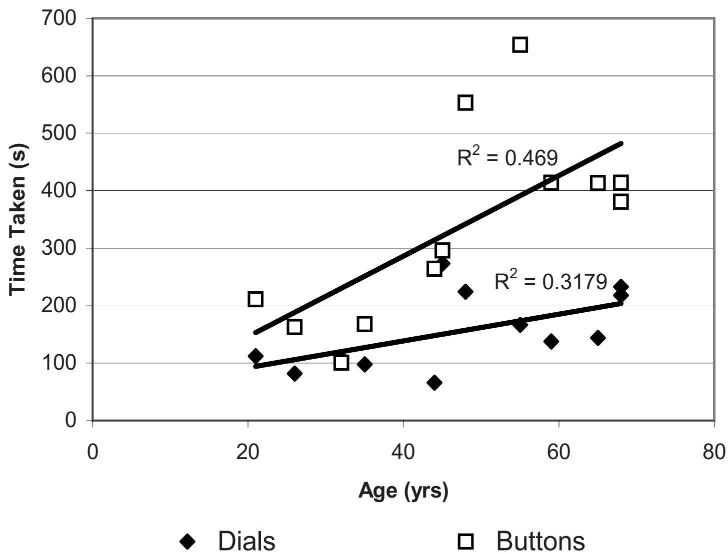

Fig. 4. Relationship of Time Taken (s) with Age

Figure 5 below shows the far lower correlation of the time taken performance measure with the experience score.

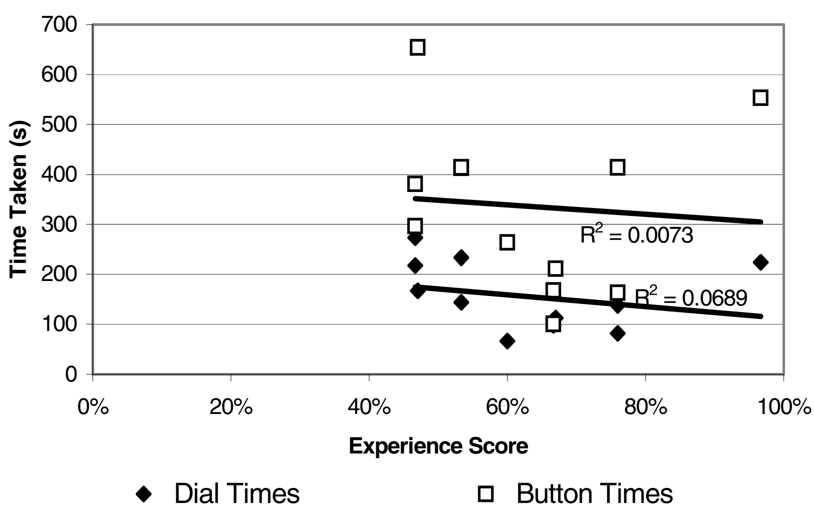

Fig. 5. Distribution of Time Taken(s) with Experience Score

A task breakdown is provided in Figure 6 for the averaged task times;

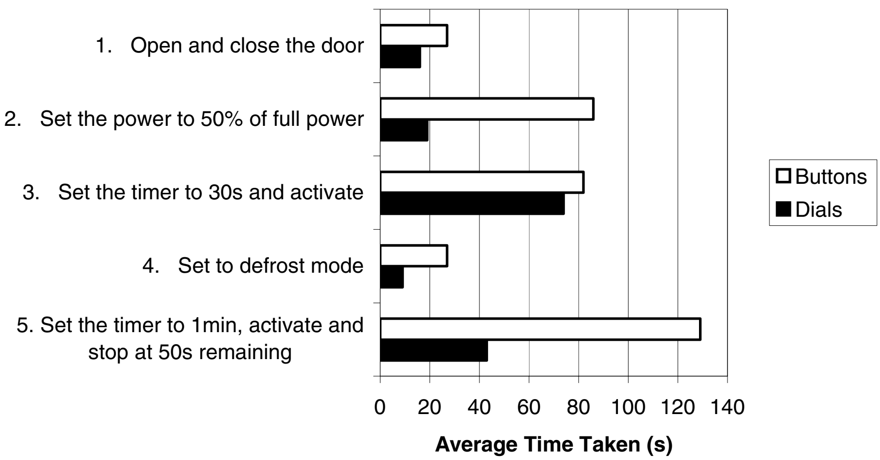

Fig. 6. Average Task times (s) for the dials and buttons

4 Discussion

The users' cognitive scores are as expected with the cognitive ability declining with age. In previous work this has offered a closer correlation [1] but there is a clear downward trend in Fig. 3. Fig. 4 shows the relationship between time taken and experience. In the previous study [1] the relationships between experience and the time taken offered the strongest correlations. Either the relevance for previous experience when using a new microwave is less than for digital cameras and cars or the differences in testing procedure have cause this result. Whereas previously an experience questionnaire had been used to assess product prior experience, for this trial users are subjected to a more specific interface features test. It is conceivable that a user may have shown a high knowledge of microwaves but perform badly in the trials. Indeed, the highest experience-scoring participant did not own or regularly use a microwave.

The strongest result from the trials is the relationship of time taken and age. The lower complexity in the dials model provides predictably shorter times for completion and a higher completion rate. The steeper trend line for the buttons model shows that the ageing effect predicted is present with an increasing difference between users' dials and buttons times.

In the previous study [1] it was noted that with no time pressure to complete the task there was no evidence of users trading speed against accuracy. In that study there was positive correlations of task times with errors. However, in these trials there is very little correlation. This may be accounted for by considering users' strategies. Some users were noticed attempting as many solutions as possible in the hope that they would chance upon the correct one. Others tended to rely on a more systematic strategy, studying the interface, looking for cues to the correct option. Both approaches can be seen to be effective but overall result in a poor correlation of times and errors. Those users with a higher overall cognitive score were faster at achieving the correct sequence of actions. Considering the sub-scales and time-taken; LTM offered no correlation, Perception and Reasoning provided reasonable correlations and STM provided a very strong correlation (Dials R=-0.701, buttons R=-0.773). The buttons model makes high demand on WM as sequences of buttons need to be remembered as well as the effects of sequences already attempted. The higher complexity of the buttons model fits the higher correlation for this model and STM relationship.

Fig. 6 shows that not all tasks fit the same pattern for the two microwaves. Task 1 was identical for both microwaves and the slightly higher result for the buttons model is likely to be due to chance. For Task 2, the dials model has one of its two dials dedicated to setting the power and users very quickly established a 50% setting. The buttons model required the user to recognise the power symbol and then press it repeatedly to decrease its displayed value. Many users opted for the incorrect solution of entering a numerical setting. This, therefore, took them notably more time to successfully complete. Task 3 took the longest of all the tasks for the dials model. The dial labeling was in minutes and many users struggled to accurately select the short time of 30 seconds. For the buttons model, the user had to first select the power and then enter a numerical time in a digital display.

Task 4 required a similar solution as task 2 for the dials model as the "power" dial needed to be moved to the lower setting adjacent to a defrost symbol. On the buttons model there were two buttons marked with the defrost symbol and simply pressing either provided the solution. Task 5 represented the hardest task to complete for the buttons model. Few users had learnt the procedure from task 3 for setting the time, most had chanced upon the solution by accident and had been unable to recall it. For the dials model, setting the minute was found to be easy but stopping accurately at a particular second, or even the nearest ten seconds, appeared to be more difficult.

There is no evidence for a generational effect at this stage in the experiment, but further trials will sample the 70+ age range where this effect was anticipated to be strongest. This would appear as a step change in graphs of time taken for the higher ages (fig. 4). In the next stages of the experiment, a sufficient number of older users will be trialled for this effect to be tested.

5 Conclusion

The time taken and age relationship is the strongest result and supports the hypothesis in showing that whilst the dials model would be quicker for all users, due to lower complexity, the extent of the difference between buttons and dials would become more pronounced with increasing age. A generational effect may still appear when further users over 70 have been trialled. It is clear that the experience testing produced no correlation with task duration, number of errors, age nor CCS20 yet in the previous study [1] this produced the highest correlations. The difference in method of experience scoring may be the cause of this since an experience questionnaire was used previously while a symbol and position recognition test was used for the current trials. Future work will consider a combination of both measures. Data collection will continue to extend this study to cover more and older users. Further analysis will classify the nature of errors made into a scheme based on a simple cognitive model used in the previous study [1].

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Experimental Study on Enlarged Force Bandwidth Control of a Knee Rehabilitation Robot

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Abstract. Providing large bandwidth of resistant force to trainees is an important requirement of a knee joint rehabilitation robot. Although large resistant force can be achieved by using big motor, difficulty will arise to achieve small resistant force because of the influence of friction, gravity and inertia of the heavy robot. This paper presents a force bandwidth control method based on admittance-control paradigm, which combines theoretical model under active mode and experimental data under passive mode to compensate the influence of the friction, gravity and inertia force upon the torque sensor signal. This method avoids the necessity to establish complex mathematic model of the friction forces. Furthermore, a digital filter method is proposed to reduce computational error of angular acceleration resulted from differentiating encoder values. An optimal filtering parameter range is chosen by Matlab simulation. Experiment results based on a physical prototype prove the enlarged resistant force bandwidth after force compensation.

Keywords: force bandwidth, admittance control, force compensation.

1 Introduction

Rehabilitation robots for training patient's joints such as wrist and knee are an important research topic [1~6]. During the process of rehabilitation, it is not only important to supply passive training mode, in which robots exert force to move human's leg, but also more important to supply active mode, in which humans exert force to make robot move [3].

In active training mode, a wide force bandwidth is an important requirement [4~5]. The challenge in achieving wide force bandwidth is to realize small resistant force using a robot with heavy arms and inherent friction, which means that the control system must overcome the influence of friction, gravity and inertia of the robot.

To achieve small resistant force, Hogan et al. present an impedance control method to control a DC motor [1]. In his method, precise friction model is needed to control the motor to compensate the friction in achieving a smaller resistance. Antonio Visioli et al. propose an adaptive friction compensation method to achieve better position control performance of a robot. However, whether the method is efficient in force

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control has not been proved [7]. Jungwon Yoon et al. compensate gravity of a haptic device by control the motor to output a corresponding force, compensate friction and inertia by creating a close loop force control system with a force/torque (F/T) sensor. Friction and inertia model are not necessary in this method, however a high performance force/torque sensor is necessary [8]. Kostas Vlachos et al. present a design methodology aims at the minimization of the mass, inertia and joint friction for a haptic device [9]. However, their method puts strict requirement for precision in manufacturing and assembly.

The remainder of this paper is organized as follows. Section 2 gives overall architecture of the robot; Section 3 proposes compensation method of friction, gravity and inertia; Section 4 presents digital filtering method and simulation results. Section 5 gives the experimental results. Conclusions are given in section 6.

2 Architecture and Mechanical Structure of the Robot

Knee rehabilitation robot is an intelligent system which aims at the rehabilitation and evaluation of the knee joint function and muscle strength. It is composed of the trainees, trainers, mechanical systems and control system (see figure 1).

During the process of rehabilitation, trainees sit in the chair, and a fixture fixes the leg to the robot arm. A lifter, which is located on linear guides, is under the chair, so the trainee could both rotate and move in line, to facilitate the spindle axis alignment with the axis of the knee joint. The torque exerted by the trainee is detected by the torque sensor. The rotating angle of the robot arm is detected by an encoder.

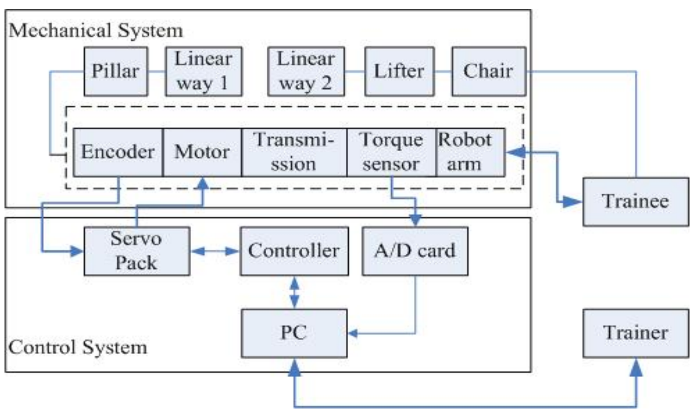

Fig. 1. The architecture of the knee rehabilitation robot

The mechanical structure of the knee rehabilitation robot is shown in figure 2. A robot arm is connected to a flange shaft, and a torque sensor is fixed between the flange and a sleeve in order to measure the transferred torque. The other end of the sleeve is connected to the gear box and the motor through a connector. The sleeve is connected to the frame through four rolling bearings. There is a fixture (not shown in the figure) connected to the robot arm to fix the leg in rehabilitative process.

Large force bandwidth is a basic requirement for knee rehabilitation robot. Trainees are those who just suffer from knee surgery. Usually, there are several phases for rehabilitation, each last about 1 or 2 weeks. In the early phases trainees can only apply weak torque to the robot. Accordingly, the robot should provide small resistance to trainees. With the increase of muscle strength of the trainee in subsequent phases, the resistant force of the robot should increase accordingly. The actuator of the robot must apply big resistant torque to the trainee, which will lead to a robot with big motor, heavy robot arm owning large friction and big inertia.

Therefore, in order to maintain large force bandwidth, the focus is to provide small resistance to trainees using the big robot. A compensation method based on admittance control paradigm is proposed in this paper to solve this problem (see figure 3). In admittance control paradigm, it is necessary to measure the exact force exerted by human. However, the torque signal measured by the torque sensor cannot reflect the trainee's real torque unless the influence of the gravity, friction and inertia force of the robot can be removed. Therefore, the challenge for increasing force bandwidth is to compensate the influence of the gravity, friction and inertia.

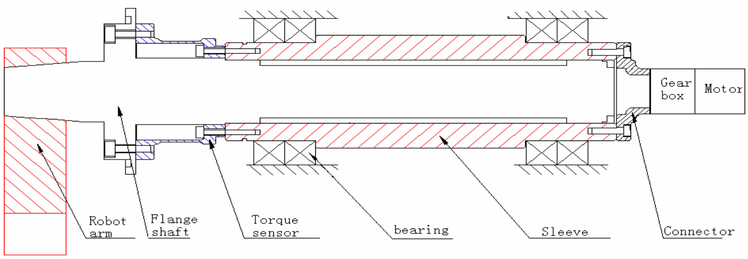

Fig. 2. The mechanical structure of the knee rehabilitation robot

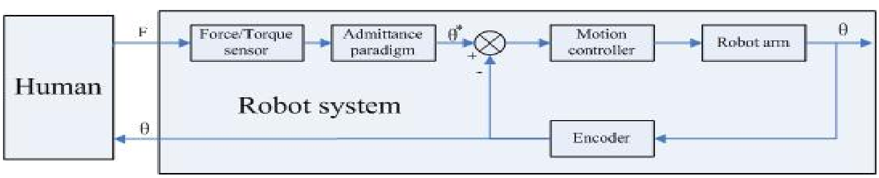

Fig. 3. Admittance control paradigm

3 Force Compensation Method

The applied forces of the robot arm are shown in figure 4. When the leg moves up, gravity, friction and inertia are resistances; when the leg moves down, the gravity is assistant force, while the friction and inertia are resistances. Under active mode, the actual torque applied by the trainee can be calculated by the following formula:

$$T_h = \begin{cases} T_t + T_g + T_f + T_i & (robot\ move\ upward) \\ T_t - T_g + T_f + T_i & (robot\ move\ downward) \end{cases}. \tag{1}$$

Where T_h and T_t are the torques applied by human and the torque measured by the sensor; T_f and T_i are the torques created by friction and inertia; T_g is the torque applied by the gravity F_g; θ is the angle of the robot arm. Under passive mode, the robot is moved by motor and human doesn't exert resistant force. Therefore, the signal from the torque sensor can be derived as follows

$$T_t = \begin{cases} T_g + T_f + T_i & (robot\ move\ upward) \\ -T_g + T_f + T_i & (robot\ move\ downward) \end{cases} . \tag{2}$$

Combined the active mode and passive mode, the compensation method is carried out in following steps:

1. Model construction: Establish model of gravity, friction and inertial force under active mode;
2. Parameter Determination: Determine parameters within the above force model by theoretical computation;
3. Parameter Validation: Modify the parameters of the above force model via experimental result under passive mode, and use equation (2) to observe the effectiveness of the compensation result until satisfied result is achieved;
4. Force Compensation: Using equation (1) to compensate gravity, friction and inertial force under active mode.

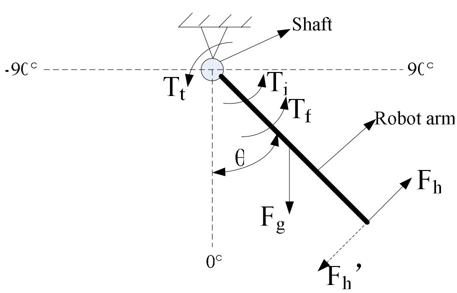

Fig. 4. The applied forces of the robot arm

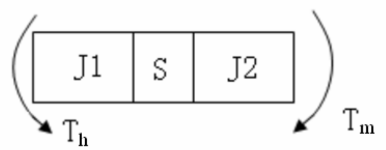

Fig. 5. The inertia force analysis

During the rehabilitation process, friction of the system mainly comes from the sleeve, the gear box and the motor. Friction from other parts of the robot can be ignored. The force which the trainee exerted to overcome the frictions could be measured by the torque sensor. One advantage of admittance algorithm is that the friction of the system can be the ignored [10]; therefore, the friction of the system can be ignored in admittance control algorithm.

Gravity is one of the main factors which influence the error between the torque sensor value and the force exerted by trainees. The gravitational torque is a variable which can be specified as:

$$T_g = F_g l \sin\theta . \tag{3}$$

Where F_g is the gravity, l is the gravitational arm.

Gravitational torque comes from robot arm, fixture, and the leg. It can be measured at the beginning of the training process and can be compensated during rehabilitation.

The transmission of the system inertia can be seen in figure 5. T_h is the torque applied by the trainee; T_m is output torque of the motor; S is the torque sensor; J1 is inertia of the flange shaft, robot arm and fixture; J2 is composed inertia of the sleeve, gear box and motor. Under active mode, when the trainee moves the robot arm at α , the trainee's torque satisfies:

$$T_h = (J_1 + J_2)\alpha \ . \tag{4}$$

The inertial torque which accelerates J2 can be specified as:

$$M_2 = J_2\alpha \ . \tag{5}$$

which can be measured by the torque sensor because it was transferred by the torque sensor. On the other hand, the inertial torque which accelerates J1 cannot be measured because it wasn't transferred by the torque sensor. Therefore, the inertial torque which needs to compensate is only the one resulted from J1, which can be illustrated as:

$$M_1 = T_h - M_2 \quad J_1\alpha \ . \tag{6}$$

Where J_1 can be computed by theoretical method, and the angular acceleration α can be obtained by double differentiation of the encoder signal.

Under passive mode, the motor outputs a torque T_m to make the robot rotating at an angular acceleration α , the inertial torque of parts of J1 was transferred by the torque sensor, so it can be measured. Therefore, the effect of inertia compensation can be validated by comparing the measured torque signal before and after compensation. Parameters of the above force model will be modified if the compensation result is not satisfied.

4 Velocity Signal Digital Filter

4.1 Principle of Digital Filter

The angular velocity and acceleration can be calculated in following formula:

$$\omega(n) = [\theta(n) - \theta(n-1)]/T \qquad \alpha(n) = [\omega(n) - \omega(n-1)]/T \tag{7}$$

Where $\theta(n)$ $\theta(n-1)$ are the joint angle within current and previous period; $\omega(n)$ $\omega(n-1)$ are the angular velocities within current and previous period; $\alpha(n)$ is the current angular acceleration. T is the sampling time.

It can be seen from formula (6) that the error of the encoder, which caused by the resolution of the encoder and the disturbance of the environment, could be magnified (1/T) times in velocity calculation, and could be achieved at a tremendous high level in acceleration calculation. That is unacceptable for inertia force compensation. Therefore, a digital filtering method was utilized.

A digital filter was proposed based on the principle of the RC low-pass filter in analog system. The transfer function of the RC filter is:

$$G(s)=\frac{Y(s)}{X(s)}=\frac{1}{RCs+1} . \tag{8}$$

Where RC is the time constant of the filter, which determines the cutoff frequency of the filter. The discrete RC filter transfer function can be obtained as

$$Y(k)=(1-\alpha)Y(k-1)+\alpha X(k) . \tag{9}$$

Where: $X(k)$——the k time sampling value, k=1,2,3…; $Y(k)$——the k time filter output value; $Y(k-1)$——the k-1 time filter output value, Y(k-1)=0 when k=1; α——filter coefficient, $\alpha=1-e^{-T/RC}$, T——sampling time.

4.2 Matlab Simulation

The cutoff frequency is the most important parameter of the filter. The lower cutoff frequency, the more the noise will be suppressed, but more useful signal will be filtered. Simulation method is adopted to get a proper range of filter parameter-RC by using Simulink module of Matlab.

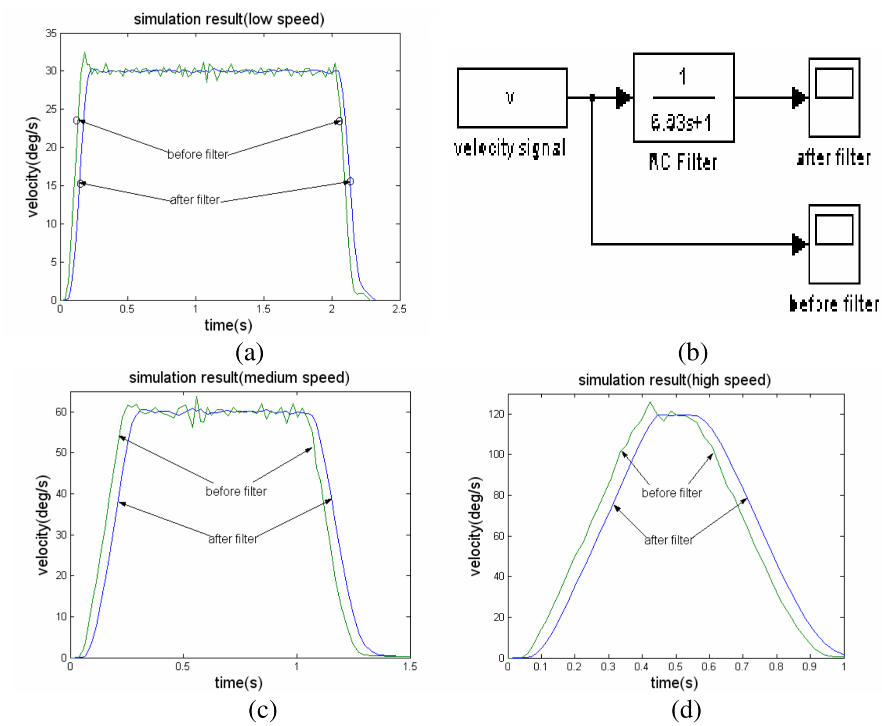

Fig. 6. Simulation result of velocity signal filtering

To obtain better compliance, the robot is controlled to slow down and speed up following an S-type speed curve. The velocity signal is obtained from the encoder signal, and is taken as the input of the filter. Two scopes are chosen to observe the effect of the filter when the RC value of the filter changes.

After simulation, it is found that a suitable RC value range is from 0.02 to 0.04 while the velocity error diminished greatly and the time-delay is small. The simulating interface is shown in figure 6 (a); the effect of the filter in low speed, medium speed and high speed is shown in figure 6 (b~d).

5 Experiment

1.3KW AC servo motor made by YASKAWA is selected as power source, and resolution of the corresponding encoder is 16384cpr. The maximum range of the torque sensor is 300Nm and the resolution 0.1%. The resolution of the A/D card is12 bit. Physical prototype of the robot is shown in figure 7.

5.1 Digital Filter Experiment

The filter coefficient α is calculated by the RC value which determined by simulation, and was validated in experiment. The best RC value is determined by experiment, which is 0.029. Effect of the digital filtering experiment is shown in figure 8. The error in uniform velocity period decreased from 4%~9% of the actual velocity value to below 2% of it. It can be seen from the figure that the velocity signal after filter was smoother and without distortion, the result will come up to the requirement of the system.

Fig. 7. The prototype of the knee rehabilitation robot

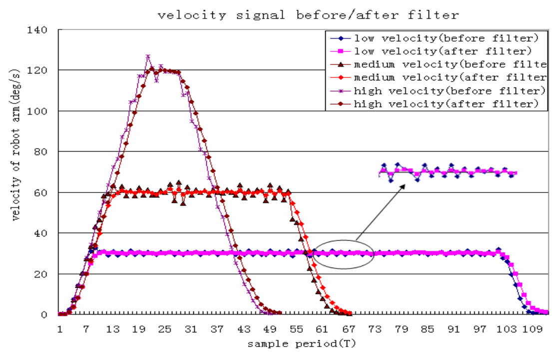

Fig. 8. Result of the digital filtering experiment

5.2 Force Compensation Experiment

There is a 30°angle between the fixture and the axis of the robot arm, so the leg moves from 30°to 90°while the robot arm moves from 0°to 60°. The robot arm was put at a known angle before the training to measure the gravity of the system by the torque sensor. Then the gravitational torque which needs to be compensated can be obtained as:

$$T_g = 7.4 \sin\theta \ . \tag{10}$$

The inertial torque which needs to be compensated can be obtained after calculating the moment of inertia of parts J1:

$$M_1 = 0.39\alpha \ . \tag{11}$$

The robot arm was controlled to speedup from 0 to 30°/s and slowdown to 0 after a few seconds, and move from 0°to 60°at the same time. The effect of force compensation was shown in figure 9. The force signal in the figure was obtained by the measured torque value divided by the arm of the force.

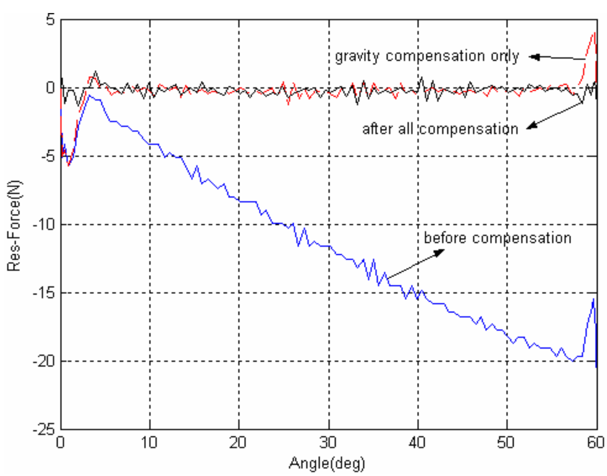

Fig. 9. Comparison of minimal resistant force before and after compensation

Before compensation, the resistant force increased with the angle increases because of the influence of the gravity, and the maximum value is up to 20 N. The force is bigger at the initiation and the termination of the curve because of the influence of the inertia, and the maximum value is up to 5 N. After compensation, the resistant force of the system decreased below 2 N. It is proved that the force bandwidth of the robot was enlarged.

6 Conclusion

In order to maintain a large resistant force bandwidth of the knee rehabilitation robot, it is necessary to compensate the influence of the friction, gravity and inertia of the robot arm. An experimental force compensation method which based on admittance control paradigm is proposed to realize this goal.

Concerning characteristics of rehabilitation robot, the admittance control paradigm in force compensation is inherently suitable in the fields where the friction is hard to be modeled or measured precisely. Furthermore, theoretical model are combined with experimental parameter extraction to compensate the gravity and inertia force. A simplified digital filter is utilized to reduce computation noise of angular acceleration, which is effective to realize satisfied result in compensation of inertia forces.

Experiment results prove the effect of force compensation. After compensation, the system can provide a resistant force as low as 2 N. Considering about the error of torque sensor, the system can output a torque bandwidth as large as 1~300Nm. The results meet force bandwidth requirement of the knee joint rehabilitation system.

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An Interactive Wearable Assistive Device for Individuals Who Are Blind for Color Perception

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Abstract. Color is inaccessible for individuals who are blind or visually impaired, as it is a purely visual feature. Given that many everyday tasks rely on color including coordinating clothing, social interactions, etc., the inaccessibility of color has an adverse effect on daily life. We propose an interactive, wearable assistive device that can recognize and convey colors of scenes or objects. As computer vision is challenging in real world environments due to, e.g., illumination or pose changes, computer vision algorithms can be augmented with sub-systems that can provide information on working environments of a recognition algorithm, and how it affects the recognition accuracy. In this paper, we introduce a framework that incorporates such measures, herein called *confidence measures*, in wearable assistive devices. By communicating to the user a quantitative measure that signifies the difference between optimal working conditions and the real environment working conditions, we can convey the reliability of system-made decisions, which enables the user to take action to improve confidence. Given that color recognition is challenging in real world settings, our system is built within our proposed framework for confidence measures. Finally, we present user recognition accuracies, both with and without confidence measures.

1 Introduction

Color information is inaccessible to individuals who are blind or visually impaired as it is a purely visible feature, unlike multimodal features such as shape or texture. Many everyday tasks rely on color such as coordinating clothing, sorting laundry, shopping, social interactions, etc., and hence, the inaccessibility of color has an adverse effect on daily life. Several commercial color recognizers are available including ColorTest Memo, Color Teller and Speechmaster Colour Detector [9]. However, these devices have several limitations: (1) they are only reasonably accurate; (2) they cannot detect the colors of scenes or distal objects; and (3) most cannot detect complex color profiles. In this paper, we propose an interactive, wearable assistive device that can recognize and convey colors of scenes and multicolored objects, both proximal and distal.

The challenge with most vision-based wearable assistive devices is obtaining satisfactory performance in real world conditions; illumination changes, pose changes,

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scale changes, image blur and noise can be problematic for computer vision algorithms. Illumination conditions, motion blur and noise all adversely affect color recognizers. Some robustness to lighting variations can be obtained through the use of an illumination invariant color space, such as Normalized RGB (NRGB) [5]. Unfortunately, color spaces invariant to intensity changes, such as NRGB, cannot distinguish between colors that vary only with intensity such as white and black, or red and dark red. The color space selected for the work presented here is RGB, which is sensitive to lighting conditions, but can be used to recognize a wide gamut of colors. To ensure robustness against environmental variations (our focus here is lighting variations and motion blur), we propose a collaborative framework wherein the user and system work together to solve a task, that alone, the system can not.

The majority of wearable assistive devices, e.g., systems for assisting individuals who are blind in perceiving or navigating environments, do not seek assistance or feedback from users to help accomplish challenging tasks such as object recognition, face recognition, etc. Repetitive delivery of incorrect results to users causes a decline in system usability and reliability. A strategy to avoid leaving the user out of the "loop" is by communicating the confidence of a system-made decision to the user, which conveys the reliability of the decision, and allows the user to take action to improve confidence. Humans often associate a probabilistic measure with judgments and can state a confidence level involved in their judgment. For example, we might be 100% sure that the object on the table in front of us is a cup, but if lighting in the room is poor, we may not be as sure since lighting is not optimal. Pattern recognition algorithms such as Naïve Bayes, Bayesian networks, etc., are designed to provide a judgment on the recognized category and convey a measure of how reliable or accurate the recognized class is. Such systems are detrimental to wearable systems because humans are sensitive to wrong judgments.

In this paper, we propose a collaborative framework that can augment recognition algorithms by quantitatively analyzing the working conditions of the system, and comparing it to its optimal working conditions. A measure of the difference between the current working condition and the optimal working condition is herein referred to as a *Confidence Measure*. A framework for *confidence measures* exploits the human capacity by involving the user during problem solving to improve system usability and reliability. The novelty of the proposed approach lies in (1) development of an intuitive measure of the difference between real working conditions and optimal working conditions of an algorithm and (2) development of algorithms to derive confidence measures.

Two specific working conditions that can influence the recognition accuracy of computer vision systems include (1) illumination conditions and (2) motion blur. Consider the following example for clarity: a vision-based wearable assistive device, for an individual who is blind, reports that an object's color is red. Without the use of confidence measures, the system conveys the recognized class, and the user must trust that the system is correct. With confidence measures, the system conveys this same decision with a confidence rating of, e.g., 70%, and informs the user that a large amount of motion blur was detected in the image. Understanding the cause of low confidence, the user may act to increase the system's confidence (in this example, he or she may stand still while the system takes another image for analysis). Hence, this is a collaborative framework in which the user and system work together through a human-in-the-loop (HIL) strategy.

The rest of the paper is organized as follows. Section 2 reviews related work. Section 3 presents the conceptual framework. Section 4 covers the experimental methodology and results. And finally, Section 5 presents possible directions for future work.

2 Background and Related Work

A number of handheld color recognizers are available commercially [9]. These devices recognize a color by analyzing the amount of reflected light when the sensor is held firmly against a surface. Hence, accuracy depends on illumination conditions, surface texture and density [9]. ColorTest Memo, from the ColorTest 2000 series developed by Caretec, can recognize over 1,000 color categories, from common colors (red, blue, etc.) to more complex colors (bright red, light yellow, etc.) [9]. ColorTest Memo can also convey a color's percentages of red, green and blue, and the amount of brightness and saturation. Moreover, the system is capable of conveying the colors of multicolored patterns. Similarly, Brytech's Color Teller offers color identification of common and complex colors, but lacks the additional analysis that ColorTest Memo offers and is much less accurate [9]. Finally, Cobolt System's Speechmaster Colour Detector can detect common colors and intensity variations (light, dark, etc.) with reasonably accuracy, but the operation of the device is challenging and requires a calibration step before each use [9].

In the way of vision-based color recognizers, Hub et al. developed a portable device for object identification [8]. An object's color can be estimated from a distance, but the device is limited to recognizing and conveying simple color profiles. Next we review the relevant literature on HIL strategies to improve system performance.

The human-in-the-loop strategy has been utilized mostly in content-based retrieval [2] and collaborative virtual environments [4,6]. Relevance feedback in content-based retrieval [2] improves query results by enabling the user to inform the system about the relevant retrieved items. Based on the user's feedback, the system adapts its search to find more relevant items. Collaborative virtual environments often lack realism due to problems such as a lack of realistic haptic feedback, network delay, etc. Rather than attempt to reduce or ignore network delay, Gutwin et al. [6] proposed to reveal it using visual ornaments called decorators to help users develop coping strategies. Experiments revealed that decorators for telepointers help users adapt to delay in the form of jitter and latency using a fading cursor effect and halo technique, respectively. These decorators are an example of computational aids that help individuals adapt to working conditions and work in symbiosis with systems.

Fraser et al. [4] investigated the limitations of virtual environments, and techniques to reveal these limitations to users to enhance communication and collaboration. Issues identified include limited field-of-view, lack of haptic feedback and network delays. A limited field-of-view causes confusion during interaction as it is not clear to users what is in another user's view. To alleviate this limitation, the authors suggested displaying the extent of a user's field-of-view using lighting. As haptic feedback devices are still in their infancy, the authors recommended conveying haptic feedback through other media such as audio or vision. And lastly, the authors suggested conveying network delay using visual indicators such as slider widgets.

In summary, confidence measures have been utilized in many fields such as content based image retrieval and online virtual environments. In this paper, we present a system to aid in recognition and analysis tasks. Lighting variations are often an impediment in visual recognition of stimuli. Another problem in wearable systems is motion blur, which can significantly affect recognition. We present a system for providing intuitive information on lighting conditions and motion blur to a user.

3 Conceptual Framework

An important element of wearable systems is to design human-in-the-loop methodologies wherein the system and user work collaboratively towards achieving certain tasks. We propose a framework for color recognition that utilizes *confidence measures* to enable the user and system to interact and achieve accurate color perception. In our system, confidence measures have been designed to assess poor lighting conditions and motion blur caused by excessive movement. The system generates a probabilistic measure of color of objects (distal or proximal), and evaluates if motion blur or poor lighting are encountered. The recognized color(s) and information on motion blur and lighting is conveyed to the user in an intuitive manner. This enables a collaborative interaction between the user and system to make judgments about color. In Section 3.1, we discuss the framework for color recognition, and in Section 3.2, we propose a framework for confidence measures.

3.1 Color Recognition and Segmentation

Given an image, each pixel is first classified independently of its neighboring pixels using Bayesian classification. A pixel is classified as the color category that maximizes the posterior probably conditioned on the pixel value:

$$P(C_i \mid x) = \frac{p(x \mid C_i)P(C_i)}{\sum_{j=1}^{n} p(x \mid C_j)P(C_j)} \tag{1}$$

where C_i is the i^{th} color category, x is the pixel value and n is the number of color categories. As shown in (1), the posterior probability is equal to the likelihood of C_i times the prior probability of C_i divided by a normalization factor, which can be ignored for the task of classification. The prior probability is the number of occurrences of a certain color category divided by the total number of pixels in the training set. The likelihood of C_i can be estimated using Maximum Likelihood Estimation (MLE). Assuming the densities are Gaussian, MLE is achieved by computing the mean and covariance matrix of each color category.

Given that vision-based wearable systems are (1) usually equipped with low-cost off-the-shelf video equipment, and (2) must operate in real world conditions with extreme environmental variations, point-based color classification often misclassifies pixels, resulting in noisy segmentation results. Instead, we can take into account a pixel's neighborhood to improve segmentation. In our framework, we use the methodology of [1], which uses the Iterated Conditional Modes (ICM) algorithm [3] to maximize a pixel's conditional probability based on its neighborhood. As in [1], we assume that the classes of neighbors are known, and each color category is treated as an independent process, modeled by the first order Gibbs-Markov random field:

$$P(C_i \mid N) = \frac{1}{Z} e^{-\lambda \frac{N_i}{N}} \quad (2)$$

where N is the neighborhood, N_i is the number of pixels in the neighborhood that fall into color category C_i, Z is the normalization factor, which can be ignored since it is constant across posterior probabilities, and λ is the clique potential, which determines the dependence of a pixel on its neighborhood. As $|\lambda|$ increases, a pixel's dependence on its neighborhood strengthens. In the ICM algorithm, (2) is applied to the image multiple times until a stopping criterion is met.

Once an image has been segmented into n or less color categories, colors are conveyed to the user as proportions. For example, if an object's color profile is half green and half red, the colors of the object would be conveyed to the user as approximately 50% red and 50% green. As motion blur, lighting variations and noise introduce segmentation errors, colors that make up a negligible portion of the image, determined by a certain threshold, e.g., 2%, are ignored.

The wearable system operates under two modes: distal and proximal. In the distal mode, the user may perceive all the colors present in a scene, and in the proximal mode, the user may hold an object in his or her hand, and move it in front of the wearable camera to assess its color profile. Before the colors of the proximal object are recognized, the foreground is segmented from the background, which can be accomplished through automatic cropping or more advanced techniques. Finally, once an image is captured and color segmented, color proportions are conveyed to the user.

3.2 Confidence Measure Framework

The proposed framework for confidence measures for wearable systems is shown in Figure 1. Given input from the environment, e.g., an image or video, the system analyzes the input and reports its decisions to the user on estimated motion blur and lighting conditions. Recognition algorithms are either deterministic or stochastic in nature. Deterministic algorithms assign a recognition class label. On the other hand, stochastic algorithms assign a probability value to a recognized class. Often, the probability value assigned to the recognized class can be employed to present users with some level of information on how well the algorithm performed. However, this measure is often not associated with the cause for performance degradation leaving users with the difficult task of guessing why the system is not performing with high reliability. Here, stochastic algorithms are grouped under algorithm-dependent factors, and may help provide an initial confidence measurement.

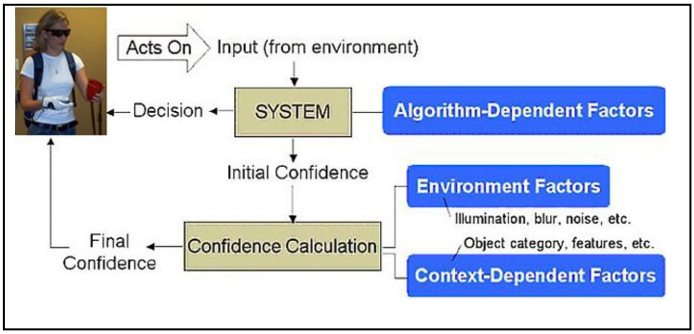


Fig. 1. Confidence measures framework

Environment factors such as illumination, motion blur, and noise can be taken into account for confidence calculation in our framework. Based on these factors, penalties or rewards are issued for the current estimate of the recognized class. In this paper, we propose algorithms for confidence measurement based on illumination and motion blur, which are presented in the next two subsections. At the final stage, context-dependent factors are considered, which may include object category or features, context, etc., depending on the application. As an example of context-dependent factors, consider an object that is classified as a bowl with 95% confidence. The system may further investigate other features of this object such as its material or size. If the material of the object is classified as cloth with high confidence, then the object is most likely not a bowl, and the original 95% confidence is penalized. On the other hand, if the material is classified as ceramic, then the object is likely a bowl, so confidence is increased. (Confidence cannot exceed 100%.)

Illumination Classification. Illumination classification attempts to match the illuminant of the scene to one of several illuminant models. One algorithm for illumination classification is an object-based approach developed by Hel-Or and Wandell [7]. For each illuminant, given the set of all surface reflectances of an object and the set of camera sensors, a cluster of points in 3D sensor output space is generated. When an image is captured, object segmentation is performed, and each set of pixels belonging to the object in question forms a cluster in 3D sensor space. Each image cluster is classified as the closest illuminant using Mahanalobis distance. The disadvantage to this approach is that object segmentation is required, which, in general, is still an unsolved problem. We propose an algorithm for real-time illumination classification that does not require scene segmentation. Our illuminant classifier categorizes the current illuminant into one of several coarse illuminant classes: poor (too dark), good (a little dark), great, good (a little bright) or poor (too bright).

To obtain an estimate of the illuminant of a scene, its luminance is estimated by computing the mean grayscale value of its image. This value is then classified using Bayesian classification to categorize the illuminant as one of the five proposed classes. The priors reflect how often each of the five illuminants occurs. Class-conditional densities are estimated using MLE. Assuming the probability density functions are Gaussian, the unknown parameters mean and variance are estimated by the sample mean and sample variance of the mean grayscale values of the training data, where sample mean and variance calculations are done separately for each class.

Motion Blur Classification. A variety of approaches exist for estimating motion blur in an image [5]. These algorithms estimate motion blur parameters, utilizing a degradation function H, to restore a blurred image. In this paper, we instead wish to classify the amount of motion blur using a measure that can be categorized as one of several motion blur levels. One approach is a no-reference, perceptual blur metric developed by Marziliano et al. [10]. This algorithm measures edge spread through edge detection followed by computing the average edge width, where edge width is defined as the local extrema locations closest to the edge. In the context of confidence measures, it is important to know why confidence has been penalized as this communicates to the user what must be done to increase confidence, and hence, improve reliability. Unfortunately, the approach of [10] is sensitive to any type of blur, and thus is not useful in this context.

We propose a real-time algorithm for classifying the amount of motion blur contained in an image, which requires no reference image and is sensitive to only motion blur. Our algorithm aims to classify the overall motion blur present in an image, whether this blur is caused by user and/or object movement. Further, our algorithm takes an indirect approach in that it does not directly classify motion blur, but overall movement, which is a good indicator of the amount of motion blur in an image. Our proposed algorithm for motion blur classification is described next.

The algorithm takes as input the current frame of the video stream as well as the previous frame. A difference image is computed by subtracting the current and previous frames. If a pixel value remains the same between the previous and current frame, it will have a value of zero in the difference image; otherwise, it will have a value greater than zero. A binary threshold is then performed on the difference image, and the image is scanned both horizontally and vertically to detect vertical and horizontal lines, respectively. The average width of vertical and horizontal lines is computed. A line is vertical if its height is more than its width, and a line is horizontal if its width is more than its height. The larger of these two averages is then classified as one of four motion blur classes: *no motion blur*, *small motion blur*, *large motion blur* or *extreme motion blur*. The range of average line widths is divided into four sub-ranges representing the four classes. These sub-ranges are determined though experimentation such that motion classifications predict the corresponding motion blur levels.

4 Experimental Methodology

We built a vision-based wearable assistive device for color perception based on our proposed framework. The system consists of a pair of sunglasses with an embedded video camera, headphones for audio output, USB number pad for input and a laptop. The proposed framework for color recognition and segmentation was implemented. Training data consisted of manually segmented color images taken from the COREL color image database. Our color categories, and respective pixel counts for training, included *white* (1600), *gray* (300), *black* (1072), *red* (1100), *light red* (400), *dark red*

(400), *green* (600), *light green* (100), *dark green* (300), *blue* (1100), *light blue* (400), *dark blue* (400), *orange* (500), *purple* (600), *yellow* (500) and *brown* (600). Both priors and class-conditional probabilities were estimated and used in (1). We assumed Gaussian densities, and used MLE to estimate the means and covariance matrices.

Through experimentation, we estimated parameters for (2). We found a neighborhood size of 3 and 3, and a clique potential of -5 and -0.1, to work well for proximal and distal mode, respectively. Our stopping criterion was when the number of classification updates is below a threshold, which is recommended by [1]; we found a threshold of 1000 to work well. As a preprocessing step, noise is reduced using median filters before point-based classification. See Figure 2 for segmentation results.

Distal mode uses the entire 320x240 captured image, whereas in proximal mode, to segment the foreground from the background, we crop the image from each side by 50 pixels. Hence, to use proximal mode successfully, the user must hold small objects close and large objects farther from the camera. This segmentation technique, although simple, was effective for our purposes.

Algorithms for illumination and motion blur classification were implemented and integrated into our system. Motion blur categories *no motion* and *small motion* did not penalize confidence, but *large motion* and *extreme motion* each generated a penalty of 30%. Both *poor* illumination categories generated a penalty of 20%, and both *good* illumination categories generated a penalty of 10%. Illumination category *great* did not penalize confidence. In our system, the initial confidence begins at 100%. The confidence measure based on illumination was trained using 1200 images of indoor and outdoor environments, captured from the wearable system. Each image was manually labeled as one of the five illuminant classes. Ten-fold cross-validation was used to evaluate the algorithm, which provided a classification accuracy of 96%. To train the confidence measure based on motion blur, we manually adjusted the decision boundaries until the four motion levels corresponded with the four motion blur classes. To test the algorithm, we collected 400 image pairs from video recorded from the wearable system. These image pairs were manually labeled, and then classified by our algorithm with an accuracy of 95%.

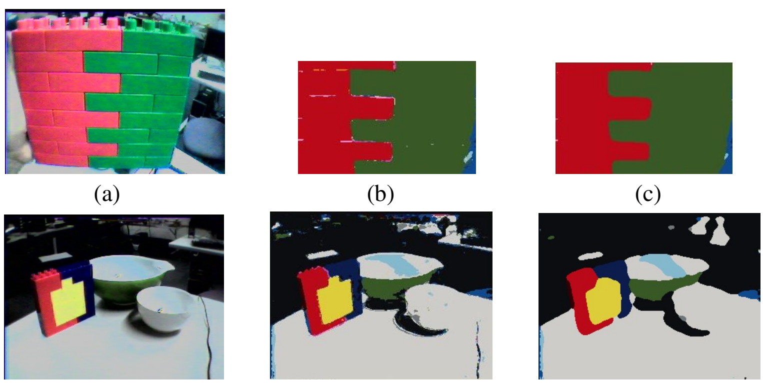
Two experiments were designed to test the validity of the system. Both were performed in an office setting, and involved three participants who are totally blind and one participant who is visually impaired but has some color perception (this participant was blind-folded during the experiment). The first experiment tested system usability (in the proximal mode) without confidence measures. During the training phase, participants learned how to use the system and were asked to perceive the color profiles of five, randomly presented objects. Before the experiment, participants were informed that motion blur and lighting can affect system accuracy. Participants repeated the training phase until all color profiles were estimated correctly. During the testing phase, ten novel objects are randomly presented, and participants were asked to estimate each color profile. Moreover, for five of these objects, which were randomly selected, the lights were turned off to simulate an environment with poor lighting. The test objects are the same for all participants; the set consists of a red bowl; black cup; yellow and white cup; green pail; white bowl; red and green block; red, blue and yellow block; blue and green block; block wrapped in wallpaper with a floral pattern; and a block covered in brown sandpaper. (The blocks were made from LEGO® blocks.)

During the training phase for experiment two, participants learned about confidence measures and how to use them. For example, if there is motion blur in the image, the participant may try again, but this time, reduce movement. Or, if lighting is not optimal, then the participant may, e.g., change their orientation or the orientation of the object with respect to the lights, or instruct the experimenters to adjust the lighting in the room (e.g., turn the lights up), and then try again. Participants first went through a training phase similar to before but with confidence measures, and then tested on the set of ten objects described before while using confidence measures. Similarly, objects were perceived in the proximal mode, and lights were turned off for five randomly selected test objects.

Table 1. User/System accuracies for Experiment 1 and 2. Accuracies are documented as the number of objects correct out of the total number of objects.

	Experiment 1	Experiment 2
Participant 1	2/10	7/10
Participant 2	3/10	7/10
Participant 3	3/10	6/10
Participant 4	4/10	7/10

User/System accuracies are shown in Table 1. An object is classified correctly if all its colors are identified and proportions are within 20% of the actual proportions. Colors with proportions of 10% or less were considered noise and ignored. These results show that our system can allow accurate perception of complex color profiles with the use of confidence measures. Further, these results show a major improvement in user/system accuracy when confidence measures are utilized as they allow the user to interact with the system to achieve better results.



(a) (b) (c)

(d) (e) (f)

Fig. 2. Segmentation results for proximal (a-c) and distal (d-f) mode. (a) and (d) are the original images, (b) and (e) are point-based classified images (cropped if proximal mode) and (c) and (f) are the final, segmented images.

5 Conclusion and Future Work

An interactive, wearable assistive device for color perception was proposed. Further, a framework to integrate confidence measures with wearable assistive devices was presented, along with algorithms for classifying illumination and motion blur, which can be used for confidence measurement. Results demonstrate that confidence measures can help make systems more reliable and usable by involving both the user and system in problem solving. Future work will involve continued testing with more participants, and the use of additional environmental and context-dependent factors.

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Integration of Caption Editing System with Presentation Software

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Abstract. There is an increasing number of rich content that includes audio and presentations. It is important to caption these contents to assure accessibility for hearing impaired persons and seniors. Initially, we conducted a survey and found that the combination of video with audio, captions, and presentation slides (hereafter "multimedia composite") is helpful in understanding the content. Also our investigation shows that the availability of captioning is still very low and therefore there is a strong need for an effective captioning system. Based on this preliminary survey and investigation, we would like to introduce a new method which integrates caption editing software with presentation software. Three major problems are identified: Content layout definition, editing focus linkage, and exporting to speaker notes. This paper will show how our Caption Editing System with Presentation Integration (CESPI) solves these problems. Experiments showed 37.6% improvement in total editing time.

Keywords: Accessibility, Captioning, Presentation, Voice Recognition.

1 Introduction

1.1 Background

Recently an increasing amount of e-Learning material including audio and presentation slides is being provided through the Internet or private networks referred to as intranets. Many hearing impaired people and senior citizens require captioning to understand such content. Captioning is a vital part of accessibility and there are national standards such as “JIS X8341-3 5-4-d”[1] and also laws such as “Section 508 of the Disabilities Act”[2] to assure accessibility to publicly available contents.

There are real time captioning techniques, but here we will focus on the post editing to assure accurate captioning for digital archives. In this paper, we introduce the method of “IBM Caption Editing System with Presentation Integration (hereafter CESPI)” which is an extension to IBM Caption Editing System (hereafter CES). CESPI completely includes all the functions within CES, but is further extended to include the presentation integration functions.

CES[3] works alone as a system but also it is an optional extension system to the Liberated Learning Project[4]. CES encapsulates the voice recognition engine for

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transcribing audio into text (CES Recorder) and also allows various editing features for error correction(CES Master and CES Client). As shown in Fig. 1, CESPI integrates presentation software in various ways for both the CES Recorder and the CES Master System.

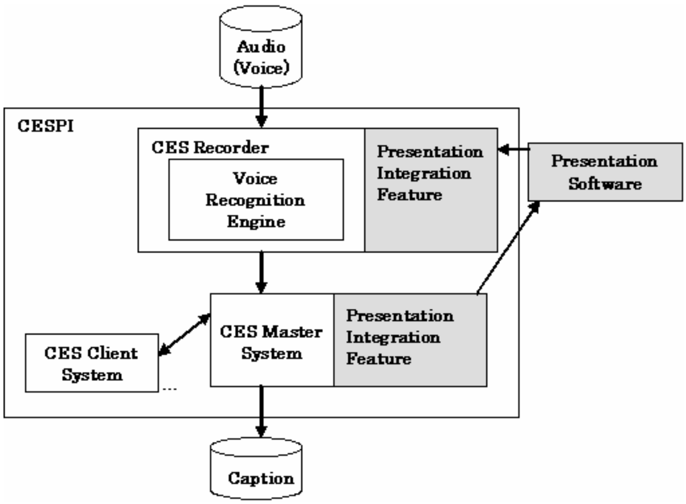

Fig. 1. CESPI receives audio(voice) input and CES Recorder by encapsulated voice recognition engine, transcribes the audio into text. CES Master System and CES Client System allows collaborative editing. CESPI adds a presentation integration feature to both CES Recorder and CES Master System.

1.2 Previous Methods

Presentation software provides many useful features to easily create effective e-Learning contents by the following 2 steps.

1. Prepare presentation file by combination of text, pictures, visual layout, and any other provided feature.
2. Make oral presentation using the slide show feature of the presentation software. At the same time record the movie by any video camera and/or oral presentation audio.

Common real time approach to caption audio contents is to use a traditional method called “stenography”[5]. The method of stenography is to basically manually type the oral presentation audio into text. The problem with stenography is identified as the cost of human labor[6].

To solve the problem of high human labor cost, some new techniques using Voice Recognition engine have been adopted[7]. Unfortunately voice recognition is not 100% accurate. Therefore for post editing, some techniques combining Voice Recognition engine and manual editing have been proposed. One such method is referred to as “respeak”[8] where a speaker with expected high speech recognition rate would totally re-speak the audio and manual correction follows[9]. Also there are methods of connecting several PCs over the network for collaboration between several stenographers [10][11]. SpeakView[12] integrates with presentation software for real time captioning. CES is a post editing method which aims to collaborate between experienced editors and novice users [13].

While many post editing captioning systems aim to reduce the human labor for accurate caption, in reality the caption editing work is still very labor intensive. Therefore, it can be said that there is still a strong demand for an effective system that can reduce the editing time required for captioning.

2 Preliminary Survey and Investigation

We conducted a survey to see whether the combination of video with audio, captions, and presentation slides (hereafter "multimedia composite") is helpful in understanding the content. We created 4 multimedia composites, and then allowed a total of 80 senior citizens and people with disabilities to view any content of interest freely. After viewing, we administered a survey, and as shown in Table 1 the results showed that 66.3% found the multimedia composite either "very useful" or "useful", irrelevant of age group. So we concluded that a multimedia composite is very useful for better understanding in e-Learning.

Table 1. The table shows the survey result by age group. 7 people found the multimedia composite to be very useful, 46 found it useful, and 27 found it not useful.

Age Group	Very Useful	Useful	Not Useful
20s	0	4	0
30s	0	1	1
40s	0	3	2
50s	0	6	6
60s	2	9	6
70s	3	21	10
80 and higher	2	2	2
Total	7	46	27

Next, we conducted an investigation to see whether multimedia composites are captioned. We searched through the internet for multimedia composites, and found that out of 100 composites[1], only 21 were adequately captioned, 1 merely provided transcript text. It seems that the main reason for this low rate of captioning is due to the high labor costs. There are several approaches for captioning, but here we focus on using voice recognition technology. Unfortunately the voice recognition accuracy rate is still not 100%, and therefore there is a still a need for an effective caption editing system to correct the errors.

The conclusion of our preliminary survey and investigation is that in order to reduce the costs of captioning content with audio and presentation slides, there is a strong need for an effective caption editing tool. The presentation slides are mostly

[1] Conditions were web sites free of charge, max of 5 composites per domain.

created by commercial presentation software. In this paper, we focus on a voice recognition error correction system which integrates a caption editing system with presentation software.

3 Problems and Apparatus

Based on the preliminary survey and investigation, we investigated the available caption editing tools that generate captions from audio, and identified 3 major problems. The three major problems between CES and presentation software were identified as "Content Layout Definitions", "Editing Focus Linkage", and "Exporting to Speaker Notes". To address these problems, we extended our Caption Editing System (CES) to integrate it with Microsoft PowerPoint, creating our new Caption Editing System with Presentation Integration (CESPI). The architecture in terms of code interface is shown in Fig. 2.

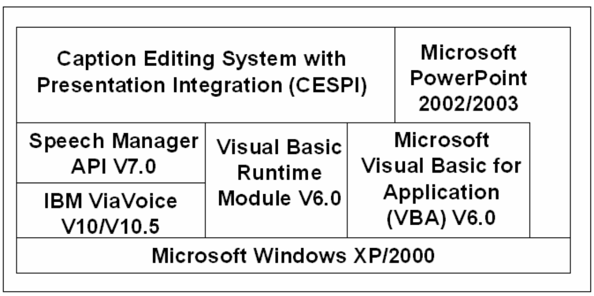

Fig. 2. The base platform is Microsoft Windows 2000/XP. User Interface of CESPI is built on Visual Basic V6.0. IBM ViaVoice[14] engine control is implemented by Microsoft Visual C++ 6.0. The interface between ViaVoice and CESPI is Speech Manager API (SMAPI) V7.0 [15]. Also, the interface between CESPI and Microsoft PowerPoint[16] is Visual Basic for Application (VBA) V6.0[17].

3.1 Content Layout Definition

A multimedia composite consists of several visual components such as video, presentation images, and captions. These components needs to be laid out effectively in position and size according to such parameters as font face, font size, number of maximum characters per line, presentation image size, vice image size, resolution, overall size, and overlapping options. (Fig. 3 shows a bad example of by excessive space, overlap, cut off.) CES (and CESPI) supports the RealOne Player[18] by SMIL[19] format and also Windows Media Player[20] by SAMI[21] format.

The task of effectively laying out these components manually can be quite time consuming. CESPI solves this problem by automatically laying out these components based on each parameter. As shown in Fig.4, CESPI also provides a layout customization feature which allows the user to easily change the details of the layout.

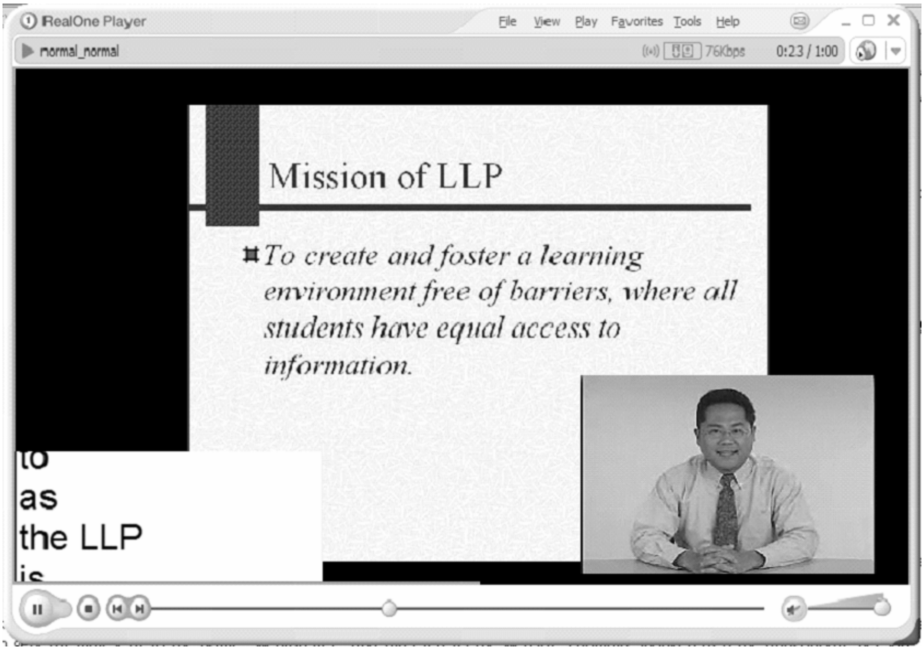

Fig. 3. The figure shows a sample of ill defined layout, where presentation image is surrounded by excessive empty space. Video and caption overlap with the presentation image. The caption is being cut off by the window boundary.

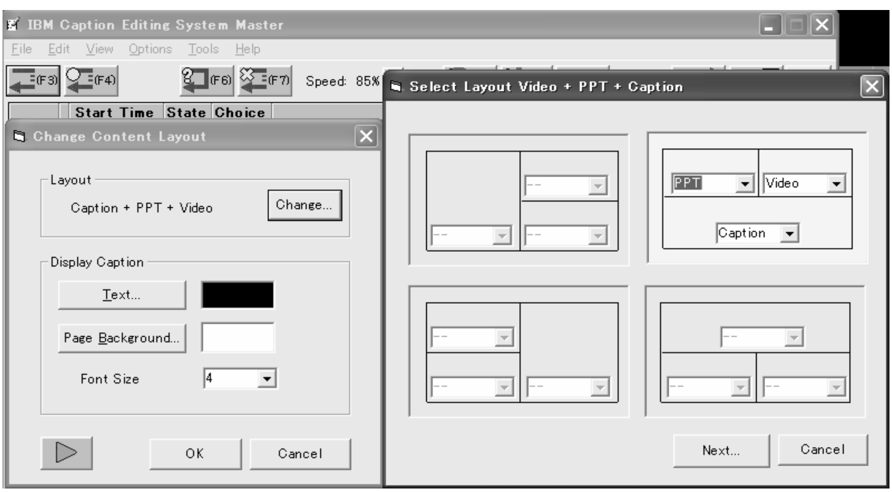

Fig. 4. The figure shows the Change Content Layout dialog on the left hand side and the Select Layout Video + PPT + Caption dialog with the focus on the right hand side

3.2 Editing Focus Linkage

While editing the captions of certain multimedia composites, it is useful to reference special terminology used in the presentation slides. Because caption editing tools and presentation software were separate applications, the operating system only allows one application to have the focus at one time. Therefore it was necessary to frequently switch the focus between these two applications. Also, the user had to change to the corresponding slide pages manually. CESPI solves this problem by automatically laying out the captions, page images, and page text in a single application window, which makes it easier to view and edit the captions. CESPI also automatically interlinks between the caption timestamps and the presentation page. In other words, the presentation page always corresponds to the focused caption. (Fig.5 shows the actual user interface of the CESPI Master Editing Subsystem.)

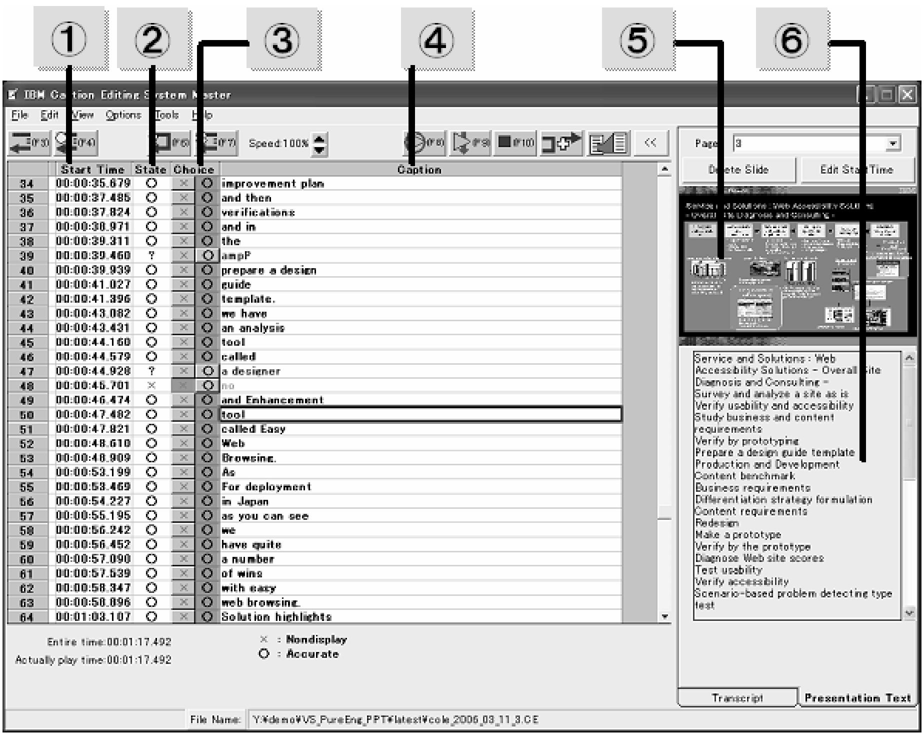

Fig. 5. On the left hand side basically shows the "Caption Line Text" (start time, state, choice, and caption). "Start Time" pointed to by the "1" represents the 0 based timestamp which to display the caption. "State" pointed to by the "2". "Choice" is pointed to by the "3". "Caption" is pointed to by the "4".On the right hand side basically shows the "Presentation Page". "Presentation Image" is pointed to by the "5" and retrieved text is pointed to by the "6".

3.3 Speaker Notes Export

Using presentation software, a speaker may define narrative notes for each presentation page (the "speaker notes[22]"). In many cases, a single presentation package used by one presenter will be later reused by another presenter. In such cases, since the captions and speaker notes are similar, it is efficient to use the initial caption. Previously, in order to export captions to speaker notes, manual operations such as moving to the proper page and then performing copy and paste operations were required. Therefore as illustrated in Fig.6, CESPI has a capability for automatically exporting the corresponding page of the caption into the speaker notes of the presentation package.

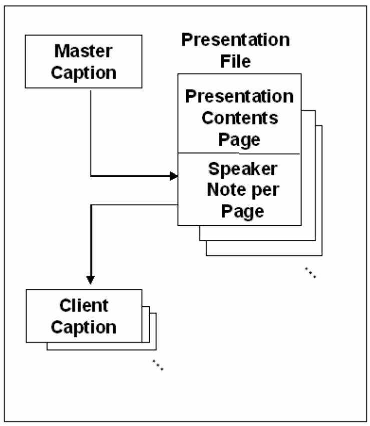

Fig. 6. Master caption is exported into the speaker notes portion of the presentation. The speaker notes can be referenced to the client caption.

4 Results

An experiment was performed to measure the editing time under the following conditions.

1. Editors are to use CES and CESPI for an approximately 30 minutes of content each.
2. It is known that as you get used to 5 editors who already have enough experience with CES and CESPI were chosen to eliminate any inconsistencies due to the learning curve effect[23].
3. Each editor was also assigned different portions of the content for CES and CESPI so that memory from the previous content will not take effect.
4. Task consists of correcting all the voice recognition errors, laying out the multimedia composite without each overlapping or excessive blank space, and

exporting the speaker notes to the appropriate page. (Conditions are shown in Table 2.)

Table 2. The table shows the conditions for the Windows Size, Component Layout Position(Video, Presentation Image, Caption), Caption Font Specification(Charset, Face, Color, Size), and other conditions

Category	Conditions
Window Size	800x460
Component Layout Position (Video)	Right Upper Position
Component Layout Position (Presentation Image)	Left Upper Position
Component Layout Position (Caption)	Bottom
Caption Font Charset	x-sjis
Caption Font Face	osaka
Caption Font Color	black
Caption Font Size	+3
Other Conditions-1	No Excessive Empty Space
Other Conditions-2	No Overlap
Other Conditions-3	No Cutoff

As shown in Table 3, the results showed that CESPI provided a 37.6% improvement in total editing time.

Table 3. The table shows the result of the exeperiment. It compares CESPI with CES and the amount of time it took to edit the contents. Editing Time Average per Content Time showed 3.30 for CESPI as opposed to 4.54 for CES. Thus, the Total Efficiency in Percentage for CESPI is 37.6%.

	CESPI	CES
Voice Recognition Rate	81.4%	80.8%
Average Content Time	28min 24sec	27min 58 sec
Number of Characters[2]	9240	9221
Total Average Editing Time[3]	93min 46sec	127 min 2 sec
Editing Time Average per Content Time	3.30	4.54
Total Efficiency in Percentage	37.6%	(N/A)

Fig.7 shows the ratio of time which accounted for the saved time by “Content Layout Definition”, “Editing Focus Linkage”, and “Speaker Notes Export”. It can be seen that Content Layout Definition accounted for approximately half of the time, while Editing Focus Linkage follows and then Speaker Notes Export made the slightest difference.

Content Layout Definition saved much time for CESPI since content layout required much trial and error type of editing for CES. CESPI practically required almost no time since layout can be done automatically.

[2] Mainly Japanese characters, number includes punctuation marks.
[3] Does not include the initial time commonly required to listen to the whole content.

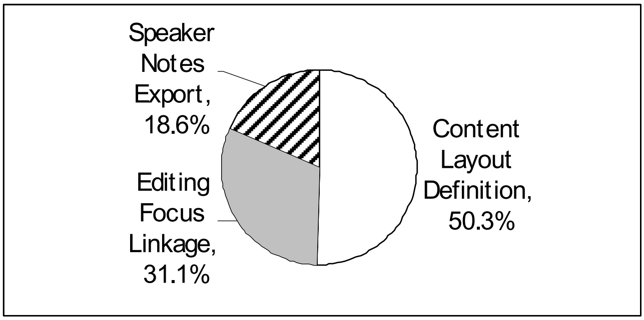

Fig. 7. Figure shows that out of the improvement of editing time shown in Table 2, 50.3% accounted for Content Layout Definition, 31.1% accounted for Editing Focus Linkage, 18.6% for Speaker Notes Export

5 Summary

The three major problems between CES and presentation software were identified as "Content Layout Definitions", "Editing Focus Linkage", and "Exporting to Speaker Notes". This paper has shown how CESPI solves each of these problems. And experiment showed a 37.6% efficiency improvement compared with the previous method. Among the 3 items "Content Layout Definition" accounted for the most improvement in time, followed by "Editing Focus Linkage" and "Speaker Notes Export" came last.

Currently CESPI only supports IBM ViaVoice as the voice recognition engine and Microsoft PowerPoint as the choice of presentation software. Future work item will be to support other voice recognition engines and also possibly to support other presentation software.

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Cognitive Styles and Knowledge of Operational Procedures of Electric Appliances

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Abstract. The objective of this research is to investigate the relationship between user's knowledge of operation procedures for some electric appliances and their cognitive styles. First, questionnaires were given to the participants. The participants answered below questions about cognitive styles. Second, to investigate the participants' knowledge of operating procedures of the electric appliances, participants were asked to write free text description on how to use an appliance without actually operating it. We found certain kinds of knowledge about operation procedures were linked to user's cognitive style.

Keywords: cognitive style, mental model, operating procedure, electronic appliance.

1 Introduction

The objective of this research is to investigate the relationship between user's knowledge of operation procedures for some electric appliances and their cognitive styles. The electric appliances investigated were home electric appliances, IT devices, information kiosks, etc., that are used in everyday life.

The first author conducted this study in Wakayama University Graduate School of System Engineering.

2 Methods

2.1 Questionnaires and Experiment

22 of the participants were in their 20s and 30s, 11 were in their 50s, and 22 were in their 65 or older. The studied appliances consisted of automatic teller machines (ATMs), air

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conditioners, copy machines, CD/radio cassette recorders, computerized dictionaries, FAX machines, home video games and electric massagers for household use.

First, questionnaires were given to the participants. The participants answered below questions about cognitive styles.

Q Please select one of A or B.

Q1.
- A. I am cautious in my thinking.
- B. I am not cautious in my thinking.

Q2.
- A. I count my own opinions.
- B. I count the many's opinions.

Q3.
- A. I am meticulous.
- B. I am not meticulous.

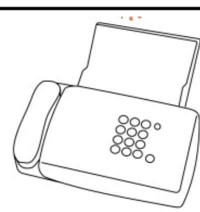
Q4.
- A. I prefer to play it by ear.
- B. I prefer to make a clear decision.

Second, to investigate the participants' knowledge of operating procedures for the electric appliances, an experiment was conducted. The experimental method consisted of the following procedures:

1. An experimenter explained the electric appliance and the goal of job, and showed a picture of it. (Table 1.).
2. The participant wrote out a free description on one card for a step to perform the task, without actually using the device.

The experiment was conducted for each participant and for each appliance.

Table 1. Samples of experimental tasks

Appliance	erse Captio	Job	Start	End	Illustration
Air conditioner	The machine is for controlling temperature.	There is an air conditioner. Now you are before going to bed. Set the air conditioner to turn on the heater automatically	Plug the power cords for the air conditioner into electrical wall outlets.	Power on the air conditioner automatically.	
Fax machine	The machine is to transfer copies of documents.	There are an fax machine and a document. Transfer copies to one of your friends from your fax machine.	Plug the power cords for the fax machine into electrical wall outlets.	Have sent the copy to your friend.	

2.2 Analysis

These cards were classified into about 300 tasks.

The participants were classified according to what tasks they answered using Hayashi's Quantification Theory III and Cluster Analysis. This analysis was conducted with respect to each appliance. The number of the clusters is from five to seven per appliance. The clusters are described as “Knowledge of Operational Procedure Type” in this paper.

We evaluated correlate between the clusters and the answers about cognitive styles (Q1-Q4) by applying Fisher's Exact Test (Extended).

3 Results and Discussion

Table 2 shows the results of the evaluation on Knowledge of Operational Procedure Type -Cognitive Style correlation. Air Conditioners correlate with Q2 (I count my own opinions / I count the many's opinions). FAX Machine correlate with Q3 (I am meticulous / I am not meticulous).

Table 2. Knowledge of Operational Procedure Type -Cognitive Style Correlation

Question / Appliance	Q1 Cautious	Q2 Independence	Q3 Meticulous	Q4 Play it by ear
ATM				
Air Conditioner		*		
Copy Machine				
CD/radio cassette recorder				
Computerized Dictionary				
FAX Machine			*	
Home Video Game				
Electric Massager				

(**: p<0.01, *: p<0.05)

3.1 Air Conditioners-Q2

The knowledge of operational procedure types about air conditioners correlates with Q2 (I count my own opinions / I count the many's opinions). We think the reason comes from that. An air conditioner is used by several users and its function reflects to other people in a family. Therefore the user uses it with communication at home. So the knowledge correlates with if the user prefers to count others’ opinions.

3.2 Fax Machine-Q3

The knowledge of operational procedure types about fax machines correlate with Q3 (I am meticulous / I am not meticulous). We focus on the type B, because the number of the participants that gave “A. I am meticulous” is most on the type.

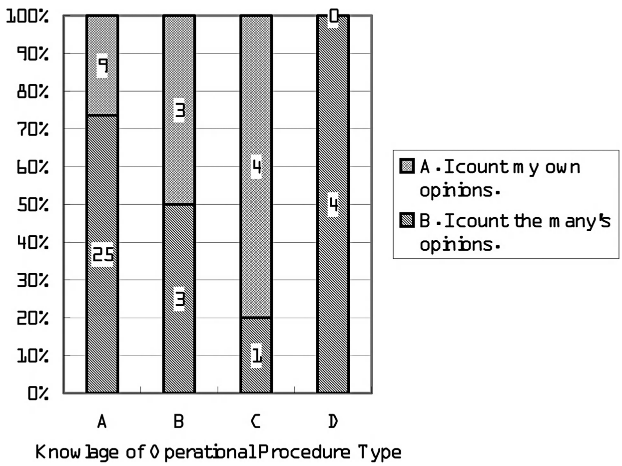


Fig. 1. Rate of Cognitive style (Air Conditioner)

More participants in the type B give "Power on" (63.2% of the type B) and "Put the machine in the fax mode" (73.7% of the type) as the answer than the other types (0%-4.8%). Many participants in the type B think that these procedures should be executed. We think that meticulous users mind upping procedures.

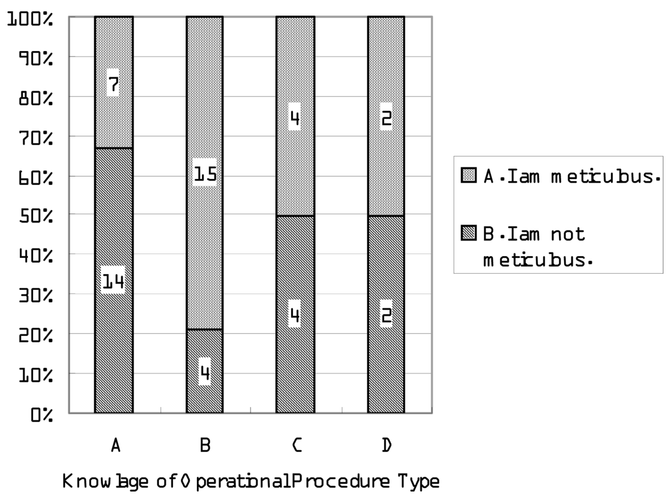


Fig. 2. Rate of Cognitive style (Fax Machine)

4 Conclusion

We found certain kinds of knowledge about operation procedures were linked to user's cognitive style. But it is partly and we cannot explain why the others are not linked the cognitive styles. We should more study aspect of other cognitive styles, user's experience and their age.

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Cognitive Scales and Mental Models for Inclusive Design

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Abstract. In keeping with a user capability and product demand approach to product assessment, this paper examines the cognitive demands placed on users when interacting with consumer products. The eventual aim is to develop a set of cognitive capability scales that could be used in the analytical evaluation of product interfaces. We explore the dimensions of cognitive capability relevant to product interaction and describe how these may be used to evaluate a given design. Planned work addresses quantitative measurement of cognitive capabilities and predictive validation of capability scales.

Keywords: Inclusive Design, Product Evaluation, Cognitive Assessment, working memory.

1 Introduction

Inclusive design is defined as the "*design of mainstream products and/or services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design*" [1]. It is therefore a design philosophy that aims to consider the needs and capabilities of older and disabled users in the design process. In addition, the approach is focused on mainstream product design as apposed to assistive technology by avoiding aids, adaptations and stigmatising designs [2]. The concept of inclusive design is similar to Universal Design which is popular in the United States and Japan. As the term 'universal' may connote a 'one size fits all' approach, inclusive design attempts to include users with reduced functional capability in mainstream product design without sacrificing product aesthetics and desirability. Recognising that a completely inclusive product is an ideal as opposed to a practically achievable result, the focus of inclusive design is on implementing a *user-centred design process*. The result of such a process should be improved product designs that *minimise the exclusion* of less capable populations [3].

Designers require information on the range of human sensory, cognitive and motor capabilities in order to evaluate their designs [4]. Traditionally, human factors information is delivered in the form of guidelines and handbooks [5-7]. However, recent research has shown that designers require quantitative data on the numbers of

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people with functional capability loss presented in accessible and visual formats [8, 9]. Currently, there is a lack of a complete, unified source of user capability data that could be used to evaluate design concepts. The following section gives the background to this research and demonstrates the need for the development of cognitive capability scales.

2 Background

The ideas of user capability and product demand provide a useful framework for design evaluation. Figure 1 shows this framework where the sensory, cognitive and motor demands made by a product are compared to the capability levels of the target user population [4, 10]. In order to measure the level of compatibility between the user and the product, various evaluation methods can be employed. These methods can be roughly classified into empirical methods and analytical methods [11].

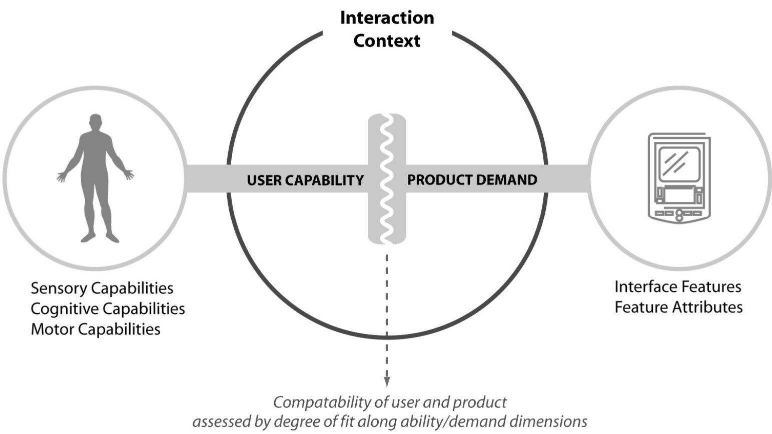

Fig. 1. A model for evaluation based on user capability and product demand

Empirical evaluation methods measure design performance in actual usage scenarios by having users perform tasks with a product design. Various performance metrics are recorded such as time taken, number and type of errors, and subjective impressions. Analytical methods rely on the detailed inspection of the product and intended scenarios of use without direct user involvement. Analytical methods can range from applying a relatively cheap and quick heuristic evaluation to the use of predictive engineering models of user behaviour. Ideally there should be a balance of both analytical and empirical evaluation methods in the design process depending on the resources available. Though the importance of user involvement in the design process cannot be overemphasised, there is value in utilising analytical methods in the evaluation process due to constraints of time, cost and logistical difficulties in recruiting and testing with real users [12]. In addition, analytical methods are especially advantageous in the inclusive design process where a group and population view on user capability is required [13, 14]. We therefore concentrate on the development of methods to analytically evaluate consumer products for accessibility and usability.

Keates [2] describes human functional capability in the three psychological dimensions of sensory, cognitive and motor capability based on the Model Human Processor [15]. This provides a useful basis for engineering model of capability for product evaluation, even though the three dimensions are not independent and do interact in the performance of real world tasks. A unique source of capability data exists in the global functional capability scales developed for the 1996/97 Great Britain Disability Follow-up Survey (DFS) [16]. Though the scales lack the granularity and completeness to evaluate all aspects of consumer products, they provide a unique set of multivariate capability data that is representative of the Great Britain population. Langdon et al. [17] describe an attempt to derive improved capability scales for assessing product interaction based on current approaches in cognitive psychology. It was shown that this was possible within the confines of the variables measured in the survey and further work is required to develop a more complete set of design relevant cognitive capability scales.

In this paper, we focus on the cognitive demands of consumer products via an analysis of product features and user tasks. We outline various categories of cognitive demand that are relevant to product interaction. In turn, these form scales of user cognitive capability that should be of adequate scope and comprehensiveness to evaluate a large range of consumer products. They should allow for valid predictions of user exclusion and difficulty to be made under normal assumptions of use. The predictions should also be sensitive to changes in product attributes allowing a designer to make changes to the design and see the effects on the predictions. Finally, the scales should also be usable by designers.

3 Cognitive Capabilities

Carroll [18] defines capability as follows: "*As used to describe an attribute of individuals, ability refers to the possible variations over individuals in the liminal levels of task difficulty (or in derived measurements based on such liminal levels) at which, on any given occasion in which conditions appear favourable, individuals perform successfully on a defined class of tasks*." This definition implies that cognitive capability is measured by the threshold levels of performance only with reference to a specified class of tasks. For our purposes, these tasks involve the mental processes that are required in product interaction. This involves retrieving previous knowledge of a particular product's features and how the product works, and using this knowledge together with task demands and product perception to form mental models in working memory [19]. When a user interacts with a product, there is a cyclic process of action, execution, and perception of the effects of the action and evaluation of the effects in terms of the user's goals [20, 21].

Various cognitive architectures have been proposed that attempt to describe the information processing sub-systems involved in cognition [22-25]. Based on these architectures, a simplified model of cognition was derived as shown in Figure 2. It consists of a Working Memory of modal stores and a central executive. The central executive controls attentional resources and facilitates the storage and retrieval of information in Long Term Memory. Using this model, measures of cognitive demand in the domains of Working Memory and Attention, Long-Term Memory and Knowledge and Language and Communication are proposed for assessing the cognitive demand of products.

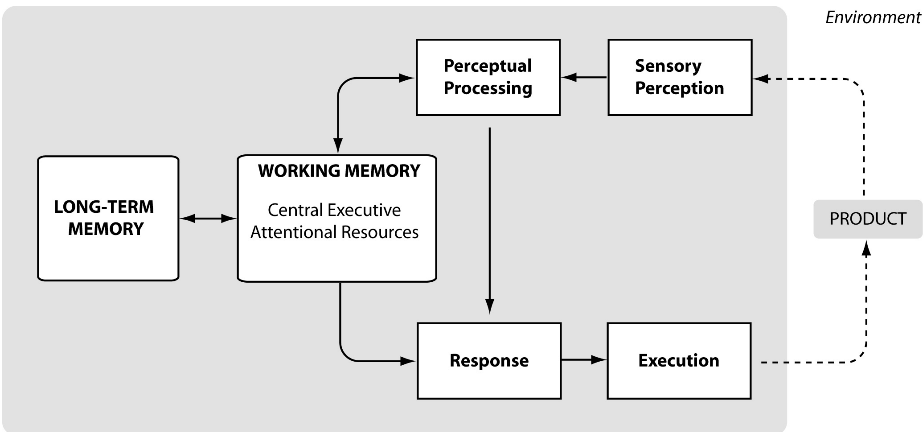

Fig. 2. A simple model of cognition incorporating sensation, perception, working and long term memories and response selection and execution

3.1 Working Memory and Attention

Working memory can be considered as a scratch-pad or rough working area for items being attended to [26]. It is organised by different modalities of storage such as visual-spatial and auditory-verbal. Working Memory has been found to have limited capacity for stored information and a duration of between 10-15 seconds. The general capacity of Working Memory system has been estimated to be around five to nine chunks of information [26]. However, more complex items such as sentences, procedures, or images can be remembered as if they were individual elements when chunked. This is after prolonged use has caused them to become well established in Long Term Memory.

Another important characteristic of the Working Memory model is that the central executive is assumed to have limited resources of attention. This can be overloaded by either increasing the volume of individual items to deal with or the number of simultaneous activities that require attention. Therefore Working Memory and attention capacities are the limiting factors when interacting with products. Thus two important performance measures for the working memory system are *storage capacity* in terms of the number of chunks that can be held and *speed and accuracy* of processing.

3.2 Long Term Memory

Long term memory is a permanent store for knowledge gathered from experience. The type of knowledge stored can be classified into various types including semantic memory, episodic memory and procedural memory. It is useful to distinguish between knowledge of product features and how the product *works*, versus knowledge on how to *use* the product in terms of action sequences that will achieve goals. These two types of knowledge are inter-related, and are both used when interacting with products. Therefore, recognition and recall capabilities are the limiting factors in the performance of Long Term Memory. Measures of recognition capability are required when comparing visible product features to information stored in Long Term Memory. Recall capability measures are needed for determining users' ability to retrieve stored knowledge about product features and behaviour.

3.3 Interaction and Mental Models

Working Memory and Long-Term Memory systems work together when faced with an episode of interaction. Users are assumed to construct mental models in working memory based on previous knowledge cued by current environmental characteristics [19, 27], and use this representation as they proceed through the interaction. These models may reflect their understanding of the behaviour of the product and how it is to be used [19, 28].

The concept of mental models has received significant attention in the HCI and applied cognitive science literature. It has been found that mental models can be incomplete, unstable, often unscientific and parsimonious and vary in complexity depending on the degree of previous experience [28]. Because of this dependence on previous experience and continuous modification through successive interactions, mental models can be difficult to capture [19].

From a practical standpoint, we use the concept of a mental model as a device that could enable the operational estimation of cognitive information processing demands. We thus use the mental model concept in a *representation* that captures the *demanded* mental model of device usage. We posit cognitive processes associated with interaction that act on this representation during the guidance of action. The mental model therefore should consist of a representation of: (1) knowledge of the various interface features and how they work and (2) a representation of the action sequences necessary for moving from an initial state to a goal state. Because Working Memory is limited, there will be a limit to the complexity of the mental model in mind and the mental operations that can be performed on it at any one time. A representation of the demanded mental model could also be used to analyse and identify states in the interaction that could mentally overload the user.

3.4 Language and Communication

Language and communication capabilities involve the comprehension and expression of verbal and written language. An assessment of language comprehension capability is necessary when reading labels and product manuals. It is also employed to interpret verbal messages from a product or system. An assessment of language communication capabilities is important for giving spoken commands to a product.

For product evaluation, the primary concern is with linguistic communication in speech and sentence construction as these are most commonly employed in product design.

4 Case Study

We now describe a case study involving the analysis of a simple toaster for cognitive demands. Toasters are common devices found in many homes consisting of a relatively straightforward interface. A simple toaster is shown in Fig 3 consisting of a chassis, slots, slider, rotary heat control and a stop button.

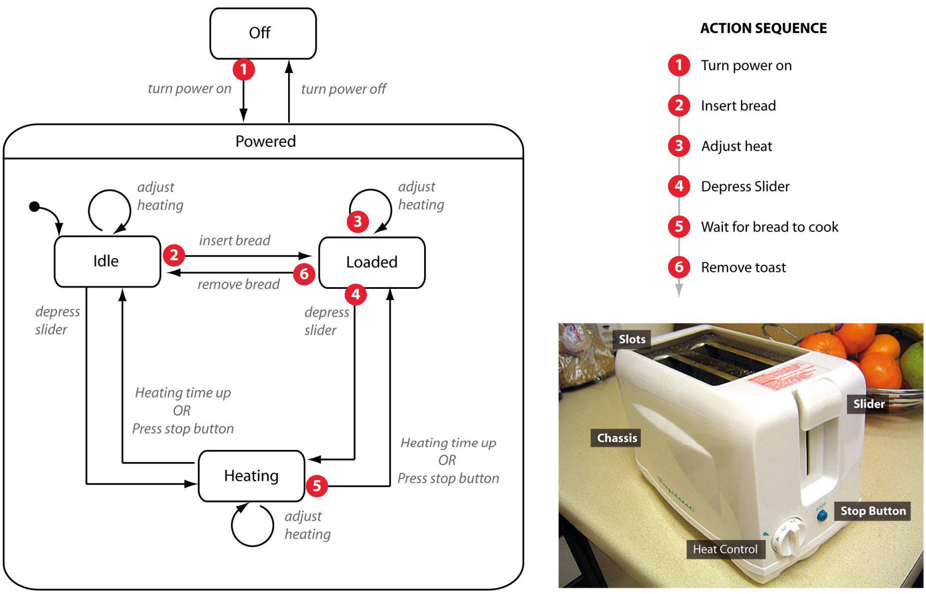

Fig. 3. Diagram showing a state chart of toaster reactive behaviour (left) with a demanded action sequence overlaid, the demanded action sequence (top right), and a picture of the toaster with relevant interface features labelled (bottom right)

The figure also shows a representation for the reactive behaviour of the toaster using a statechart. Statecharts are a part of the Unified Modelling Language and thus provide a standardised way of representing the response of the toaster to various user actions. Statecharts are also commonly used to specify the design of reactive systems and are familiar to designers of embedded systems. The demanded user action sequence for making toast is also shown in Fig 3 consisting of six steps. An objected oriented representation of the interface features and associated properties could also be developed for the toaster using UML notation. However, for the purposes of this paper, the statechart alone is shown.

The representation can be used to derive the action sequences that form users' mental models by analysing variations to the demanded action sequence. For example, if step 1 of powering the toaster is omitted, an error of omission occurs and the toaster slider will not activate. In addition, the state based representation of the use process allows for the evaluation of adequate feedback on each state of the device. By examining the toaster, it is evident that inadequate feedback is provided in the powered state and in the heating state. An improvement to the design is immediately possible by including a visual signal such as an indicator light to indicate that the toaster is powered. An auditory feedback on reaching the bread cooked state would be another improvement to indicate to the user that the toast is finished, which can also benefit visually impaired users.

4.1 Working Memory and Attention Demands

The action sequence shown in Fig 3 represents first time use. If the assumption is made that people commonly leave their toaster on a particular heat setting most of the time and the power is on; the user has to plan for four steps: (1) put bread in, (2) depress slider, (3) wait for bread to cook and (4) remove toast. Thus the user is only required to keep track of the state of the bread. The attention demands are therefore relatively low assuming that there are no other distractions in the cooking environment that would be outside the control of the toaster designer. However, apart from the toast popping up, the toaster does not signal that the bread has been toasted. As previously mentioned, an auditory alert could be a design improvement, especially if users may attend to other tasks while bread is toasting.

The toaster also does not demand a high working memory capacity. The number of steps in the action sequence can be used as an indicator of the level of demand on planning capabilities of the user as he/she plans through the sequence of actions that will be performed on the toaster. There are also no time demands for task actions that could exceed the Working Memory time limit on storage. For any given design, the aim should be to reduce the number of actions that users have to perform in order to reach their goals thus reducing the cognitive demands of planning and Working Memory.

4.2 Long Term Memory Demands

Toasters are relatively common consumer products, and the design of the example toaster follows the traditional toaster form factor with slots at the top and a slider at the side (Fig. 3). The interfaces features of slots, slider, rotary control and button are standard features that are also straightforward and prevalent on other toaster designs. Thus the demands of the toaster on the knowledge and Long Term Memory of users is assumed to be relatively low. However, the toaster introduces a prospective memory demand where the user is required to remember to remove the toast once it is finished cooking. Again, the simple toaster does not signal that the bread has been toasted, or is being toasted, apart from the toast popping up. A more distinct visual or auditory alert could be a design improvement.

4.3 Communication and Language Demands

Communication and language demands are relatively low for the toaster because no graphical symbols are used. The user is only required to read and understand the 'STOP' button label and the red text of a safety sticker on the toaster. Reading the safety sticker is not essential to using the toaster, so within the defined task bounds the toaster does not demand a high degree of written comprehension capability. Visuospatial communications demands are also relatively low for the toaster as no graphical symbols are used.

4.4 Learning and Feedback

Feedback plays an important role in the learnability of a product. As previously mentioned, the representation of mental models allows for the evaluation of adequate feedback on each state of the device. This supports the user *forming* an adequate mental model of device operation where cause and effect associations can be learnt. When faced with novel products or situations with few generic features, users typically resort to trial and error exploration of the interface [29]. By designing the product to support this type of exploration through salient feedback of its current state, users will be supported in their attempts to learn how the product works.

5 Discussion

In this paper, we highlighted the types of cognitive demands that could arise when interacting with consumer products. We also utilised the concept of mental models in the form of sequences of use overlaid on a state-based representation of product behaviour. This is just one possible form of representation that could enable the estimation of cognitive demands. For the purposes of evaluating cognitive product demand we do not require a model that is a precise evocation of the cognitive processes that are involved in an interaction. Nor do we require one that is capable of accounting for detailed findings and predictions of cognitive psychology. Instead, our aim is to further develop this approach into a quantitative method that can estimate various levels of cognitive demand based on simple representations of mental models of product functioning and use. This should empower designers to make decisions on how to improve the product while reducing the number of people who may be excluded or have difficulty because they do not have sufficient levels of cognitive capability to access and use the product.

6 Conclusions and Further Work

A simple model of cognition was used as the basis for outlining categories of cognitive capability and demand for assessing consumer products. The concept and representation of mental models was also utilised as an approach for extracting cognitive demands. Further work involves developing quantitative measures of the outlined capabilities and investigating the predictive validity of the analytical approach to evaluation through user trials and product case studies.

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Three Dimensional Articulator Model for Speech Acquisition by Children with Hearing Loss

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Abstract. Our research indicates that acquisition of phonetic skills in voiced and voiceless speech sounds was improved by using Computer Aided Articulatory Tutor (CAAT). The interface of CAAT displays the place of articulation and relevant image objects for articulatory training simultaneously. The place of articulation was presented by using three dimensional articulatory tutor. Suitable computer graphics and Magnetic Resonance Imaging (MRI) techniques were used to develop inner articulatory movements of the animated tutor. Ten hearing impaired children between the ages 4 and 7 were selected and trained for 30 hours across four weeks on 50 words under 10 lessons. The words were selected from the categories of voiced and voiceless stops namely Bilabial, Dental, Alveolar, Retroflex and Velar. The articulatory performance of HI children was investigated to find out their speech intelligibility.

Keywords: 3D Modeling, MRI Techniques, Speech perception, Speech production, Computer aided articulator model.

1 Introduction

Many deaf children leave elementary school without required phonetic knowledge, which creates learning difficulties in their mainstream study. Many a time, children fail to follow the lip movement of teacher (1, 2). Inaccurate articulation is also considered as a speech defect (3). Most of the laboratory studies argued that auditory-visual speech perception is superior to visual or auditory perception alone. Three dimensional Synthetic head helps to enhance the intelligibility of audible speech (4). The previous experiments also indicated that the synthetic face can be used to transmit important visual speech information to hearing impaired children (5). The visualization of speech production helps the children to know about the place of inner articulators and to control his (or) her speech organs (6). Children hearing loss require constant guidance in articulation of such kind of speech sounds. Some of the distinctions in spoken language cannot be heard by children with degraded hearing. Due to hidden articulators and other social issues, visual speech perception is a complex task for hearing impaired children. Children with a moderate Hearing loss develop spontaneous speech, but their pronunciation often suffers from distortions and lack of articulatory precision. Our three dimensional vocal tract articulatory model has more visual

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appearance and allows a realistic movement of the jaw, tongue and lips. Articulatory movements of Vocal Tract are simulated by employing suitable modeling and animation techniques. In India, most of the severely and profoundly hearing impaired rely on the visual modality alone for speech reception since speech and hearing training facilities are not readily accessible to them (7). The earlier mid-sagittal and 3D models focused on VT area research but none of them developed a complete articulatory model to train and improve the speech intelligibility of Hearing impaired children in Indian languages. Tamil is historically very old Indian language and articulating bilabial, dental, alveolar, Retroflex and Velar stops along with laterals and trill speech sounds are complex.

2 System Design

Hearing impaired children face the problem of distinguishing between the phonemes with place of articulation. The aim of our study was to develop a three-dimensional articulatory model based on a set of vocal tract geometrical data acquired by MRI on a reference subject [AR]. MRI is the dominating measurement method for three-dimensional imaging. No other method can compete with MRI today. Even though Electro-Magnetic articulography [EMA] and Electro-Palato Graphy [EPG] represent the kinematics in a limited way, it was found that MRI in the current status provides better overall kinematics of the oral cavity. So, MRI was selected as the basis for the 3D modeling and also the kinematics of articulations measured. MRI is non-hazardous for the subject also the reason of selection.

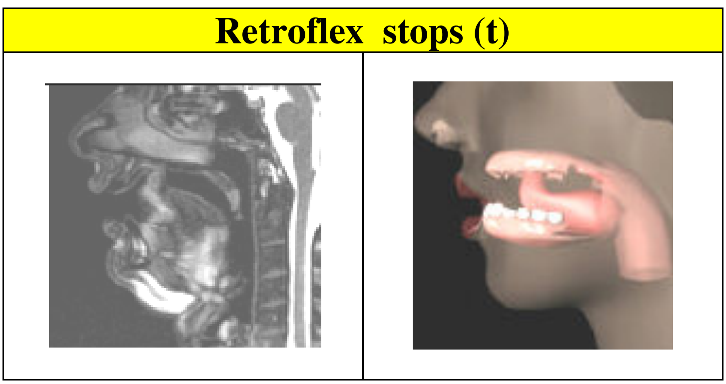

Fig. 1. (a) MRI (b) 3D Vocal Tract Model

The 3D articulatory model can be combined with a human face, creating a more familiar environment (8). Several researchers recognized the need to represent the tongue in a facial animation system (9). In our study, a realistic tongue was developed to achieve increased intelligibility among HI children (refer figure 1). Vocal tract information obtained from MRI scans (GE 1.5T Scanner) in the mid-sagittal, axial and oblique planes, which allowed us to construct 3D VT articulatory model. The 3D data are obtained from MRI of the subject, and front and profile video images of the subject's face. The tongue movements were built by animating tongue raise, tongue contact (with palate) and tongue curved.

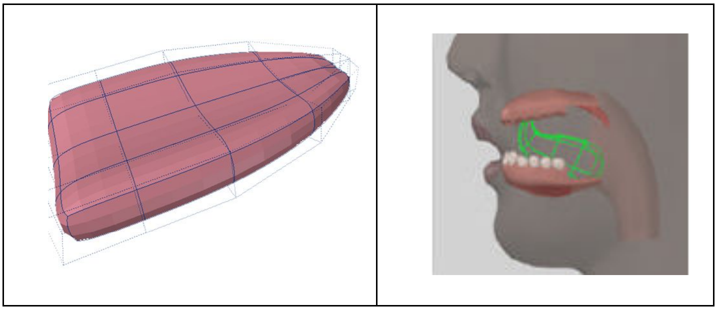

Fig. 2. (a) Parameterization of tongue (b) Tongue in Vocal Tract

The tongue model has been constructed from 50 control points. Five control points have been identified along the tongue from tip to back: two at the ends and three more to control the movement of the tongue tip, blade and dorsum. In the crosswise direction also five control points are located - two along each lateral and a medial point. The parameterization scheme chosen requires the medial position of the three lengthwise control points (excluding those at the ends) and two tongue lateral positions. The entire 3D shape of tongue was developed by using polygon mesh. Key frame techniques and interpolation between a finite set of visual targets were used to achieve speech articulation (11).

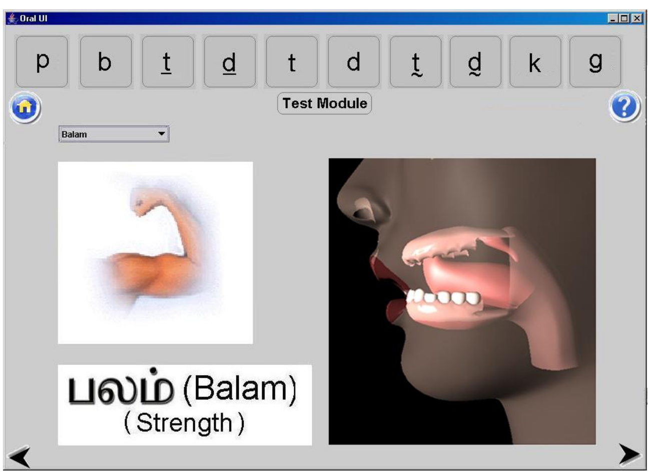

Fig. 3. The interface of the software model

The parameters used to construct 3D Vocal Tract model are a) jaw b) lips c) Tongue (tip, body, width) d) Velum (refer figure. 2). Natural speech of speaker was then synchronized as realistic audio visual sequence. The articulation of voiced speech sounds were indicated by coloring the vocal cord portion of model. In order to avoid the confusion in perceiving the similar speech sounds, visual cues were used in the software interface model to differentiate. For example, the visual cue ‘palam’ (fruit) was used for speech sound ‘p’ and the visual cue ‘ball’ was used for teaching syllables starting with ‘b’. The upper-teeth were an obstacle to perceive the place of tongue position by the children and so were removed from the model. The inclusion of velum articulator is important to train the speech segments of Tamil stops. The graphical user interface of computer aided articulatory model was developed by using Java programming (refer fig.3). The necessary navigation controls were incorporated for moving between lessons, test module, training module, home, help, next and previous word. The user can select any one of the ten lessons by clicking on the button highlighting the sound and then choose a particular word from that category from the drop down list box. Once a word is chosen, the corresponding picture, the Tamil equivalent and its meaning are displayed on the left side of the interface. The right side of the panel displays the tongue position during the articulation of the sound, in the background of the human face. The tongue model has been developed using Java 3D. By employing the five parameters extracted from the MRI clipping and the value of the standard thickness of the tongue, the complete tongue model consisting of fifty control points is generated through suitable calculations.

3 Method

Five male and five female HI children aged between 4 and 7 were chosen for this study. All of them are profoundly deaf and they were given enough training to interact with Computer Aided Articulation Tutor (CAAT). There were three stages in this study: an initial test, training given by CAAT for 4 weeks and a final test. The combination of consonants [p, b, t̲, d̲, t, d, ***t***, ***d***, k, and g] and short and long vowels [a, e, I, o, and u] helped us to build 50 meaningful words under ten lessons for this computer aided articulation test (refer table.1). Each lesson consists of 5 words and five lessons allotted for voiced and remaining five for voiceless sounds. Every day, they spent 45 min each in fore-noon and after-noon sessions over the period of 4 weeks. Children were engaged by the computer aided articulatory tutor in acquisition of complex articulatory position of speech sounds placed in meaningful words at different contexts. In the interface of software model, based on the phoneme input and selection of corresponding word, the three dimensional tongue articulatory positions is shown along with Image object and title. After 4 weeks training, children were instructed to articulate the speech sounds and syllables in front of software model. The articulatory performance of children was investigated to find out in detail as follows a) Voiced lessons – Pre and Post-test b) Voiceless lessons – Pre and Post-test c) Lesson wise – Pre and Post test d) Gender wise.

Table 1. Place of articulation (Stops) [10]

Phoneme (Voiceless)	**Place of articulation (Stops)**	**Phoneme (Voiced)**
- p – puspam (flower), uppu (salt), appaa (father) - Lesson 2 -	**Bilabial-** In its production the lips are closed and the soft palate is raised to close the nasal passage. When the lips are opened the air suddenly comes out with explosion. Voiceless doesn't have vibration in the vocal cords.	**- B -** Balam (Strength), bimbam (Image), ambu (Arrow) - Lesson 1 -
- t̲ – tattu (plate), taamaray (lotus), Patthu (ten) - Lesson 4 -	**Dental-** It is produced when the tip of the tongue touches the upper teeth. The soft palate is also raised so that the air cannot get through the nasal cavity in its production. When the tip of the tongue is released from the upper teeth the air suddenly escapes through the mouth. There is no vibration in the vocal cords for voiceless sounds.	**- d̲ –** Darram (wife), pandam (torch), dikil (terror) - Lesson 3 -
- t – kattay (bundle), vetri (success), netti (forehead) - Lesson 6 -	**Alveolar-** In its production the tip of the tongue is placed against the alveolar ridge. The sides of the tongue are in contact with the teeth firmly. The soft palate is also raised so that the air cannot get through the nasal cavity. When the contact is released the air escapes through the mouth. There is no vibration in the vocal cords for voiceless.	**- d -** Andru (that day), indru (today), pandri (pig) - Lesson 5 -
- ṭ – tin (tin), ettu (eight), vattam (circle) - Lesson 8 -	**Retroflex-**It is produced by the tip of the tongue curved towards the back and making contact at the roof of the mouth. The soft palate is raised as in the production of other stops. There is no vibration in the vocal cords. When the contact is released the air escapes through the mouth.	**- d –** Kaday (shop), taaday (jaw), andam (world) - Lesson 7 -
- k – kadal (sea), kannadi (mirror), kay (hand) - Lesson 10 -	**Velar-** In its production the air stream is blocked by the back of the tongue while it is in firm contact with the soft palate. The soft palate is in raised position so that no air escapes through the nasal cavity. When the back of the tongue is released suddenly the air comes out of the mouth with explosion. There will be no vibration of the vocal cords during its production for voiceless.	**- g –** guru (teacher), Tangam (gold), ganapathi (Lord Ganesha) - Lesson 9 -

4 Results

Before computer aided articulatory training, the speech segments were presented to HI children to articulate those sounds first time. The mean and SD of Pre-test results were 40 and 6.57. Many of them have not performed well in Pre-test since the voiced and voiceless made them confused. For example, the phoneme 'B', '***D***', 'D̲', 'G', 'D','t' and 'k' were misarticulated due to its complex place of articulation as detailed in table 2. The misarticulated speech sounds were noted by us to focus more on those phonemes during training session.

Table 2. Pre-test results (Sample data)

Lesson No	Target Phoneme	Misarticulated
1	***B*** -alam (strength)	***P***-alam
	B -imbam (Image)	***P*** –imbam / **m** - ambam
2	***Pu*** -l (grass)	***Pa*** -l
3	Pan- **d̲** -am (torch)	Pat- ***t*** -am
	D̲ -aram (wife)	**T** -halam
4	Ta- ***t̲*** -tu (plate)	Te- ***r*** -ru
5	Pan- ***d*** **-**ri (pig)	Pat- ***t*** -ri
	In - ***d -*** ru (today)	In – **n** - ru
6	Net- ***t*** - ri (forehead)	Ne- r – ri, ne - n - ni
	Vet – ***t*** – ri (success)	Ver – r – ri, ve- n -ni
7	Ka- ***d*** –ay (Shop)	Ka – ***t*** - tai
	An – ***d*** –am (world)	At- ***t*** -am
8	Vat- ***t*** –am (circle)	Val – ***l*** -am
	Ti – n (tin)	***Ta*** -n
9	***G*** –uru (Teacher)	***K*** - ur/ uru/ ulu
	Tan – ***g*** –am (gold)	Tak- ***k*** -am
10	***K*** – adal (sea)	***A*** -adal
	K - ay (hand)	***Th*** - ai

The mean and SD of Pre-test results were 33 and 15.08 for voiced speech sounds and 36.5 and 10.98 for voiceless speech sounds (refer figure.4).

During four weeks training period, children were instructed to articulate the given list of speech sounds and meaningful words until they achieve maximum accuracy. Training time varied to individual based on their pre-test performance. As per our observation, most of the misarticulated speech sounds were corrected during training.

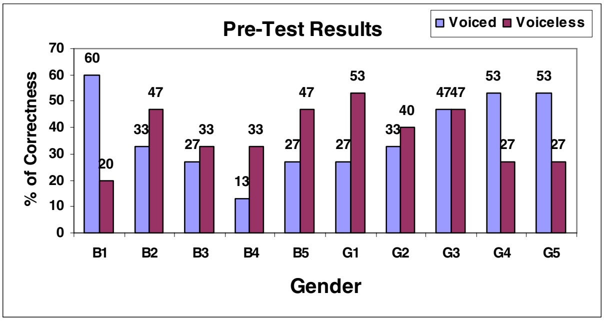

Fig. 4. Pre-test results (Voiced and Voiceless)

Table 3. Post-test results (Sample data)

Lesson No	Target Phonemes	Misarticulation
1	***B*** – imbam (strength)	***Ma*** - mbam
2	***P*** – akal (Day – time)	***Pa*** - lal
3	Pan- ***d*** -am (Torch)	Pa- ***tt*** -am
4	Tat- ***t*** –u (Plate)	Ta- ***d*** - u
5	Kan – ***r*** – u (calf)	Kan- ***n*** -u
6	Net – ***t*** –ri (Fore-head)	Ner – ***r*** -i
7	Ka- ***d*** –ai (Shop)	Ka- ***tt*** -ai
8	***T*** – in (Tin)	***T*** -en
9	***G*** – uru (Teacher)	**U** -ru
10	***K*** – adal (Sea)	K-a- **tt** - al

Most of their misarticulation was corrected during training and found satisfactory. Even after four weeks training, some of them have not performed well as per the details presented in table 3. The reasons for misarticulation may be due to voicing, individual capacity and acquisition time. The mean and SD of post-test results were 76.5 and 14.04. The mean and SD of Post-test results were 80 and 16.87 for voiced speech sounds and 73 and 17.20 for voiceless speech sounds (refer figure 5).

The overall performance of girls was better than boys in both pre- and post-test results (refer fig 6). In voiceless experiments (refer figure 6(b)), boys secured 36% (pre-test) and 61% (Post-test) against girls performance of 39% (pre-test) and 75% (Post-test). In voiced experiments (refer fig 6(a)), boys secured 32% (pre-test) and 75% (Post-test) against girls performance of 43% (pre-test) and 83% (Post-test).

The aim of computer aided articulation test was to increase the performance in articulation of speech sounds under every lesson. The pre-test and post-test results are shown in figure 7. The mean and SD of pre-test results are 37 and 4.81. The mean and SD of Post-test results are 75 and 9.38.

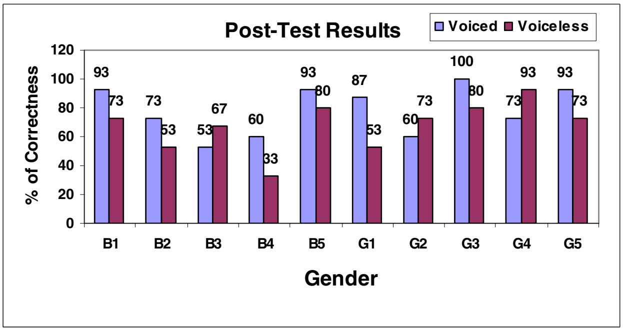

Fig. 5. Post-test results (voiced and voiceless)

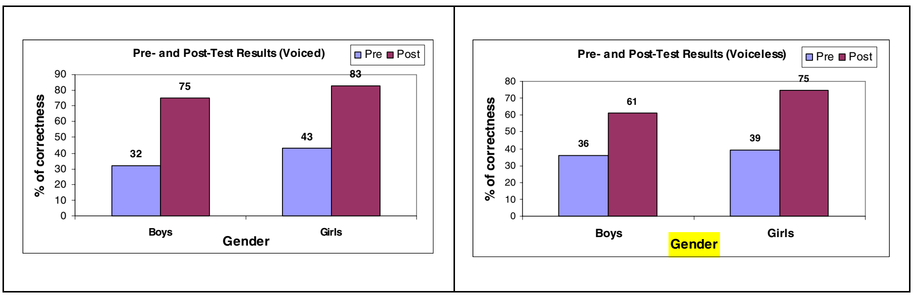

Fig. 6. Gender performance (a) in Voiced (Pre- and Post-test), (b) in Voiceless (Pre- and Post-test)

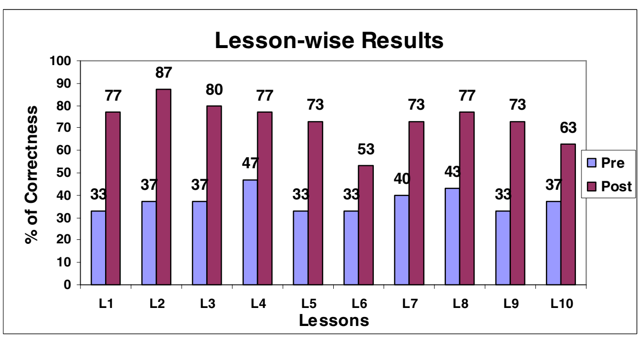

Fig. 7. Lesson-wise performance by children –Pre and Post-test results

5 Conclusion

The goal of our study was to examine the effectiveness of CAAT in teaching place of inner articulatory position of complex speech segments. Hearing impaired children were trained by computer aided articulatory model to perceive the place of articulation of speech segments. The misarticulated speech sounds were corrected during training period and the children improved the articulation to the accepted level in post-test performance. Realism of the visible speech is measured in terms of its intelligibility to the speech readers (12-16). This model succeeded in improving the speech intelligibility of hearing impaired children. This articulatory model is made available as an instructional tool for training syllables to HI children very effectively without involving any physical strains as human beings.

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DfA Products and Services from a User Perspective to Facilitate Life at Home for People with Cognitive Impairments

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Abstract. Supportive technology is expected to facilitate life at home for people with cognitive impairment. To study the usability of a number of support-installations in ordinary homes a three-year project was launched in Sweden. Three sites, each planned to comprise some twenty participants about sixty years of age and upwards, suffering either from a cognitive impairment such as an acquired brain injury or other forms of cognitive impairments, have been engaged. One goal was to acquire knowledge and experience about technical support, their appropriateness and adaptability to the users and to the organisation supporting them. Another goal was to develop and test supportive technology and a third goal was to explore ways to the market for Design for All products which are necessary for some but useful to most of tenants. The housing companies played an important role for the development of the project and the way to the market, as many technical aids basically are parts of the physical building structure.

Keywords: Supportive technology, Design for All, cognitive impairment, independent living, housing companies.

1 Introduction

A three-year project has been launched addressing people with cognitive impairments residing in their own homes. Supportive technology is to be applied in order to offer these people a safer and a more independent life to the benefit for themselves, their carers and their relatives. The project – Technology support at Home (Hemma med IT is the Swedish Acronym) - was initiated by the Swedish Ministry of Social Affairs and it is managed by the Swedish Handicap Institute (SHI). The original budget for the project comprised about 1,2 million Euro. Additional funding for technical development has been raised during the project period. The Competence Fund of the City of Stockholm has contributed. Research aspects associated to some perspectives of the evaluation is funded by The Swedish Formas Research Council. The Royal Institute of Technology in Stockholm is engaged as external evaluator of the project [1].

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2 Background

In line with the European Commission's Work Programme eInclusion for 2005-2006 also this Swedish project aims to provide input to meet the challenges of an ageing population, including the maximisation of user involvement. This project will hopefully provide information and guidance as well as it will provide a basis for future decision making among different stakeholders in EU and elsewhere when it comes to the question on how to implement new technology with the aim to promote independent living among vulnerable people [2].

Home care of older people is an important issue. Caring for people in old age has always been an important objective of social systems. How to ensure the social inclusion of older people will be an increasingly significant challenge. Increased life expectancy is one of the great achievements of the 20th century; we want to ensure that the majority of the extra years can be spent in health and independence. This project put focus on the IST objective to develop intelligent systems that empower persons with disabilities and ageing citizens to play a full role in society and to increase their autonomy.

Changes in demography is a result of a successful policy resulting in longer life expectancy. Providing services to a growing group of elderly people is of increasing concern.

As people live longer, as a result of a successful social policy, the demand on society's resources to meet their individual needs increases. During the coming 10 years the number of elderly over 65 years of age will increase with 27 % while the increase last 10 years was limited to 1 % in Sweden. This dramatic increase in the number of elderly is very much also a business opportunity for the company sector. The challenge is to maintain or increase quality of life by introducing supportive technology for people with lacking abilities when it comes to physical and cognitive abilities.

3 Increased Quality of Life with Technology Support – A Potential to Explore

Elderly people and others with special needs want to stay in their normal environment, in their own home, where they have a closeness to friends and relatives, as long as possible. Several questionnaires have shown this very clear. In spite of the wishes of older people to remain in their habitual environment for both health care and ordinary care, the debate is often focused on elderly´s need of special living institutions. In many cases older people and more often, their relatives need the assurance and comfort of the person being safer rather than just comfortable. The sad fact is that today there is no supply of prepared, easily comparable technical "coherent solution" which make an ordinary living to a comparable alternative with health care institutions or institutional living for elderly patients and the responsible municipalities or local government agencies.

Not only technology and care matter; an equally important question is how accessible the apartments are adapted to care, aided by new technology. In addition, it is important to understand how the service delivery chain can be organised in order to meet the requirements satisfying quality criteria. It is a widely spread opinion that the information and communication technologies (ICT) have the potential to compensate for the lack of resources in the caring professions without inferring a lower quality of care. At the same time it is important to underline that personnel can not be replaced by technology but supported. Sometimes there is a reluctance to before or in the beginning of an introduction of new technology. Our experience is that when personnel and users discover the potential with new supportive technology, reluctance and fear often are turned into interest and acceptance. User acceptance is necessary if you want to have a sustainable autonomous living for elderly and people with disabilities.

It is not foremost an expansion of special institutional apartments that are needed, the most important thing is to develop and adapt the present and future housing supply to vulnerable peoples needs, that is the general policy at the moment in my country.

"A growing number of older people are living in houses that do not correspond to their specific needs. The expected increase in the older population poses serious challenges to national housing policies. It has been argued that the main approach should be to support living at home for as long as possible, also allowing people to make a positive choice to move into more convenient or appropriate accommodation as they age. This being the case, more attention needs to be paid to ensure that homes are accessible, convenient and safe, and are capable of meeting the needs of residents with declining mobility." (The Social Situation in the European Union 2000, p.94, European Commission Directorate-General for Employment and Social Affairs).

According to the Commission Green Paper families will not be able on their own to solve the matter of caring for these people, however dependent or independent they are. The improved health profile of "younger elderly" generations holds out the hope that the elderly of the future will remain self-sufficient for longer times, and that they wish to remain in their homes as long as possible. High-intensity care will be increasingly concentrated towards the end-of-life period. Nevertheless, it seems that there will also be more people than today who will need such high intensity care in ordinary homes as a result of reduction of beds in hospitals and institutions.

Today there are supportive technologies that could solve a lot of problems and meet the needs of people, relatives and staff, but unfortunately they are not used.

Why are they not used? There are many reasons, ranging from the fact that the users do not feel involved, difficult and indistinct supply systems, to the lack of knowledge competence, and training, as well as a misplaced fear that costs will be high.

One of many approaches would be to develop the potential for new technologies supporting older people, both directly (for those 80+) and indirectly (by facilitating the caring tasks for elderly workers i.e. those 55-64) and for the younger proportion of the retired population (65-79). The complexity has to be considered; there are many obstacles for introduction of supportive technology in care sector. Many ask why it takes so long time.

A key issue is that organisations involved in ICT-care and telemedicine have to be involved. There is a huge gap today between on one hand those responsible for development and providers of products and services and on the other hand users and personnel in care sector.

Currently there is much research about the contribution of technology to elderly care in institutions and at home. Several European projects have been focused on independent living. Amongst other things, safety alarms, smart sensors and remotely monitored devices have been developed, installed and investigated.

SHI will in the coming four years be involved in a new EU project on Mainstreaming on Ambient Intelligence (MonAmi), the project will demonstrate how accessible and useful services can be delivered in mainstream systems and platforms to elderly people and persons with disabilities [3].

Also on national level a variety of research and development projects have been initiated in Sweden and other countries in EU that in various ways investigate the possibilities for elderly people with acquired brain injuries to remain in their own homes.

These projects have clearly stated that the technology is there! Now it is a matter of implementation and a strategy for implementation.

4 Technology Support at Home – A National Project[4]

Three site projects have been linked together within a framework. The Swedish Handicap Institute has been the co-ordinator of the whole undertaking. In this presentation the broad lines will be outlined.

The project has the purpose to facilitate for people with cognitive impairments to remain at home maintaining a high quality of life, avoiding a transfer to special institutions apartments.

The intention has been to support people with a cognitive impairment to make it possible remain an active person. Making it possible for the user to be part of society, follow and interact with the outside world.

Technology Support at Home was initiated by the Swedish Handicap Institute and the Swedish Disability Federation, and it was jointly financed by the Swedish Inheritance Fund, three municipalities and three public housing companies. The project started in May 2004 and runs for three years.

The main reference is to persons at the age of 60 or elderly and who experience obvious problems in their daily lives due to documented cognitive impairments such as persons suffering from external injuries or strokes or Alzheimer's disease.

The technology to be applied varies from person to person, though some supportive technologies are more common.

One of the objectives of the project is to establish co-operation between the different actors involved and to find a sustainable structure for participation. This depends significantly on the complicated co-ordination between the responsible caregiver, often the elderly services of the municipality sometimes in combination with health care sector, and the housing company, which hirers out and runs the flats. It should though be stated that it was also found that some of the users in the project did not, before the project, have any contact with the social or health care sector. They managed on their own thanks to an informal support from relatives and friends.

5 Cognitive Impairments – What Do We Mean?

The cognitive impairments vary, depending on trauma or disease. Their hampered functions may fluctuate over the day or week. Common cognitive problems are as follows:

- memory loss, especially episodic memory,
- psychic endurance and lack of initiative,
- attention and concentration,
- communication, handling phones and remote controls,
- time management,
- learning integration, e.g. difficulties to adjust to change,
- inability to perform movement of some complexity such as an inability to handle articles for everyday use.

6 What Do Partners Want? Win-Win-Situation!

The stated goal was to collect evidence based knowledge about products, services and activities that can provide a more secure and easy way of life for older persons with cognitive impairments, who are still living in their own homes.

All stakeholders' different expectations were stated. The starting point was to establish a situation where all stakeholders are winners.

The perspective of the individual is crucial, the person with cognitive impairment in his or her living situation, need of care and social context must be defined.

The technology perspective, the appropriateness, the availability and the functionality of it was, of course, important.

Another issue was the caring perspective, which relates to the caring staff and how it can adapt to new technique and services built upon it.

A crucial component of the whole delivery chain is the organisational perspective. It encompasses the caring chain, the support, and the maintenance and quality assurance of the functionality of technology and services over time. A viable situation was to be developed where the caring organisation, the housing company and the technology provider are to find viable procedures for effective co-operation.

The housing companies' prime task is to construct and operate housing premises as efficiently as possible related to cost. Already before the housing companies meet these people with cognitive impairments. A study was made in the beginning of the project where it was stated that the lack of appropriate support ended up in incidents of all kinds such as flooded bathrooms or kitchen, fire, unlocked doors resulting in intrusion of unknown people in the buildings. Additional costs due to special measures necessary for the housing of persons with special needs should be covered, from the housing company's perspective, by the authorities responsible for the proper care of these persons. This includes not the least a viable business model from which the individual as well as the society will benefit.

Finally a societal perspective and a cost-benefit perspective addressed the long term effects based in particular on the aforementioned demographic development and on the economic values of the outcome.

7 Technology Support

Focus has been on security, safety, communication and structure of the day. The technology to be applied assists cognitively disabled persons in many different ways with related functions in the daily life.

Technology envisaged are functions like computerised memory aid, go-away-lock (i.e. a lock that will turn off all electricity connected to household appliances like, toaster, stove, iron, water boiler and more), an intelligent key (a key with a display showing whether the door was locked when the person left the apartment), different alarms (activity driven, fall detection, over-heated stoves etc.) and various forms of communication systems. The choice of technology and applications of the three sites have been open but there has been an ambition to harmonise.

8 Objectives

The overall objectives of the entire project were:

- to increase knowledge about what products, services and actions could contribute to realise a more independent and safer living for older persons with cognitive disabilities in their own homes,
- to increase the knowledge of how to deploy supportive products aimed at people with a cognitive disability. Target groups are on the one side the users/older people themselves, healthcare personnel, paramedics, social workers; and on the other side, housing site staff, who meet the tenants/older people in their daily work.

Informal carers, relatives and friends were to be involved in so far as they already were engaged with the users/tenants.

Co-operation between different responsible bodies were regarded as a key factor in the quality of delivery. It was esteemed that this approach also would affect the costs. Cost-efficiency is a necessity, otherwise only a few of those in need of the technology will be offered it. These and other aspects are being evaluated by the Royal Institute of Technology [5].

9 Supportive Technology – Future DfA Products

In the following a number of products and services will be listed.

Installations have been chosen from a user perspective. (Installations that normally today, in Sweden, cannot be prescribed by an occupational therapist, though the project aims to change the present structure for prescribing technical support for independent living.)

Visitor validation unit with video and sound – Constitutes a display with image and sound who is at the entrance door (or door of the apartment). The image can be connected to the TV set. More indoor displays could be possible.

Reminder panels of different kinds – The panel indicates if doors and windows are locked, and if other functions are on/off (stove, cooker, etc.)

- Go out lock – Deactivates different functions in the home (electricity outlets, water supply, open locks, etc.) when the door is locked with the key.
- Intelligent key – Type of electronic key, indicating if locking took place when the tenant/user left the home.

- Cognitive-oriented assistive technology that today more regularly can be prescribed by authorised personnel in Sweden.
- Reminder clock – Programmable speaking clock with alarm and reminder
- Big picture phone – Phone with picture buttons activating a call to the person pictured.
- Pocket memory – Different kinds of small devices for recording alarms and reminders.
- Do not forget calendar – An electronic calendar displaying the correct day and time.
- Cognitive-oriented assistive technology that not always can be prescribed in Sweden today.
- Carecall – On-button cellphone with pre-programmed numbers. This device makes it possible for relatives/carers to support.
- Locator – Small emitters attached to devices to be identified by a remote control which helps users to find lost things in the home.
- Medication reminder – Alarms for medication and offers correct dosage until it is taken. Could also send an alarm in case medication intake is missed.
- Talking labels – small recorders fit for tins, parcels and cans. By pressing the button it says: 'this is your heart medication – take one when you feel short of breath and then phone your carer'.
- Door speaker – a device that starts a pre-recorded message when going out.

Beside all these above listed other measures could be home adaptations, including adaptations of bathrooms and kitchens.

The projects belief is that several products or technical support services used in this project could be used by a broad segment of ordinary consumers/tenants. This would also mean that products initially designed more or less as assistive device technology could be broadened to main stream market by using the concept Design for All. Of course this would also imply a design process normally used when it comes to ordinary house hold products.

The installations at the three sites have all the time also been available at demonstration apartments at the test sites and in conjunction with the facilities of SHI – the demonstration apartment SmartLab. Some of the installations have also been filmed. In a short time they will be available on the home page of the Swedish Handicap Institute [6].

10 DfA and Users Needs

As the project addresses a vulnerable group, it was essential that long and complicated procedures were to be avoided. The handling of the equipment by the care-taker (and the staff) should be user friendly.

The documentation had to be adapted to the real ability of the users. Finally, for tenants/users it has been shown that motivation is fundamental if they are to accept new technique and to use it voluntarily. They have to understand why and get enough time to adapt to it.

Other studies made concerning elderly and usage of new technology it is demonstrated that elderly are willing to make use of new technology if they can identify a clear benefit from usage of the product/service [7].

A challenge for the project has been to participate in a development process of new technology together within an environment strongly characterised by a caring perspective on people with reduced cognitive capabilities.

Occupational therapists have been local project leaders at each site. From a method point of view DfA has been used as the base line. By introducing the applications for people with cognitive disabilities the project has chosen a difficult target group for evaluation of benefits. If it is shown that the target group can make use of the products/services a broader market is also available for housing companies within the coming years as a result of the demographic change.

The Design for All concept has had priority over the Assistive Technology and Adaptable Design concepts. The ranking indicated below is fundamental.

1. device/products/services should be produced so they can be used by as many persons as possible (the Design for All approach)
2. If this is not possible (for technical, safety or other highly significant reasons),.the product can be used in combination with assistive devices. (the Adaptable Design approach)
3. If neither 1. nor 2. are possible, the following could prevail; persons that are excluded should use the product/service under certain restrictions or must be excluded. (the Assistive Technology approach)

As the project aims to contribute to deployment of mainstream products this strategy has been crucial. Alternative a) has been in focus in the project.

11 How Is the Effect Measured/Evaluated?

The direct observations of the tenants/users behaviour and relationship to the installed technical equipment have been recorded by the regular staff during scheduled periods for at least four occasions of the three-year project. The qualifications of the staff that have been responsible for the interviews and the observations are important, as well as their instruction prior to each observation period. It has also been of importance to know the staff's attitudes to changes when simultaneously involved in the implementation.

An external evaluation has been executed, run by the Royal Technology Institute in Stockholm. The outcome of this external evaluation is a benefit assessment for all actors involved.

12 Implementation – Follow-Up

In 2006 a group was established constituted by housing companies, those already members of the project and some others and the national organisation of SABO - the Swedish Association of Municipal Housing Companies (the organization of the municipal housing companies in Sweden) [8]. The aim was to facilitate the implementation phase. The idea was to already in advance of the finalisation of the project present some activities and results. By doing so we made it possible to look into the aspects of the housing companies. Contacts have also been established with an organisation dealing with procurement on behalf of housing companies, the organisation is member of SABO. The idea was to investigate how to procure technical support for tenants on a larger scale. Marketing and financing of these installations will of course have to be dealt with, though these aspects finally is in the hands of the individual housing companies, sometimes in conjunction with societal financial schemes.

13 Final Report in 2007

The project is still in progress and is scheduled for completion in mid-2007. Results, so far, should then be considered as preliminary. However, the results are positive both when it comes to the technology support and the organisational experiences, i.e. information on the introduction of supportive technology in the homes of older people suffering from cognitive impairments.

All the solutions have been based on the needs of the users themselves. The aim is to speed up the development and usage of technical devices that can increase the quality of life for both the users and their relatives. The project has used practical solutions to show how technical solutions can contribute to increased independence and comfort.

The idea is also to spread awareness of the opportunities created by this new technology among decision-makers in the municipalities and county councils, housing companies and staff within home care and primary healthcare services.

Special development grants have been available during the project time to promote the development of knowledge, methods, products and services. Municipalities, county councils, staff groups, disability organisations, companies, etc. have been invited to apply for these grants. A comprehensive report from all involved partners will be available in 2007.

At the time of the HCI 2007 results will be available from the project.

Notes

1. The Royal Institute of Technology in Stockholm, Architecture. Agreement in (2004)
2. European Commission, http://ec.europa.eu/index_en.htm
3. www.hi.se; http://www.hi.se/templates/Page____2339.aspx
4. http://www.hi.se/templates/Page____1786.aspx
5. Molina, G., Petterssonb, C., Jonssonc, O., Keijera, U.: Living at Home with Acquired Cognitive Impairment – Can Assistive Technology Help? (An article in process in special edition on Technology in Dementia Care of the publication Technology and Disability)
6. www.hi.se (SmartLab)
7. Government Committee (2003), http://www.regeringen.se

8. SABO is the organization of the municipal housing companies in Sweden. SABO is the biggest organization on the Swedish housing market. In: The approximately 300 companies affiliated manage some 830.000 dwelling units. This is 20 % of the total housing stock in Sweden and about one third of all dwelling units in multi-storey houses. Altogether 1,4 milion people live in SABO homes.

   The size of the SABO companies varies considerably. More than 60 % have 500 - 5.000 dwellings. The largest SABO company owns and manages some 50.000 dwellings. SABO provides expertise in different fields, exchanges experience between its members and cooperates with national authorities and organizations. SABO also arranges conferences and takes on consultancy assignments. (www.sabo.se)

Design Implications of Simultaneous Contrast Effects Under Different Viewing Conditions

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Abstract. This paper proposed that the viewing conditions for printed matters and projected images are quite different for three major reasons. Therefore, the brightness perception phenomenon and brightness perception theory generated from the printed matters should be revised and modified when applied to the projected images. The purposes of the present research were to examine the effects of brightness illusions while viewing the projected images, to understand the brightness perception process in projection environment, and thus to generate design implications for better usage of the projectors.

Keywords: Projector, Luminance, Brightness perception, Brightness illusion.

1 Introduction

One of the well-known brightness illusions is the simultaneous contrast effect. As shown in Fig. 1, the two central medium-gray squares are the same shade of gray, but look different because they are against different backgrounds. A square on a dark background looks brighter, and one on a light background looks darker. Previous researchers have proposed some explanations for this effect such as the lateral inhibition in the retina [4, 7], cognitive approaches [2, 6, 10], Gestalt approaches [3, 5, 8, 9], etc. Along with the remarkable progress and application of display projecting industry during recent years, more basic and applied research related to projecting efficiency and brightness perception are needed. However, most of the past studies regarding brightness perception are based on the research results from printed matters and cannot generalize to projected images.

The viewing conditions for printed matters and projected images are quite different for several reasons. First, people usually read printed matters at high level of illumination and the photopic vision (>3.4cd/m^2) is used in this situation. Cones on the retina are activated. On the other hand, dim illumination is applied to the usage of a projector and the mesopic vision (0.034cd/m^2~3.4cd/m^2) is used in this case. Both cones and rods are functioning when visual process takes place in dim lights.

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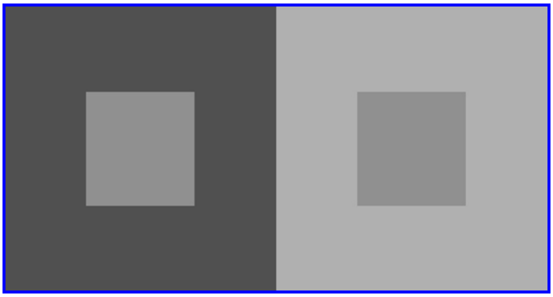

Fig. 1. The simultaneous contrast effect

Second, viewing distances and visual angles of the observed objects are dissimilar for these two viewing conditions. When a projector is used, the viewing distance is usually longer and the observed objects are larger. And, visual acuity is influenced by viewing distances and visual angles.

Third, printed matters are static real objects and projected images are dynamic virtual ones that are refreshed by light beams from a projector. For example, NTSC (National Television System Committee) runs on 525 lines per frame and its vertical frequency is 60Hz. These flashed pixels integrate in human brain to form visual experiences and perception.

Hence, the brightness perception phenomenon and brightness perception theory generated from the printed matters should be revised and modified when applied to the projected images. The purposes of the present research were to examine the effects of brightness illusions while viewing the projected images, to understand the brightness perception process in projection environment, and thus to generate design implications for better usage of the projectors.

2 Methods

2.1 Subjects

A laboratory method was adopted and thirty university students (10 females and 20 males, 20~24 years old) voluntarily participated in the present experiment. One color-blind test and one visual acuity test were used to screen the subjects to ensure their abilities in identifying color differences and having normal or corrected to normal visual acuity (above 0.9).

2.2 Experimental Design

The fully factorial within-subject design was applied in this study. Dependent measures were the perceived brightness levels and the measurement of photometric data collected using a luminance meter. Then, the derived illusions are operationally defined as the practical luminance values (measured by a luminance meter) minus the perceived ones (adjusted by subjects according to their perception). Hence, positive illusion values represent under estimation of the brightness; negative illusion values represent over estimation of the brightness; and no (or fewer) illusion error when this value is around zero.

Independent variables included two viewing conditions (looking at printed matters in bright illumination vs. looking at projected images in dim illumination), five luminance levels of the background areas (10, 30, 50, 70 and 90 cd/m^2), and five luminance levels of the center areas (20, 40, 60, 80 and 100 cd/m^2). Because the adjusted area was on a dark surrounding, people may perceive this area brighter than it really was according to the simultaneous contrast effect. In other words, in order to have the same brightness perception, people do not need to adjust luminance as bright as the compared square (center area). Therefore, under estimation of brightness may occur.

2.3 Procedures

Each subject experienced 50 experimental trials (2×5×5) in two stages; one for printed matters and the other for projected images. Within each stage, random sequences were used to counterbalance the possible fatigue or learning effects. When subjects completed one experimental trial, they might go to next randomly assigned trial until all trials were done.

At the stage of viewing projected images, the standard settings of projecting environment suggested by ANSI were applied [1]. Fig.2 is one sample tested screen programmed by Visual Basic before the experiment. Subjects used a scroll bar to adjust the luminance values of the experimental square (adjusted area in Fig. 2) until they perceive the experimental square having the same brightness level as the compared central square (center area in Fig. 2).

While looking at the printed matters, subjects examined several squares of different degrees of gray levels with a dark surrounding and chose one printout close to the brightness level of the compared center area.

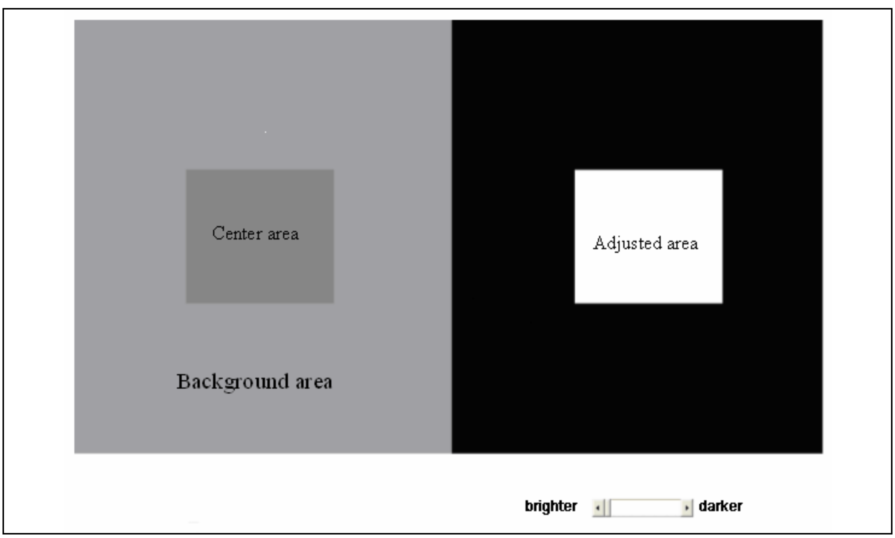

Fig. 2. One sample screen

3 Results and Discussions

Three-way ANOVAs with repeated measures were conducted to analyze the effects of two different viewing conditions and various luminance levels of center and background areas on brightness illusion. The ANOVA summary table and average values are provided in Table 1 and 2, respectively. Three-way interaction was

Table 1. The ANOVA summary table of the illusion values

Source of variance	Sum of square	d.f.	Mean Square	*F₀*	*P-value*
Viewing conditions(A)	18769.091	1	18769.091	225.356	0.000*
Error(A)	2415.309	29	83.287		
Background luminance(B)	4905.777	4	1226.444	23.969	0.000*
error(B)	5935.543	116	51.168		
Center luminance (C)	1741.231	4	435.308	10.253	0.000*
error(C)	4925.089	116	42.458		
AB	4081.116	4	1020.279	16.394	0.000*
Error	7219.084	116	62.233		
AC	3179.769	4	794.942	14.585	0.000*
Error	6322.631	116	54.505		
BC	2599.083	16	162.443	3.961	0.000*
Error	19027.597	464	41.008		
ABC	6629.824	16	414.364	9.864	0.000*
Error	19491.176	464	42.007		
Total	107242.3	1470			

* P< 0.05

Table 2. The summary table of the average illusion values

Projected images						Printed matters					
	10	30	50	70	90		10	30	50	70	90
20	-4.40	-2.00	0.87	5.73	10.00	20	1.17	2.50	5.67	6.50	20.50
40	-5.47	-3.23	0.33	4.83	5.37	40	-1.00	-1.83	3.33	10.17	15.50
60	-7.53	-4.33	-0.13	2.67	4.13	60	-0.33	-2.83	1.67	7.33	5.50
80	-5.03	-3.27	-1.20	3.47	4.93	80	-3.00	-3.00	0.83	0.00	2.00
100	-4.93	-5.07	-0.60	2.97	5.80	100	2.17	-1.00	-0.17	2.00	5.50

A: luminance of background area (cd/m^2), B: luminance of center area (cd/m^2)

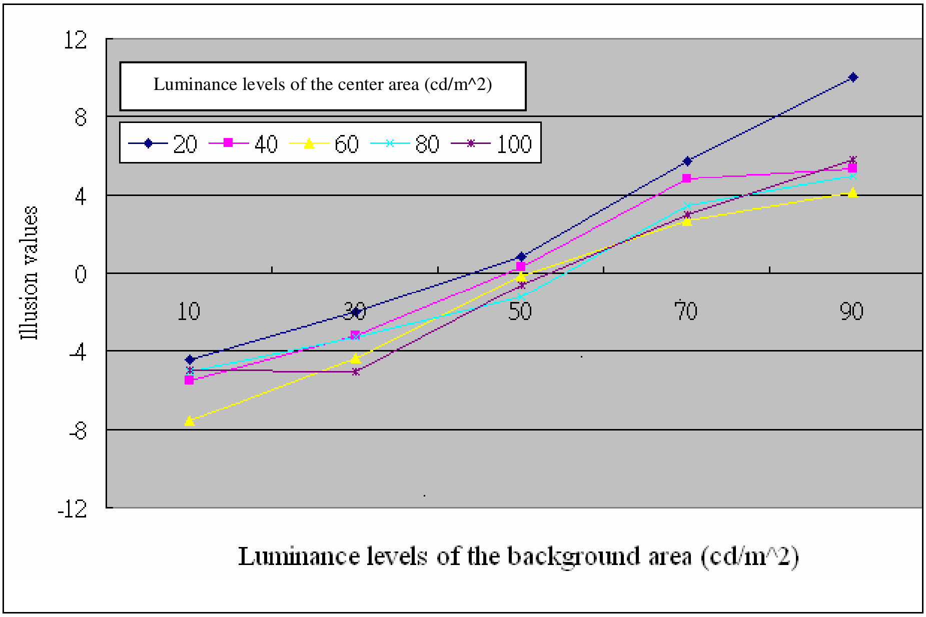

Fig. 3. The average illusion values while viewing projected images

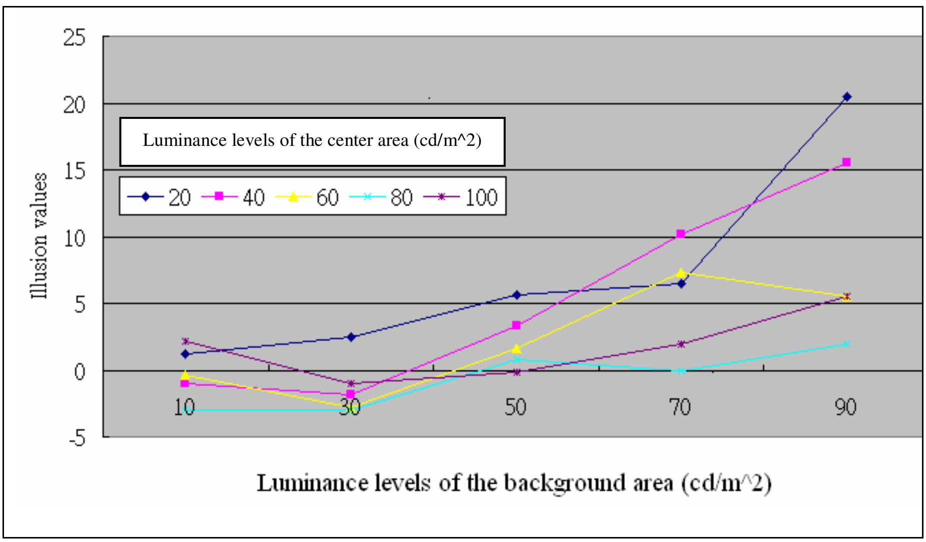

Fig. 4. The average illusion values while viewing printed matters

statistically significant and the other effects (including two-way interactions and main effects) were also significant. It means that simultaneous contrast effects were influenced by viewing conditions, background and center luminance.

The average illusion values under two viewing conditions were depicted on Fig. 3 and 4. On the other hand, the LSD post hoc analysis methods were used to examine the relationships between treatments. It indicated the illusion patterns along with various brightness contrasts while viewing projected images were significantly different from the ones while viewing printed matters. Few over estimation (few negative illusion values) and larger variance (ranges from -3 to 20.5) happened in printed matters condition. In other words, subjects experienced salient simultaneous contrast effects (perceiving brighter when surrounding is dark) in printed matters conditions; however, subjects depended on the combinations of center and background contrast producing brighter or darker perception in projected images condition. People may under or over estimate brightness while viewing projected images.

In addition, situations caused more brightness illusions were identified in this study. When projected images were seeing, there was nearly no brightness illusion at a background luminance of 50 cd/m^2; over estimation of brightness if background luminance lower than 50 cd/m^2; and under estimation of brightness if background luminance higher than 50 cd/m^2 (see Fig. 3). When printed matters were tested, the brighter the background area was, the larger the under estimation of brightness occurred especially if background luminance higher than 50 cd/m^2 (see Fig. 4). And, the illusions seemed to level off when background luminance is lower 50 cd/m^2 while viewing printed matters.

4 Conclusion

Since the display projecting industry is one of the most important industries during recent years, more basic and applied research related to projecting efficiency and brightness perception are needed. Especially, the findings of this research revealed the results of past studies on printed matters can not directly generalize to projected images. Therefore, more future research efforts regarding projector usage are highly encouraged.

It is also obvious that the physical luminance is not equal to the psychological brightness perception as the present and previous research indicated. In order to let projector users to “feel brighter”, the luminance of background is suggested not to exceed 50 cd/m^2. Because the under estimation of brightness may happen when the luminance of background is above 50 cd/m^2.

On the other hand, even though basically the higher luminance of projected images the better the visual effects are. The images with luminance of 40-100 cd/m^2 have slight difference in brightness illusions. However, when luminance of a projected image as low as 20 cd/m^2 may deteriorate the projecting efficiency.

Finally, we’d like to emphasize that illusion is not a worse but a real phenomenon. Not only projectors manufacturers but also the designers of projected images and the projector users need to recognize this phenomenon and to make better usage of brightness illusion to create the visual experiences of perceiving brighter and clearer.

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Beyond the Constraints of QWERTY Keyboard: Challenges to Provide Alternative Input Methods for Japanese Older Adults

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Abstract. Standard QWERTY keyboards are considered as a major source of reluctance towards computer usage by Japanese elderly, because of their limited experience with Western typewriters and the high cognitive demand involved in typing Japanese characters with them. This paper discusses the difficulty in typing Japanese characters using QWERTY keyboards, and then introduces two alternative approaches. The first approach makes use of touchscreen and software keyboards. Touchscreen enables users to enter Japanese characters more directly and is expected to moderate their resistance. As the second approach, a trial to develop a mechanical keyboard that is able to change its key layout dynamically is introduced. The proposed keyboard is also capable to change colors of keys, to flash keys to attract users' attention, and to hide unnecessary keys to avoid errors.

Keywords: interface, keyboard, touchscreen, elderly, gerontechnology.

1 Introduction

For elderly Japanese users, one of the major sources of resistance towards computers is thought to be the use of keyboards [1]. Two major reasons can be assumed. First, because the number of Japanese elderly people who have experience with Western typewriters is limited, they have to get accustomed to QWERTY keyboards as a totally new interaction paradigm before they start learning about computers. Second, although handling Japanese characters is essential in Japanese daily life, the process of inputting Japanese characters requires a relatively high cognitive demand. Thus, alternative ways to use computers without using standard QWERTY keyboards need to be considered in order to lower the resistance of elderly Japanese users towards computers so that they would have more opportunities to take their first steps.

This paper discusses the problems that Japanese older users might face when they handle Japanese characters with conventional QWERTY keyboards. Then two alternative approaches for character input are introduced. The first approach makes use of touchscreen and software keyboards. Touchscreen enables users to enter Japanese characters more directly and is expected to moderate their resistance. As the

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second approach, a trial to develop a mechanical keyboard that is able to change its key layout dynamically is introduced.

2 Problems in Japanese Input with QWERTY Keyboards

One of the major problems specific for Japanese older users is handling Japanese characters on computers [1]. Japanese populations who have experiences with Western typewriters is limited in number, especially among older generations. Besides, because of that huge number of characters used in the language, it is almost impossible to input all characters directly from “keyboards” with ordinal number of keys. These together make input of Japanese characters with QWERTY keyboards quite demanding, especially for elderly people.

Japanese language can be expressed in three different forms of expressions. The first and most fundamental expression is using Chinese (“Kanji”) characters along with phonetic (“Kana”) characters. Japanese language is usually written in this form. The total number of Chinese characters is said to be about fifty thousand, six thousand of which are frequently used [2]. Every Chinese character has its own meanings and pronunciations, while a number of Chinese characters may share the same pronunciation. Thus, it is often difficult to identify a Chinese character uniquely based only on its phonetic characteristics.

The second form of Japanese expression uses only phonetic characters. Each character is associated to a unique phoneme; these characters are phonetic symbols and have no meanings themselves. Although it is possible, it is not usual to write in Japanese using only phonetic characters, because most of the semantic information held by the Chinese characters would be lost. Basically there are only 48 phonetic characters with some extensions, systematically organized in the standard table form. This standard table is popular among all generations of Japanese; all Japanese elementary schools teach the table.

Finally, the third type of written representation uses a Roman character transliteration that has been developed to represent Japanese language phonemes with the Roman alphabet. Any sound in Japanese can be represented by one vowel or a combination of a consonant and a vowel. This expression, called Roman characters expression, has one-to-one mapping to phonetic characters.

Among methods to input Japanese using computer keyboards, most of popular and widely accepted methods make use of the conversion between these three expressions of Japanese. Fig. 1 shows a comparison of input processes of English and Japanese languages using QWERTY keyboard. Typing an English word is straightforward; users can type keys along with the actual spell of the word. On the other hand, in order to input Japanese characters, it requires users to convert their intended Japanese sentences first into sound (phonetic) characters, and then into Roman characters expression. As shown in Fig. 1, this conversion demands users a certain amount of cognitive processing, comparing with typing Western languages using Roman alphabets. Although Japanese younger generations are well accustomed with this type of methods, the cognitive demand can be significant for older users.

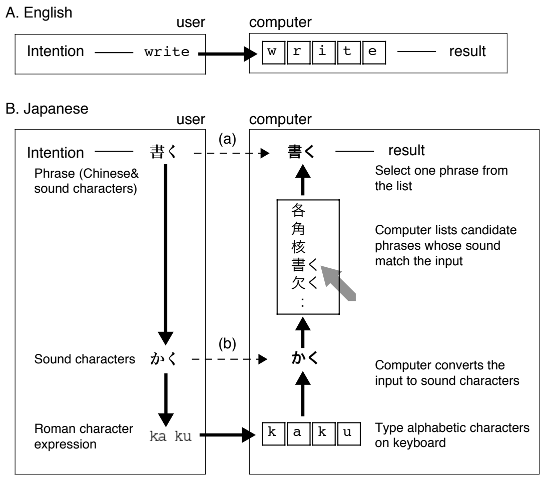

Fig. 1. Comparison of input of English and Japanese characters using QWERTY keyboard [1]

One possible intervention could be direct input of characters (dashed arrow (a) in Fig. 1). However, the large number of Chinese characters is making it very difficult to implement such direct input of all Japanese characters. (There have been, though, a few implementations of this idea using "table-size" keyboards. See [2] and [3] for detail.)

Another possibility for intervention would be using phonetic (sound) characters set (dashed arrow (b) in Fig. 1). Because the number of phonetic characters is limited, it is feasible to lay them out on a standard-sized keyboard or on a screen. Furthermore, if the standard table of phonetic characters is used as the key layout, users should be able to look up characters easily. The following two sections will introduce two alternative methods that have utilized this idea.

3 Intervention 1: Touchscreen and Software Keyboards

The first alternative input method for older Japanese users introduced in this paper is the direct input of phonetic characters using touchscreen and software keyboards, as discussed in the previous section. The most important characteristic of touchscreen is the ease of learning and operation [4]. When used with a software keyboard, the touchscreen enables direct input of characters, and is free from the constraints of traditional keyboards, such as layouts and sets of characters [5]. Tobias [6] suggested that a touchscreen is a suitable input device for elderly users.

Umemuro [7] designed an e-mail terminal with touchscreen technology and examined its effectiveness to lower elderly Japanese users' resistance toward computers. Apple Computer's iMac personal computer (OS ver. 9) was customized so that it offers e-mail handling as its principal function when users logged in. Fig. 2 shows an example of screen layouts of the customized terminal. Fig. 3 illustrates actual operation by older Japanese users.

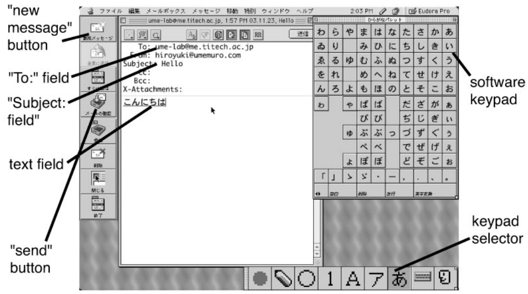

Fig. 2. E-mail software with software keyboard input for Japanese characters [7]

Fig. 3. Touchscreen operation by older user

The developed terminal was compared with another terminal that had the same design except that it had a standard keyboard and a mouse instead of a touchscreen and software keyboards. Older Japanese adults' computer attitudes and subjective evaluation were assessed for each of these terminals and compared. In the study, it was shown that elderly users' anxiety toward computers diminished after the training session with the touchscreen-based terminal, while users who experienced the keyboard-based terminal did not show a significant decline in computer anxiety. In addition, all touchscreen condition participants were not only able to send and receive e-mails on the developed terminal after a short training, but also expressed higher evaluation in terms of overall impressions of the terminal and a stronger willingness towards future use.

The developed terminal was also evaluated through a long term test by 16 older participants for twelve months, and the effectiveness as an intervention for older users was confirmed [8].

4 Intervention 2: Keyboard with Dynamic Key Layout Change

Although touchscreen and software keyboards enables changes in key layout, it is also reported that reduced tactical feedback to fingers may lead to low usability, especially for older users, and that users may prefer to use mechanical keyboard rather than touchscreen for the tasks that require a number of inputs [9].

The second alternative approach introduced in this paper is a development of a mechanical keyboard that is able to change its key layout dynamically [10]. Semi-opaque material was used for key-tops, and letters or symbols were projected from below. By changing the patterns projected onto the key-tops and accordingly changing the mapping between keys and input data, the proposed keyboard was able to change its key layouts freely. It may use the standard table for Japanese phonetic characters, while standard QWERTY layout may be used for Roman alphabets. The proposed keyboard was also capable to change colors of keys, to flash keys to attract users' attention, and to hide unnecessary keys to avoid errors.

The proposed keyboard was evaluated in both performance and subjective evaluation in comparison with standard QWERTY keyboard and touchscreen conditions. Results with older subjects showed that error rate was smaller with the proposed keyboard and touchscreen than standard QWERTY keyboard. Older subjects evaluated the proposed keyboard as comparable to the touchscreen condition and higher than the standard keyboard in dimensions of satisfaction, learnability and efficiency.

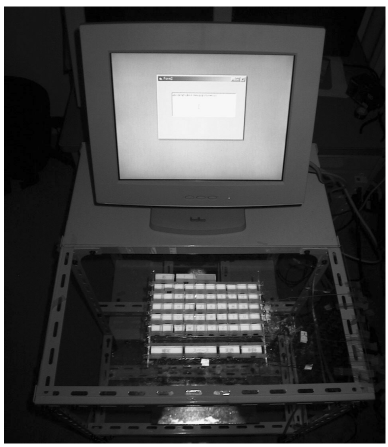

Fig. 4. Keyboard that enables dynamic key layout changes

5 Conclusion

Recently, alternative input methods, such as voice recognition, motion capture, and bio-sensing interfaces, have been emerging. However, explicit input methods and devices for them such as keyboards will still be necessary, especially for situations where voices or motions are not appropriate, where input speed is important, or where explicit data entry is necessary. Thus development and improvement of these input devices should be continuously pursued, taking older users in scope.

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Embedding Expert System into a Computerized Assessment Tool for Mouse Proficiency

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Abstract. This paper described an assessment system which embedded expert system based on the idea of neural network. Authors developed a computerized assessment tool for mouse operating proficiency and applied into clinical service. The result indicated that the objective tool had great contribution for selecting suitable pointing device for the client. However, clinical also found that comparing the effectiveness between different device and operation environment by some parameters was labor consuming. Expert system may be an available solution for clinical professional to select suitable pointing and selecting device more efficiently. Therefore, this study aimed to develop an embedding expert system into a computerized assessment tool for mouse operating proficiency.

Keywords: neural network, cursor movement, expert system.

1 Introduction

Mouse and keyboard are two popular kinds of devices used for interacting with computer. Mouse operating occurs more frequently than keyboard in graphic user interface (GUI), moreover, mouse movement is an integral part of human-computer interaction [1]. Operating a mouse poses no big problem for people without

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disabilities. However, people with physical impairment experience many difficulties when using mouse.

There were many studies that focused on the issue of mouse operating for people with physical impairment [1],[2],[3],[4]. In the previous researches, the researchers suggested many parameters and explored their effectiveness. However, the objective assessment tools of mouse operating for clinical use were short on, so that the evaluator has to assess the mouse operation performance with subjective and nonsystematic methods. Besides, those measurement parameters were not integrated for the clinical practice.

Cursor moving, clicking and dragging are three essential mouse operating tasks needed to interact with computer. And the performance of these three tasks should be considered simultaneously when deciding a suitable pointing device. However, it is not easy for clinical professionals to make a suitable decision without objective tools. Therefore, authors developed a computerized assessment tool for mouse operating proficiency and applied into clinical service. The result indicated that the objective tool had great contribution for selecting suitable pointing device for the client. However, clinical also found that comparing the effectiveness between different device and operation environment by some parameters, such likes speed, accuracy and trajectory, task by task was labor consuming.

Expert system may be an available solution for clinical professional to select suitable pointing and selecting device more efficiently. Therefore, this study aimed to develop an embedding expert system into a computerized assessment tool for mouse operating proficiency.

2 Previous Research

In the research of cursor control measures, the analysis of computer screen cursor trajectories can provide insights into the factors limiting efficient cursor positioning and can assist in the design and improve the usage of the mouse. According to the literature, a number of mouse operating studies were on the basis of Fitts' law that examined gross characteristics of mouse movement, such as target sizes, target distances, directions, speed, accuracy and movement time [5],[6], [7],[8],[9],[10],[11], [12]. Next, throughput had been regarded as a new standard indicator to measure the effect of mouse recently (ISO 9241-9).

However, in stead of explaining the reason of the differences, these studies only indicated the existence of the differences. Therefore, some researchers began to propose the new accuracy measure methods and figured out some accuracy measurement parameters. Mackenzie, Kauppinen, and Silfverberg (2001) brought up seven new parameters as new measurement indicators, including target re-entry (TRE), task axis crossing (TAC), movement direction change (MDC), orthogonal direction change (ODC), movement variability (MV), movement error (ME), movement offset (MO)[7]. The result of their experiment indicated that only TRE and MO made a significant contribution to the prediction of throughput. Keates, Hwang, Langdon, Clarkson, and Robinson (2002), studied the cursor trajectories according to the users' submovement structures, added missed click (MC) and ratio of path length to task axis length (PL/TA) to measure the course movement [2].

3 Method

This study aimed to embed expert system into a computerized assessment tool for mouse operating proficiency. The system was developed based on the previous efforts of the Computerized Assessment Tool (CAT) [13],[14].

3.1 The CAT System

Chen and his colleagues developed the CAT system [13],[14]. CAT was developed based on the results of related literature and the task analysis of mouse operating proficiency. The CAT system comprises three subsystems, namely Basic Skills (CAT-BS), Mouse Proficiency (CAT-MP) and Functional Performance (CAT-FP).

CAT-BS focuses on essential mouse proficiency testing, and provides standard evaluation tasks and procedures. The major aim of CAT-BS is to evaluate the fundamental mouse proficiencies. Evaluation results can be adopted to compare a user's performance with the average performance of all users. CAT-MP enables clinicians to set up various testing situations to explore the specific difficulties and suitable environments when client interacts with computer, such as appropriate interval between double-clicking, proper size of target for clicking, preferred color of the background. The CAT-FP system is used to determine the performance of multi-step functional interactions after equipping the client with some proper devices. This paper adopted the test tasks of CAT-BS and CAT-MP to develop the expert system.

3.2 Idea of Embedding Expert System

An Artificial Neural Network (ANN) or commonly just neural network (NN) is an interconnected group of artificial neurons that uses a mathematical model or computational model for information processing based on a connectionist approach to computation [15]. The back-propagation network (BPN) is more popular than other neural network types.

The major idea of the system was based on the neural network approach. The neural network consists of three-layers structure, namely, input layer, hidden layer and output layer. The neurons of input layer were the collected data that generated from clinical services. The adaptive computer device professionals evaluated the client's performance of operating different devices and operating in different environments by adopting the CAT system. The CAT system could collect speed, accuracy and coordinates that could be transformed into measurement parameters. The variables used for input layer are listed in table 1. As the table 1 released, there are 19 variables that resulted from the previous researches.

Table 1. Variables used for input layer

input variables	parameters
X1	Directions: 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°
X2	Target sizes: 0.5*0.5, 1.5*1.5
X3	Target distances: 5cm, 15cm
X4	Subtest: moving single clicking, moving double clicking, dragging
X5	Tools: mouse, joystick, trackball
X6	Accuracy: true or false
X7	D_CK_T: double click speed
X8	Path: actual distance of the path of the client's moving
X9	PL/TA: ratio of path length to task axis length
X10	RT: Movement Time, a target displayed for selection to the time the client activated the pointing device to move the cursor
X11	MT: Reaction time, the duration the cursor spent for reaching the target
X12	TT: Total Time, task complete time, TT=MT+RT
X13	Speed: cursor movement speed
X14	MDC: movement direction change
X15	ODC: orthogonal direction change
X16	TAC: task axis crossing
X17	MV: movement variability
X18	PV_Max: maximal peak velocity
X19	MU: movement unite

The number of neurons in the hidden layer was determined through experimentation. The neurons of output layer were the result of expert decisions . the parameter used for output layer are listed in table 2.

Table 2. Variables used for Output layer

Output	parameters
Y1	adjust the mouse speed
Y2	adjust the double-clicking speed
Y3	small size target practice
Y4	big size target practice
Y5	near distance practice
Y6	long distance practice
Y7	alternatives pointing devices

3.3 Tools of Developing Expert System

The authors developed an assessment system which embedded expert system based on the idea described above. The authors adopted MATLAB to construe the expert system. The system framework is shown in figure 1. As the figure 1 indicated, a client interacts with computer based on the requirement of the assessment tasks generated from evaluation program. The program collects the response and stores the data into database. Then, the analysis program analyzes these law data into measurement parameters, as mentioned above. These parameters are adopted as input layer variables to train MATLAB Neural Network Toolbox for better understanding of cursor movements and then thought as an expert to propose the suggestion for individuals, ex. to adjust the Windows environment parameters, to use the alternative point devices.

For training neural network, authors used 41 training samples, 21 grade 5-6 primary school students and 20 mentally retarded students participated in experiment. By way of training, the neural network can provide correct classification for untrained patterns. Let the neural network learning iterative, until each input can be corresponding to the output correctly.

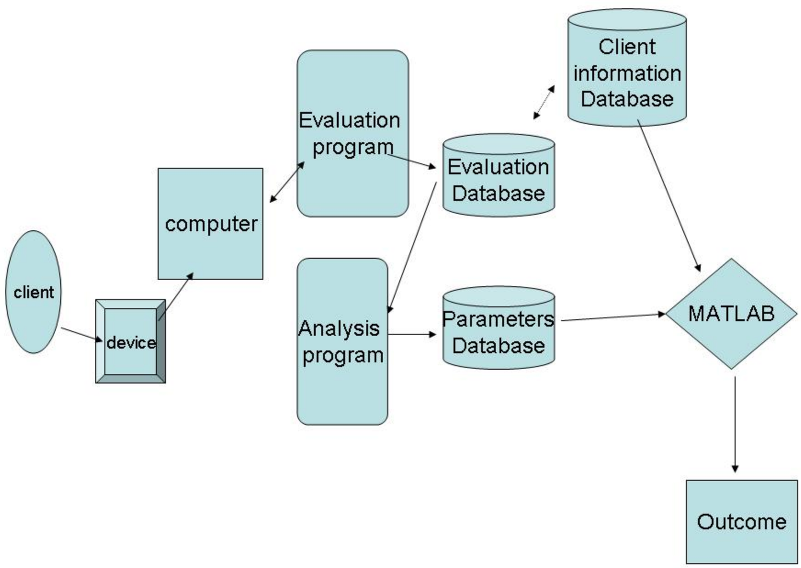

Fig. 1. The framework of an mouse proficiency assessment embedded expert system

4 Discussion and Conclusion

In this paper, the authors presented a novel method to analysis the cursor movement. In order to reduce the loading of analyzing mouse movement, authors tried to embed a expert network that adopted the result of the professional's decision and the data collected from CAT system. Then the authors conducted an experiment to exam the fitness of decisions between the real expert and the expert system. After training a neural network on parameters data, the trained neural networks successfully make the cursor trajectories of the test subjects less chaotic.

In the future, this embedded expert system could not only used to assist professionals to select suitable pointing devices more objectively and efficiently, but also help some professionals who do not have enough experiences of selecting pointing device to make suitable decision. Moreover, the system will help to diagnose specific difficulties and tailor interface environment or select suitable point device.

For future work, the embedded expert system will require more training samples and parameters for learning to reach the optimum. Furthermore, various tests will conduct in neural network model to determine the crucial parameters that affect the course movement performance.

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Urgent Information Presentation Using Listed Sign Language

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Abstract. This paper proposes a listed sign language system that combines written expressions in table form with sign language fragments. The system generates urgent video style messages that offer rapid, certain, and easy understanding for environments such as railway carriages. We developed a prototype of the system and conducted an evaluation experiment. The results show that the system improves the level of understanding urgent messages. Participants confirmed that the messages scored highly in terms of ease of understanding, high accuracy, rapid understanding, and sense of security.

1 Introduction

It is an important social issue for minimizing disaster damage that urgent information should be surely and rapidly passed to the public when a disaster such as a large-scale earthquake occurs. For instance, what happened?, where should I take shelter?, what means do I have to move?, etc. Even if the train operation has become disrupted, the announced message may not be heard due to high background noise levels. This may prevent the public from taking the appropriate steps. Voice announcements are completely ineffective for the hearing impaired. In order to support maximum number of people in public spaces, a universal information presentation system that uses sign language in addition to written expressions is needed. However, only a few people understand sign language, and there is individual variation in the proficiency of sign language. Moreover, there is individual variation in the understanding level of written expressions.

This paper proposes a listed sign language system that combines written expressions in table form with sign language fragments. The system generates urgent video style messages that offer rapid, certain, and easy understanding for environments such as railway carriages. We developed a prototype of the system and conducted an evaluation experiment. The results show that the system improves the level of understanding. Participants confirmed that the messages scored highly in terms of ease of understanding, high accuracy, rapid understanding, and sense of security.

2 Message Generation by Listed Sign Language

2.1 Design Concepts of the Listed Sign Language

The listed sign language aims at reducing the impact of personal variation on discernment of alert messages. We aim to achieve an interface that can present an urgent

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message easily and promptly. The design concepts of the listed sign language are summarized by the following four points.

- (1)Present written expressions and sign language video images at the same time.
- (2)The written expressions are displayed in table form for conciseness and easy understanding.
- (3) All written expressions are shown from the beginning. As the sign language fragment is shown for each expression, the expression is highlighted in yellow.
- (4) The written expressions and the sign language fragments are displayed on the same screen.

Figure 1 shows the example of a message based on the listed sign language. The written expressions are displayed in table form at the left side of the screen. Sign language movie is arranged at the right side of the screen. The proficiency of sign language and the individual variation concerning the understanding levels of Japanese sentences could be overcome by using listed sign language.

Fig. 1. An example of listed sign language message

2.2 Expression of Sign Language in Fragmented Form

The sign language fragments for the five written expressions in Fig. 1 are shown below. H means the hand is in the home position, and P means a temporary stop. Word inside the parenthesis is sign language expression.

- Title: H < report >< train >< moment >< stop >H
- The second line: H < train >< start >< expectation >P< time >< 17 >< 40 >H
- The third line: H< substitute >< substitute ><method >P< nothing >H
- The fourth line: H< reason >< why >P< shine >< break >H

- The fifth line: H< stop >< section >P< from / to >< HINOKI >P< train >< station >< name >< KEYAKI >< place >< KAEDE >< place >< section >H

The following description is an expression of the same content by the long sentence form.

- H:< HINOKI >< line >< station >< name >< KEYAKI >< station >< from >< KAEDE >< station >< section >< moment >< stop >< reason >< why? >H < MOMIJI >< station >< place >< shine >< break >< train >< start >< expectation >< time >< 17 >< 40 >< moment >H.

3 Experiment 1: Subjective Evaluation

3.1 Participants

In order to verify the effectiveness of the listed sign language, a subjective evaluation was done. Eight messages on train status, generated by the proposed system and the straight sentence equivalents, were presented to 17 subjects who were mostly hearing impaired (used sign language in daily life); their subjective opinions were collected and evaluated.

3.2 Questionnaire

The subjective evaluation examined eight items; Q1. accuracy, Q2. promptness, Q3. ease of understanding, Q4. suitability for emergency use, Q5. sense of security, Q6. sense of incongruity, Q7. irritation, and Q8. efficiency. Each items for the questionnaire were as following.

- Q1: I think that the content of the message is accurately transmitted.
- Q2: I think that the content of the message is promptly transmitted.
- Q3: I think that the content of the message is easily understood.
- Q4: I think that this method of the display is suitable for the presentation of an urgent message.
- Q5: I think that there is a sense of security in this method of the display.
- Q6: This method of the display has the sense of incongruity.
- Q7: In this method of the display, there is impatience (feeling to get irritated).
- Q8: I think that this method of the display is suitable for seeing both sign language and written sentences.

3.3 Results

Figure 2 shows the results of the evaluation. The participants thought that the listed sign language was superior in terms of "Accuracy", "Promptness", "ease of understanding", and "sense of security";. The difference was significant at the 1% level as confirmed by ANOVA. In addition, it was found that the listed sign language was highly rated for the presentation of urgent messages. The long sentences created more irritation and incongruity. Five participants were queried as to their understanding of the messages. Their average correct answer rates were 0.95 for the listed sign language messages and 0.80 for the long sentence messages. Therefore, the listed sign language messages could be well understood.

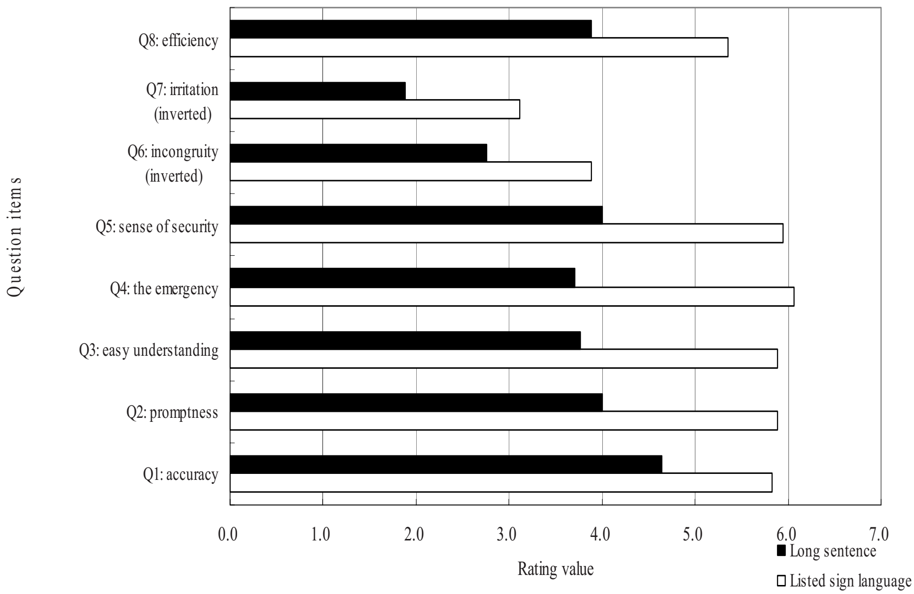

Fig. 2. Results of the subjective evaluation by 17 participants

4 Experiment 2: Performance Evaluation

4.1 Participants

In order to verify the performance of the listed sign language, an evaluation experiment was done. Five subjects from 26 to 45 years old participated in Experiment A. All of them were hearing impaired and used sign language in daily life.

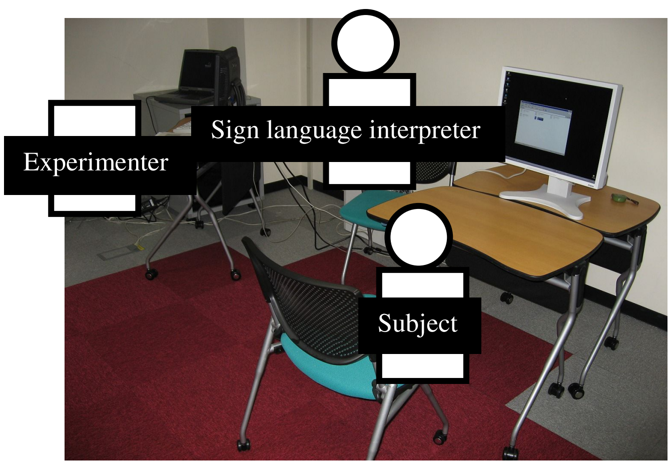

Fig. 3. Configuration of experimental apparatus

4.2 Procedure

Vehicle operation information was presented by using sign language (real video) and Japanese sentences for the subjects. Afterwards, the recognizing tests concerning the vehicle operation information was done. The subjects read the experimental message displayed on the PC screen set up on the desk in the laboratory, and answered the question presented immediately after the message display. Read out time of the displayed message and the correct answer rate of the recognizing test were measured. The subjects were made to assume the situation that the train stopped suddenly and the message was displayed on the screen in the train. Figure 3 shows a configuration of experimental apparatus. Figure 4 shows a screen example of performance test.

Fig. 4. Screen example of performance test

4.3 Results

(1)Time to read message

Results of the performance test are shown in figure 5. Figure 5 shows an average read time rate for each display format. Read time rate is defined as equation 1. As shown in figure 5, the read time rate was 1.39 in the list sign language and 0.83 in the long sentences form. Read time rate for the listed sign language form is higher than the long sentence form. Significant difference was detected between two forms(f(1, 38) =18.84, p=0.00<0.001) with ANOVA.

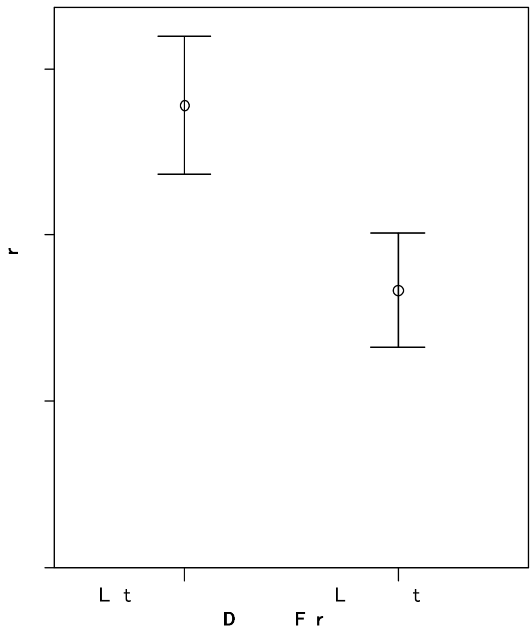

Fig. 5. Average time rate for message reading

(2) Correct answer rate of message understanding

Figure 6 shows the average correct answer rate of message understanding for each display format. As shown in figure 6, the average correct answer rate was 0.95 in the Listed Sign Language form and 0.80 in the Long Sentence Form. The result reveals that the subjects could be able surely to understand the content of the message with the List Sign Language Form rather than the Long Sentence form. However, no signifi-cant differences(f(1, 38) =2.06, p=0.16 > 0.05) were detected between two forms.

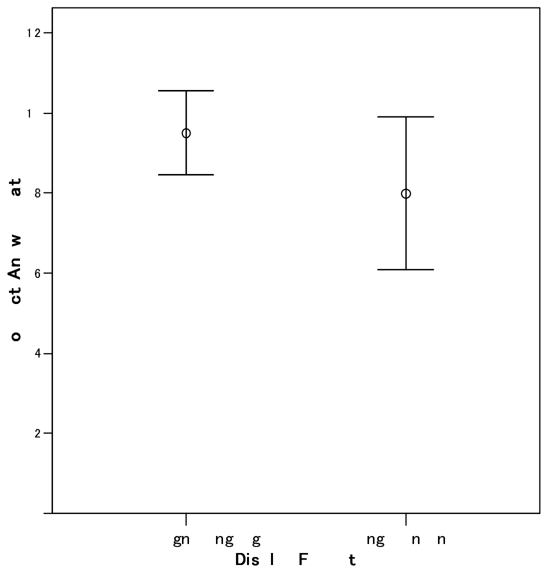

Fig. 6. Correct answer rate of message understanding

5 Conclusion

In this paper, we proposes a listed sign language system that combines written expressions in table form with sign language fragments. The system generates urgent video style messages that offer rapid, certain, and easy understanding for environments such as railway carriages. We developed a prototype of the system and conducted an evaluation experiment. The results show that the system improves the level of understanding. Participants confirmed that the messages scored highly in terms of ease of understanding, high accuracy, rapid understanding, and sense of security.

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SMART Rehabilitation: Implementation of ICT Platform to Support Home-Based Stroke Rehabilitation

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Abstract. Stroke is the biggest cause of severe disability in the UK. The National Service Framework for Older People recommends that rehabilitation should continue until maximum recovery has been achieved. However, due to cost factors inpatient length of stay is decreasing and outpatient rehabilitation facilities are limited. The level of therapy could be improved by providing assistive technology, in the form of tele-rehabilitation, within patients' homes. This paper presents the development of the SMART rehabilitation system, a home-based tele-rehabilitation system to argument upper limb rehabilitation, with the emphasis on the implementation of the system ICT platform and user interface design.

1 Background

Stroke is the biggest cause of severe disability in the UK. A quarter of a million people in the UK are living with long-term disability as a result of stroke, significantly affecting their independence and quality of life; most of them are elderly people. Research has shown that organised stroke care and active rehabilitation improves outcomes (Stroke Unit Trialists Collaboration, 2005; Forster and Young, 2002). The National Service Framework for Older People recommends that rehabilitation should continue until maximum recovery has been achieved (DoH, 2001a). However, due to cost factors, inpatient length of stay is decreasing and outpatient rehabilitation facilities are limited (Royal College of Physicians 2002). Consequently, research has been carried out in tele-rehabilitation and home-based rehabilitation to enhance evaluation of daily living activities, and to provide more frequent and timely intervention. The salient challenge is how to monitor and assess interventions in a home environment. Various position-sensing technologies and motion tracking systems have been reviewed (Zheng, Black and Harris 2005) for human motion tracking to identify feasible techniques which can

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be applied to upper limb rehabilitation. Inertial sensors (accelerometers and gyroscopes) have advantages over others for the home-based rehabilitation. Readers are referred to (Zheng, Black and Harris 2005) for more detailed information.

The smart rehabilitation project, entitled 'SMART rehabilitation: technological applications for use in the home with stroke patients', is funded under the EQUAL 4 (extend quality of life) initiative from the UK Engineering and Physical Sciences Research Council (EPSRC). The project aims to examine the scope, effectiveness and appropriateness of systems to support home-based rehabilitation for older people and their carers (http://www.shu.ac.uk/research/hsc/smart/), and it focuses on supporting upper limb home-based rehabilitation for post stroke patients.

The SMART consortium consists of one NHS Trust, four universities and one voluntary organisation, namely Royal National Hospital for Rheumatic Diseases, University of Bath, Sheffield Hallam University, University of Essex, University of Ulster and The Stroke Association. It is an interdisciplinary research group with expertise spanning occupational therapy, physiotherapy, psychology, engineering, ergonomics, informatics and medical physics.

The remainder of this paper is organised as follows. Section 2 provides an overview of the SMART rehabilitation system. The user involvements and usability study is presented in Section 3 followed by the implementation of the ICT platform detailed in Section 4. The paper is concluded by a brief summary and future work in Section 5.

2 Overview of SMART Rehabilitation System

The SMART rehabilitation system consists of three primary components: a motion tracking unit, base station and web server.

In the motion tracking unit, two MTx inertial sensors (Xsens Dynamics Technologies, Netherlands) are used to track patients' upper limb movements (Zhou and Hu 2005). As shown in Fig. 1, one sensor is placed on the wrist and the other is worn on the upper arm.

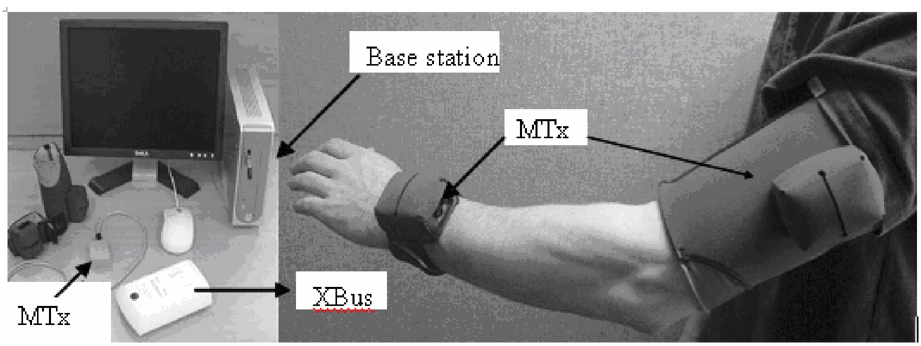

Fig. 1. Motion tracking system and base station

An MTx sensor consists of a three-axis accelerometer, a three-axis gyroscope, and a three-axis magnetic field sensor, which can measure movement information including position and rotation. The motion data of wrist and elbow joints are recorded with a sampling rate of 25Hz and then transmitted wirelessly to the base station via a digital box called the XBus which is worn on a belt around the patient's waist.

The base station consists of a personal computer and a touch screen. The sensor fusion and optimisation is implemented using Visual C++ and runs on the base station.

An ICT decision support platform is also operating at the base station. This platform is integrated with sensor fusion and data acquisition. It directs the users throughout each rehabilitation intervention and provides the various types of feedback to the user, such as three dimensional (3D) movement display, exercise history and a summary of outcome variable measurements. It also provides a questionnaire, diary, calendar and comment functions to support the rehabilitation as it progresses through different stages.

The base station is connected to a central server providing web services (Zheng, Davies and Black 2005) to the user. Fig. 2 illustrates the infrastructure of the SMART rehabilitation system. Therapists can tele–monitor their patients' rehabilitation progress, analyse the movements and give advice to patients and their carers. Patients and their carers can also access the system to view their own exercises via the screen connected to the base station, compare one movement with a target movement, read comments from their therapists and results from movement analysis, and to send comments to their therapists.

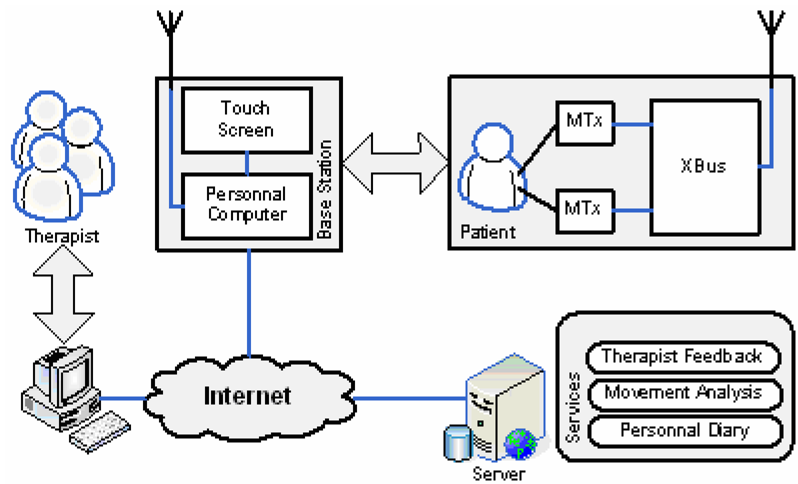

Fig. 2. The infrastructure of SMART rehabilitation system

3 User Involvements and Usability Study

A systematic review of literature on user acceptance and satisfaction with assistive rehabilitation technology was undertaken in the early stages of the SMART project. The review shows the importance of incorporating users' views at an early stage in the design and development process and concludes that unless devices meet the needs of users in terms of outcomes and usability they will not ultimately be used clinically (Mountain et al 2006).

The SMART project adopts user involvement as the design strategy. Potential users of the system, including patients, carers and health-care professionals, were engaged in the design and development phases of the project. Seven focus groups were conducted with 32 patients and carers. They helped to ensure that proposed technical solutions, methodology and outputs were acceptable. They were also used to gather feedback on the system, such as sensor attachments and the type and format of information provided to users by the system.

In phase one, key issues were identified in regard to the system design, for example, the device/system should be simple to operate; can be used by stroke patients preferably without assistance from the carer; and should be able to give encouraging feedback to patients about outcomes even when progress is slow.

In phase two, users and carers were asked to give feedback on the screen interface as well the various attachment methods for the movement sensors. This helped to modify the way sensors were attached and refine the display of screen information.

Stroke rehabilitation therapists are also users of the system and have been involved in the user consultation process. Groups of therapists have given feedback on the appropriate movements for target exercises, the display of patient information and the ways they would like to use the equipment in practice. Readers are referred to (Mountain and Ware 2006) for detailed information on the user involvement study.

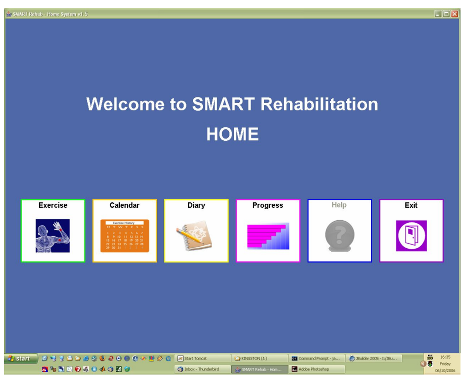

Fig. 3. Welcome screen after user login. Menus are designed using large icons to accommodate touch screen technology.

The usability of the software interface was also assessed. Usability testing scenarios were developed from hierarchical task analysis and cognitive walkthroughs of the system. Usability tests were conducted with adults recruited from stroke groups and a stroke rehabilitation ward. A range of low- and high-fidelity prototypes were developed for the tests, which were videotaped then scrutinised for usability issues. Subjects were also asked for their opinions on the system. Many subjects were unfamiliar with computers and had difficulties even using a mouse and keyboard. The software interface underwent iterative development based on the results of the usability tests:

Modal dialogue boxes caused navigation difficulties and were discarded; the office-style layout of the early prototypes was replaced by a simple interface comprising large colour-coded buttons with labels, explanations and images to provide clues to function (Fig. 3); tree-style navigation was replaced by a calendar after consideration of suitable metaphors for the target audience; the keyboard and mouse were abandoned and replaced with a touchscreen and an on-screen keyboard, as shown in Fig. 4. The results of the design phase of the project showed that it is possible to design an interface that is widely acceptable to stroke patients and allows them to interact with the system in an effective manner.

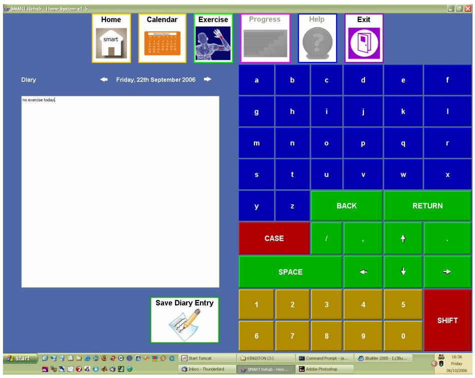

Fig. 4. An on-screen keyboard is designed to allow users to input comments on the touch screen

4 Implementation of ICT Platform

The ICT platform consists primarily of five modules: database, interface, decision support, communication and a feedback module.

4.1 Database Module

The database module maintains various types of information such as system information, personal information, rehabilitation movement information, target template movements, comments/instruction from/to heathcare professionals and movement analysis.

After a movement is completed, the motion information is recorded and added to the database with the information of time, date, and intervention type. A calendar service provides the ability to store a patient's entire history of rehabilitation. Through the calendar function (Fig. 5), users can look up a movement information for a specific date and time and load it into the system for viewing and analysis. On the top row, the menu of this screen is represented by a list of image icons indicting the relavant functions, which is easy to select by touch. On the left-hand panel, users can select the month and year by easily accessilbe up and down buttons. The calendars main function is to provide a visual listings of previous movements carried out. Information on the type and time of the intervention are presented. Different icons are used to differentiate between intervention types; for example, a blue triangle indicates a drinking movement, while a red rectangle represents a reaching movement. When a file is seclected, personal comments and/or thearapist's comments, if there are any, will be shown on the text area at the left hand side.

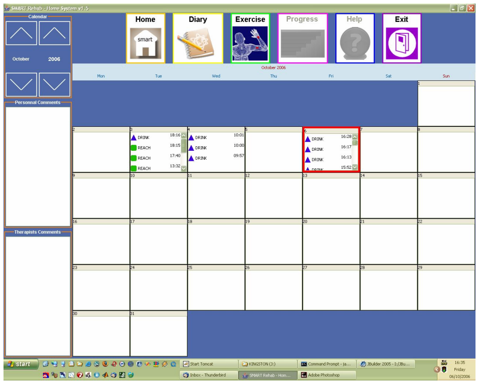

Fig. 5. A calendar is applied to replace the tree structure for navigation

4.2 Interface Module

The design of the interface module provides easily accessible and understandable menus. It guides the user through the system by simple, clear and sufficient instructions. For example, after the user logs on to the system, it instructs the user to start an exercise, view their calendar and diary and obtain some feedback on their rehabilitation progress (Fig. 3). During the movement exercise, prompts are used to inform the

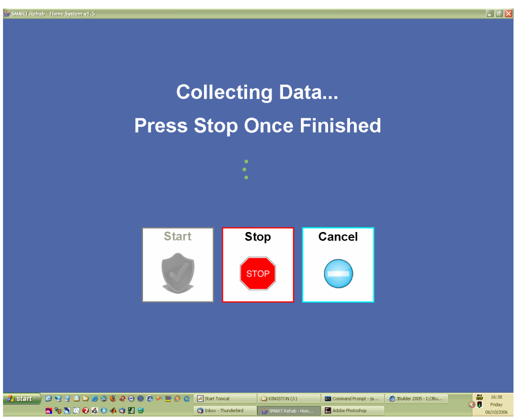

Fig. 6. The prompt screen during the data collection

user of the procedures and guide them through the exercise. Fig. 6 shows a typical prompt screen during an exercise. When the user finishes an exercise and touches the *stop button*, a new screen will be displayed, indicating that the exercise has been recorded and provide the icon menus for other functions (Fig. 7).

The design of the interface module was largely informed by the fact that users would interact with the software via a touch screen display. Its main aim is to provide easily accessible and understandable menus, especially for stroke patients, as most of them are elderly people and have limited IT skills. Therapists can monitor and assess patients' movements, and make comments using keyboard and mouse if they prefer.

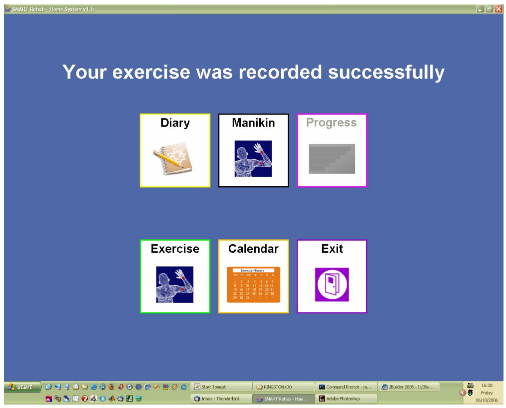

Fig. 7. The menu screen when the user selects *Stop* in Fig. 6

4.3 Decision Support Module

The decision support module analyses the movement data and provides the key outcome variables relating to physical performance for each exercise. Additional trends in these outcome variables can be monitored over an extended period of time

The system compares patients exercise movements to target template movements. The target movement is personalised and can be changed by therapists according to the rehabilitation progress. The decision support module provides the comparison both in the measurement of kinematic variables and in the form of 3D movement (Fig. 8).

The kinematic variables measured includes elbow flexion/extension; forearm rotation; shoulder flexion/extension and upper arm rotation. A closeness-to-target score is then given by comparing the exercise kinematics to the target kinematics. This score provides information on progress and could be used to modify the exercise plan or justify the target template. In terms of motor relearning, the kinematic variables and 3D movement correspond to extrinsic feedback to the patient in the context of a goal or correct movement. This permits the patient, with the support of the therapist, to identify strategies in their movements that are not appropriate. This recognition may additionally promote motor learning on an intrinsic level.

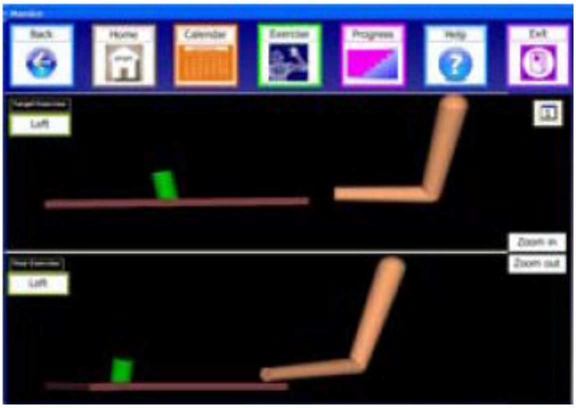

Fig. 8. Comparison of one patient movement with the template in 3D models. Upper panel: template movement; lower panel: patient movement.

4.4 Communication Module

The communication module manages the transfer of information between the base station and the central server.

All the SMART home-based systems are linked to a central server via the internet. Patients' movement data and comments/queries from patients can be sent to the central server.

A therapist can log into the central server via the internet when required, to view patients' movement data. The therapist can then provide appropriate feedback and respond to any comments (input by patients via *Diary* service in the system)

There are three main processes that run on the server to manage the entire system: MySQL server to control the database module, TomCat server to manage all internet traffic and MATLAB to analyse the movement data.

4.5 Feedback Module

Feedback module provides feedback to both the therapists and the patients. Feedback to the therapists is delivered over the internet. The therapists can access patients' movement data, diary (which contains comments from the patients), kinematic variables, closeness-to-target score and the progress analysis. They can also review the movements and compare the movements with templates in the 3D environment.

Patients and their carers can access the comments from their therapists, replay and compare their movements against the template movements in the 3D environment.

Fig. 9 shows a screen shot of the 3D rendering using a virtual body and arm. On the left-hand side, the system provides *Play, Stop, Start, Back, Next, End* and *Repeat* functions for users to review the movement, e.g. continuously or frame by frame. On the right-hand side, the system provides various tools to allow the users to view the movement in different axis views and also provides a zooming feature.

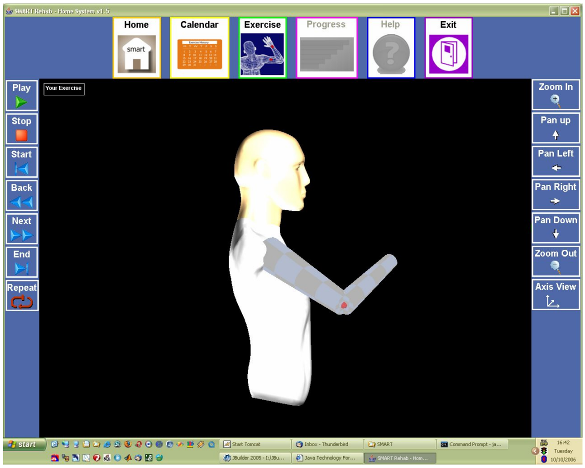

Fig. 9. Software screen shot of 3D rendering

The kinematic variable measure can be display in graphics, such as the example given in Fig. 10.

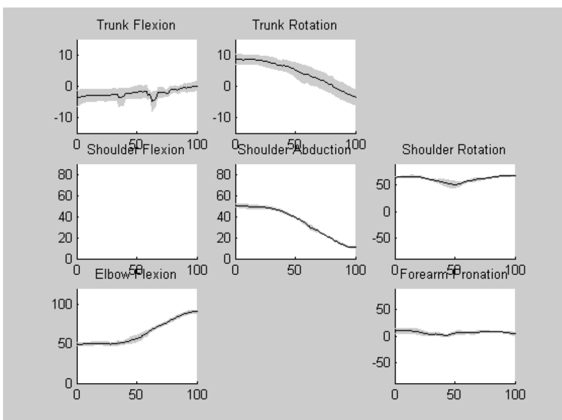

Fig. 10. Graphic feedback of seven kinematic variables measured: trunk flexion, rotation; shoulder flexion, abduction, rotation; elbow flexion and forearm pronation

5 Summary and Future Work

The SMART project developed a home-based telerehabilitation system for stroke patients in order for them to gain maximum rehabilitation in the home environment. This project demonstrates the feasibility of applying emerging motion sensor, information and communication technologies to develop a low-cost home-based system that could be used to support post stroke rehabilitation. The project also demonstrates the importance of user involvement and usability testing in the design and development phase of a healthcare system. The clinical evaluation phase began in Nov. 2006 and upon completion the results will be presented in a subsequent paper.

Additionally, the system permits the capture of large volumes of kinematic data. Future research will apply machine learning and data mining techniques to better characterise upper limb impairment after stroke.

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We would like to thank the patients and carers who have given their time and support to the project. We would also like to thank Design Futures from Sheffield, Xsens, Charnwood Dynamics Ltd. and the Stroke Association for their support.

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Perceptive Supplementation for an Access to Graphical Interfaces

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Abstract. Studies using the sensory substitution devices reveal that perceptive activity itself is embodied in a living body capable of movement and possessing its own spatial dimensions. To study the conditions of a prosthetic perception, we developed a minimal device, Tactos, which carries out a coupling between the pen of a graphics tablet and tactile sensory stimulators. This system allows subjects to explore virtual tactile pictures and is intended to give to blind people an access to computer graphics. We will present here experimental results regarding the different aspects of perception using this device.

Keywords: Sensory substitution, haptic and tactile perception, Perception/action coupling.

1 Introduction

Sensory substitution systems offer to blind people (and blindfolded subjects) a new kind of perception, a new sensorial modality which can compensate a lost sense and/ or be added to the other modalities in order to perceive the world. One of these devices is TVSS (Tactile Visual Substitution System) [3] which converts an image acquired by a camera into a ‘‘tactile picture’’. This tactile image is produced by a matrix of vibrotactile stimulators (400 stimulators) placed on a subject's abdomen, back or forehead. Bach-y-Rita's work with TVSS showed that perception is active, and not simply a passive reception of information. To perceive the information appropriately it is necessary to interact with one's environment, in order to understand the laws which control one's actions and sensations [8] and which enable one to perceive things. With TVSS, the human subjects (sighted and blind) displayed a real recognition of shapes, but only if they were in full control of the camera. If the camera is fixed, the subject feels a prickling sensation on the skin but cannot describe the object depicted. On the other hand, when handling the camera oneself one comes to understand that a particular action corresponds to a particular sensation and vice versa, thus activating a circular process between actions and sensations, giving rise to perception via the device. An absolutely essential observation is that this shape recognition capacity is accompanied by perceptual externalization. Whilst moving, the user is able to recognize objects, forgetting the prickling sensation and perceiving objects in space.

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From this observation the idea was born within our research team of creating an ultra-simplified device (1 sensor and 1 stimulator) to explain and understand how a human subject learns to perceive and recognize objects via sensory substitution devices [7]. Starting from a very basic prototype, we would then improve the interface, either by increasing the number of stimulations (points of sensation) or by enriching the points of action. This prototype named Tactos [5] is a platform which allows the exploration of digital 2D shapes on a computer screen using tactile stimulations of the index finger. It includes three parts: a computer, a graphics tablet with stylus, and tactile stimulators (see Fig. 1). The stimulators are two electronic Braille cells, each including eight tactile pins. They are connected virtually to a sensor able to distinguish figures on the screen from the background. In other words, when the sensor is on the outline of the figure a signal is transmitted to the stimulators and the corresponding pin is raised. The idea is to move the stylus on the graphical tablet so that a figure on the computer screen can be explored and recognized even though the user is blindfolded. The whole allows the recognition in blind mode of writing and/or drawing on the computer screen. Subjects used the stylus to sweep over the tablet while keeping the index finger of the left/right hand (according to the dominant hand) on the 16 tactile pins (two Braille cells of 16.7 mm x 6.4 mm). Each shape or drawing displayed on the screen is haptically perceived according to the movements of the stylus on the tablet. The subject feels the stimulators being activated under the index finger each time the cursor (which corresponds to sensors) comes into contact with the outline of the shape on the screen.

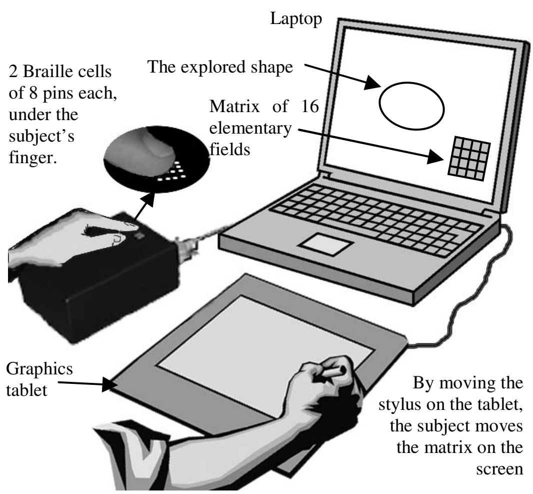

Fig. 1. Tactos

Virtual sensors can have different shapes (circular, square, and rectangular), different sizes (the smallest sensor is a square of one pixel while the largest one can cover the total area of the screen), and can contain a variable number of elementary receptor fields (see Fig. 2).

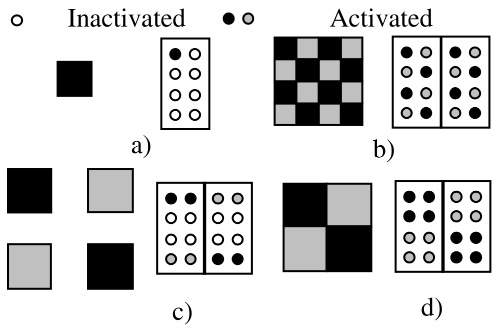

Fig. 2. Examples of pin activation using different matrices: a) mono-field matrix activating one pin, b) 16-field matrix activating 16 pins (black and grey are only used to make the schema clearer), c) 4-field matrix activating 8 pins, d) 4-field matrix activating 16 pins

1.1 Working with Visually Impaired Partners

Tactos initially designed in its minimal shape is the current subject of an ergonomic process of conception and evaluation. Tactos offers a non-visual access to 2D numerical forms and is designed to be used in learning mathematics. The formalization of its efficient appropriation is at stake. The methodology is based on a longitudinal study which was managed in two stages. The first stage was conducted in collaboration with two blind adults. The second one is being achieved with four blind schoolchildren and pursues the work with the two adults. The experiments showed the heuristical advantage of the strategies analysis whose comprehension allows us to propose new specifications.

For the blind, one of the major limits of digital technologies is the accessibility and interaction with graphic objects. Tactos offers haptic access to digitized graphical documents. The objective of this work is twofold [1]: to define the conditions under which the device is appropriated by blind secondary school pupils and to propose specifications for the design of future versions of Tactos. Our analysis focuses particularly on exploratory strategies which allow an efficient perceptive activity. The methodology employed follows a constructivist tradition and implements a minimalist approach: initially, the device is restricted, in order to characterize better the strategies employed, which in their turn are used to improve the design of the device. A longitudinal study carried out with six blind subjects (two adults and four teenagers), allowed us to systematize the analysis of their perceptive capacities. We preferred working in individual sessions in order to be able to characterize the subjects' strategies in their variability and in their potential convergence.

The tasks proposed to the subjects got gradually more complex, from the exploration of simple mathematical forms to the use of Tactos with mathematical software during an individual course of geometry. These studies show that the recognition of geometrical forms was feasible and improved substantially across the different studies. Four types of exploratory gestures were identified (see Fig. 3):

1. the continuous follow-up : the subject tries to maintain a constant contact with the form
2. the micro-sweeping : the subject voluntarily leaves the form while oscillating along the line
3. the macro-sweeping : the subject crosses the line right through
4. the lateral tap : the subject rebounds on the line without crossing it.

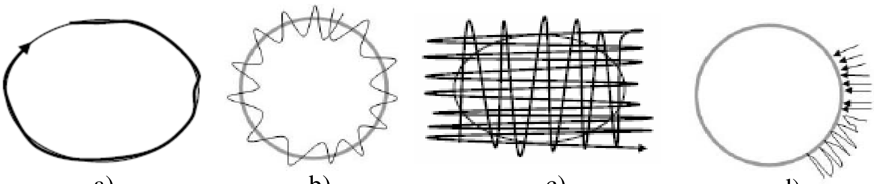

Fig. 3. a) Continuous follow-up, b) micro-sweeping, c) macro-sweeping, d) lateral tap

The personal profile of how these four gestures are used defines an exploratory style [12]. The results highlight the essential character of the exploratory technique: the continuous follow-up proves to be a superior strategy for correct recognition of mathematical forms. The mastering of this latter strategy made it possible for the blind pupils to interact with a complex geometrical digitized figure in a mathematical exercise. Using Tactos, Geoplan[1] and Jaws[2], the pupils were able to create a figure, recognize it, move it and modify its dimensions. These graphical transformations helped them to take note of what remains invariant through all these transformations and deduce the mathematical property of the figure. This encouraging study justifies a continuation of this work to find the optimal specification of the interface. The design issues considered so far associate simultaneously:

1. How to assist and guide the perceptual activity (for instance bi-modality to enhance some elements of the figure) and use the zoom (see sections below).
2. How to teach specific strategies.

2 Experiments and Results

2.1 Shape Recognition

Several results [2, 10, 13] clearly demonstrate that shape recognition is possible with even minimal forms of sensori-motor coupling. A point of interest in this approach is that the perception of shapes takes time, and requires the external deployment of exploratory activity. Precisely for this reason, traces of the patterns of exploration can be easily stored for subsequent analysis. Analysis of these dynamic patterns shows that experienced subjects deploy identifiable strategies, which can and must be

[1] Geoplan is a software of edition of dynamic and interactive mathematical figures into two and three dimensions, available at: http://www.geoplan.com

[2] A screen reader, http://www.freedomscientific.com/fs_products/software_jaws.asp

learned for rapid and reliable perception to occur successfully. The essential role of action in the progressive emergence of structured percepts strongly suggests that what is perceived, or recognized, does not derive from invariants in the sensory information, but rather from invariants in the sensori-motor cycles which are inseparable from the activity of the subject. This action allows the subject to seek and construct "rules" of constant relations between actions and subsequent sensations. Spatial localization, as well as form recognition, correspond to a temporal synthesis of successive sensations in accordance with a law linking action to sensation.

2.2 Parallelism

The tactile stimulators are two Braille cells and are activated when the cursor crosses the shape. The cursor is a virtual sensor called matrix of elementary fields and can have various shapes and contain various fields and that we called parallelism of elementary fields. In general, application of the parallelism concept enables information to be accessed more precisely and easily when the number of sensors is high. Results show that by applying the parallelism concept to the detection field, people with visual impairment can increase the speed of exploration of geometric forms without decreasing the level of accuracy: thus avoiding a speed-accuracy trade-off [10, 11].

2.3 Bimodality

The perception of mathematical forms by two blind subjects, by means of the Tactos device, is substantially improved when an additional sensory modality (the audition associated to the tactile sense) is introduced to emphasize salient points of the geometrical figure (the summits of the polygons make a sound), or in order to facilitate the differentiation between a curve and the axes of the Cartesian coordinates. This is an interesting innovation in the design of an interface making it possible for non-sighted subjects to read, to draw and generally to appropriate mathematical concepts in an operational fashion [1].

Indeed, in mathematics a coding is used to indicate a conceptual difference between the elements of a figure. This traditional coding improves both perceptive discrimination and conceptual distinction. For instance, the gradations will not have the same size whether they correspond to a whole number or a decimal number and a right angle is symbolized by a small square. Relief figures - that are commonly used by the blind - need to compromise between the simplification of the figure (in order to facilitate tactile recognition) and the presence of distinctive features adapted to tactile perception. With Tactos we propose to the subjects bimodal signs to facilitate the reading (the axes) and the organization of their perceptive activity (the possibility to create a reference point thanks to an audio marking). In addition, in the context of mathematical learning, the use of sound seems to benefit the reading of alpha-numerical characters.

2.4 Haptic Zoom

In general, a zoom corresponds to a change in the resolution of an object. This can be represented as a window of constant size moving on a vertical axis of scales [4]. If the object becomes small relative to the window, this corresponds to moving away; if the object becomes large relative to the window, this corresponds to a movement towards the object. It is the relation between the size of the image and the size of the window which defines the level of zoom ; this can be expressed by the formula z = I/F, where z is the level of zoom, I the size of the object, and F the size of the window (see Fig. 4).

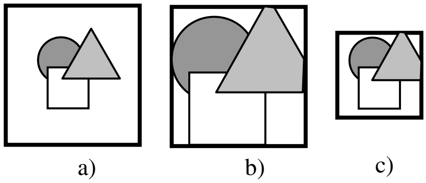

Fig. 4. a) original image b) zoom on the image with a fixed window c) zoom on the window with a fixed image

On the basis of this formula, we can examine the situation when the size of the image remains constant and it is the size of the window which changes. In this case, when the size of the window F increases, the level of zoom decreases; when the size of the window decreases, the level of zoom increases. Technically, this situation is functionally equivalent to the classical situation. Concretely, using the sensory substitution device Tactos, the "window" corresponds to the size of the matrix of receptor fields. The Tactos device makes it possible to explore 2D graphical objects by moving a stylus on a graphic tablet. These displacements of the stylus command the displacement of a matrix (the virtual window) on the computer screen, and which give rise to a tactile stimulus if the receptor field encounters a (virtual) object on the screen. This "window" which moves on the screen can be compared to a virtual screen which moves over fixed numerical objects. By changing the size of this window, we can obtain the resolution and precision required. Thus, the smaller the size of the window/receptor field, the higher the resolution; the larger the size of the window, the lower the resolution and the (virtual) zoom. Technically, this corresponds to a change of scale. To obtain full functional equivalence with the classical form of zoom where it is the size of the object which changes, the movements of the stylus (and hence the movements of the virtual cursor on the computer screen) must be scaled down in strict proportion to the size of the window [14, 15].

2.5 The Eye-Hand System

The eye-hand system [9] proposes a solution to the problem of missing points of reference. This system exploits two types of receptive fields: « The hand » is based on the same principles of haptic compensation and exploration that we used in our other studies previously described. « The eye » is connected to two additional Braille cells (i.e., the system needs four cells altogether). Its receptive field consists of 16 elementary receptive fields and covers the entire monitor. It indicates the absolute position of the cursor by activating one of the 16 pins. Figure 8, illustrates the set up of the eye-hand system.

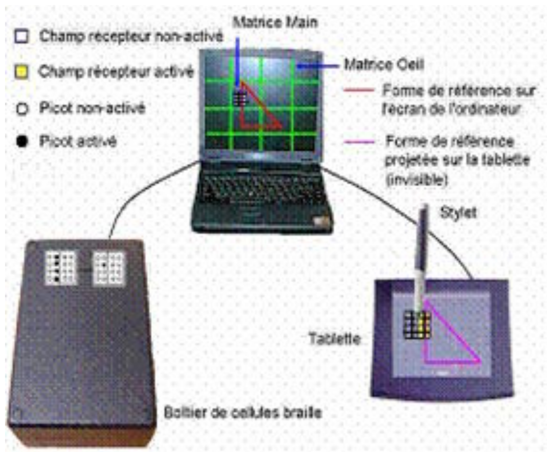

Fig. 5. Eye-hand system

3 Perspectives

In addition to shape recognition and parallelism, others possibilities of the Tactos device were experimented such as the "Tactos network", the "Basic Tactos Task", the Tactos Mobile, etc.

3.1 Tactos Network

If several Tactos devices are networked, a same digital image can be explored by several users situated in different places. A tactile interaction space is therefore created: when, by means of his receptive field, a user meets the receptive field of another user, he receives a signal at the same time as his partner. This can be called a "distal caress" since each person moving his receptive field on the partner's one is touched and touching at the same time. It was demonstrated that the tactile interaction dynamics that arise allow each user to discriminate between the perception of objects and the perception of the other subjects perceiving him simultaneously.

3.2 The Basic Tactos Task

Unlike other tactile and haptic displays, which function in closed virtual world, Tactos allows the exploration of the graphical user interface. The blind users are invited to explore the bi-dimensional space in which the sighted are used to interact. Therefore, Tactos has a twofold advantage over the other haptic devices:

1. It is integrated into a familiar technological context (Braille cells, graphical interfaces and screen readers).
2. It provides access to the graphical objects of the interface.

Further studies will be necessary to establish to which extent the direct manipulation of these objects is useful and efficient for blind users.

3.3 The Tactile Stylus

A first version of the tactile stylus combines the stylus and the Braille box on the same effector (Figure 5). Actually, the fact to dispose of a free hand could allow the subject to receive additional spatial cues. The effector is mounted on a rectangular basis that can be used to trace lines. Comments by the blind subjects and preliminary results [11] led us to conclude that this type of effector is problematic. The stability of this effector helps following lines and gives the subject a good perception of his own movements. However, this effector makes it impossible to rotate the wrist on the horizontal plane and, therefore, restricts the subject in the exploration of curves. We are considering the possibility to integrate the Braille cells directly in a stylus small enough to be used by young blind subjects. Nevertheless, before opting for this effector we need to carry out further experiments with both blind and blindfolded subjects.

Fig. 6. Tactile stylus

3.4 MobiTact: A Mobile Version of Tactos

In order to compensate for the small size of the screen of PDAs, we introduced an additional haptic modality in a mobile haptic prototype, called MobiTact. Our aim is

Fig. 7. TactiPen

to investigate how a user interacts with a mobile haptic interface. MobiTact is a mobile version of Tactos equipped with a "haptic zoom". It consists of an IPAQ PDA running under Linux and using TactiPen [6], a tactile stylus. As shown in Fig. 6, Tactipen has been built using the body of an electronic marker, big enough to contain a single Braille cell (8 points). The electronic marker was emptied of its contents; the PDA stylus, the Braille cell, a micro-controller interfacing the Braille cell and a serial port, were then inserted.

5 Conclusion

As long as one holds fast to a classical conception of perception in terms of the acquisition of information, one will be stuck with the principle that it is always better to have access to more information. In this framework, persons with sensory handicaps will inevitably be considered as defective. We have proposed an alternative conception, in which "sensory substitution systems" are rather thought of as supplementation devices which bring about new modes of coupling with the environment. They do not make a difference disappear; rather, they create new differences – and they have applications which are not exclusively reserved for handicapped persons (for example, artistic applications, games, augmented reality, the development of portable and intuitive systems for the detection of heat, radioactivity....). In spite of appearances, it is the classical perception which carries the germ of exclusion since it considers that the problem of handicapped persons lies in a quantitative difference. By contrast, true respect for the world of handicapped persons lies with better knowledge and understanding of the qualitative difference of possible perceptual modes.

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Elderly and Disabled Travelers Needs in Infomobility Services

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Abstract. Within ASK-IT project, an extensive survey of the needs of elderly and disabled travelers using infomobility services has been performed. More specifically, 39 past and on-going research projects have been reviewed, having a common aim to ASK-IT. The user needs that have emerged after the testing of the developed systems are highlighted in this document for the transport and tourism areas. Results do not refer only to the visual and acoustical HMI of systems and services for information provision while traveling, but also to the content and the design aspects of the HMI, in order to satisfy accessibility.

Keywords: infomobility, needs, elderly, disabled, accessibility, HMI.

1 Introduction

The abundance of advanced solutions and innovative services that exist in the market today in the area of transportation and mobility, promote the mobility of users, as long as they don't have any kind of impairment. Unfortunately, little consideration has been given to the accessibility of these services by people suffering from functional, communication (illiteracy, dyslexia), hearing or visual limitations, which have an imminent negative effect to their mobility, as mobility often depends on the possibility of getting access to information. Information is meant both in terms of planning before travel and orientation during travel.

Earlier studies suggest that blind people, in comparison to sighted people, need more detailed information before travel and have to rely on less perceptual information from the environment during travel [1]. Moreover, users with specific impairments (visual and acoustic) need guidance within buildings, especially when these buildings are big and chaotic.

ASK-IT project, which is co-financed by the European Commission, develops an integrated service delivery system, accessible by people with mobility limitations. This innovative system covers a wide range of services, namely:

- transport: bus routes, bus stops, parking, train/metro/platforms, airports, train stations;
- tourism & leisure: hotels, cultural sites, sport venues;

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- personal support services: public buildings, online assistance;
- education support: accessible libraries;
- social & community building: local user group organisation with website, including local relevant events.

Focusing to the transport and tourism services, the idea is that the user will be able to find information on travel, accessible transport and accommodation, events and sites of interest, and advice on getting there. He/she will have access to relevant and reliable services, that are available on call by him/herself throughout a journey, and to geo-referenced services, that allow to request info and services "nearby". Finally, the user will have the possibility to book and purchase the relevant service in a convenient way and also to use all environmental elements (i.e. terminals, throughout the journey as any other user). It should be underlined here, that the main aim of the above services is to satisfy the needs of the target group, i.e. of people that they are designed for.

Thus, the identification of users infomobility needs was among the first tasks that were realized in ASK-IT, which was based on a review of current and past research projects, existing products and services.

2 Accessibility Aspects

The accessibility issues for the design of the interface of infomobility terminals, that need to take into consideration special needs specifications, refer to the following areas:

- The system interface
- The system's controls
- Pre-trip information
- On-trip information
- Multimodal transport
- Interchange information

The systems' specifications include the accessibility issues, that should be considered to design those interfaces. The most common information systems are listed below:

- Public Interactive terminal
- Electronic bus stop display
- On-board information
- At home/office information
- Enquiry office terminal
- Hand-held terminal

Among the most popular hand-held means for receiving infomobility information are the PDA and smart mobile phones. In order to be able to be used by elderly and disabled travelers, there are certain parameters related to the design of such devices, that should be taken into account. The first one involves the weight of the device, which should not be more that 280g and its edges must be rounded, so that it prolonged use will not discomfort to the user. The overall design of the devices should allow use with one hand. Telephones without flaps are preferable. Finally, the device should be able to lie stable on a table and not roll, rock or slide while dialing (e.g. by using a flat battery and rubber feet) [2].

The buttons and the body of the phone should have big contrast, while raised sections of phone (keypad side) are not recommended, as they can be mistaken for keys. Each key should have minimum area 0.6–0.8 cm^2 and the top should be flat rather that round. The keys should be raised at least 5 mm above the body of the mobile phone. The pressure required to activate a key should be between 0.5N and 0.9N (not being too tight), which is especially important for people with limited power at the upper extremities. A clear indication should be given upon key activation (both tactile and audible in loudspeaker). On/off keys should be clearly separated from other keys. Controls that need to be pushed and rotated at the same time must certainly be avoided. The characters/symbols on the keys and keypad must be easily readable (e.g. using large characters and high contrast between characters / keys). To aid blind and visually disabled people, the <5> dialing key should have a clearly perceptible tactile marking to distinguish it off from the other dialing keys (ETSI Standard ES201381). The appropriate distance between numeric keys is preferred to be between 5.6 - 7.5 mm. A keypad lock preventing the user from inadvertently pressing a key is recommended. The option for audio and tactile feedback for pressing keys should be provided [2].

Some basic functions for the ability to operate the phone are of great importance. For example, hands-free with automatic feedback to the phone/PDA should be available for users with dexterity problems. All functions in the GSM phone should be possible to operate with only one hand by one-handed users or in situations where only one hand is free. A simple and natural dialogue should be designed, with clear instructions to the user, supporting the user's native language. The system should provide feedback (audible, tactile, visible) upon its status and progress/changes. For visually-impaired users, the possibility of audio presentation of SMS is very useful. Error message should offer precise information in a form, which allows the user to identify the problem and solve it [2].

3 Needs Regarding Visual and Acoustic HMI

TELSCAN project has identified certain protocols that should be followed when including elderly and disabled people in the design and evaluation process [3]. Various methods and tools either may not be appropriate for certain people or may require specialised knowledge for their use. The following table provides an overview of developmental needs.

3.1 Visual HMI

According to Deliverable 1.1 of MORE project [2], the display of the mobile device must be fully illuminated, with clear black writing against a white background. A user

Table 1. Overview of existing areas in need of development or new solutions [3]

System function requirements	Interface requirements	Information requirements
– Facilitation of initial contact between assisting-staff and travellers including waiting location of staff and arrival location of travellers. – Improved contact and communication in emergencies. – Contactless smart card with information regarding user requirements. – Improved methods for comparison of trip alternatives with reference to user requirements and price. – Reliable information and information systems.	– Speech recognition, widespread use of speech input – Improved contactless means of payment automated payment – Simple easy-to-use solutions	– Improved multi-modal trip information dissemination – Detailed information with reference to specific user requirements e.g. calm traffic conditions, non-smoking areas, access to special diet foods, luggage assistance, access to inductive loopset for hearing aids etc. – Improved information to traffic operators regarding their passengers' requirements.

must be able to select the colours, brightness and contrast for screen operations. Saturated primary colours should be avoided, as well as red/green and yellow/blue combinations. Control information on screen should be given in different ways (e.g. icons, pull down menus with text). Icons should also have text labels and standardised symbols should be used. The symbols and icons should be kept simple, without too many small details. The characters on the display must be clear, to allow checking that the right keys are pressed (i.e. characters of proper lines and readable type).

The text size is very important (icons size, contrast, etc.). The recommended size is a minimum of 9 mm for text output. Already 16 point bold on screen can be read by many people with visual disabilities. The font size should be selectable. Even word spacing and slightly more open on display than on print is suggested. Normal lower case text is easier to read than text in only capital letters. Combination of lower and upper case type is recommended, while underlining should be avoided.

Finally, as far as accessibility issues are considered, in order to achieve "Usability for all" for mobile phones, since these are the devices targeted to be used for provision of infomobility services nowadays and even more in the future, there are certain issues. Visual indicators could be helpful e.g. on/off light. The choice of language on the display is ideal.

3.2 Acoustic HMI

For hearing impaired people there are problems when receiving the voice signal. An additional 20 dB amplification of the voice signal can be introduced to the acoustic output. It will help people with mild or moderate hearing loss. For people with low speech level an additional amplification of the input signal is needed.

More detailed guidelines for a mobile phone [2] suggest that the audio volume should be adjustable to min. 90 dB SPL, with a clear visual indication of audio volume settings. Furthermore, the operating noise should be below 55 dB (A), warning signal 15 dB above background noise. The signals from the system such as status information and alarms should have adjustable volume, pitch and frequency.

As far as the ringing tone is concerned, it must be clear i.e. it should be loud and it should include low as well as high frequencies. Adjustment of ringing tone should be infinitely variable to min. 70 dB SPL. It would be ideal if the device is able to speak the text of the menu and sub-menus out aloud, e.g. over the earphone, as it would allow blind people to use all its functions. Speech synthesised output could be provided for textual/numeric output for visually-impaired users.

Based on the ARIADNE project [4], the users needs for indoors (i.e. within big private – such as big companies – or public buildings) acoustic messages, in order to minimise their confusion and processing difficulties, suggest that relative directional references should be avoided unless the orientation is clear. Also, messages should not contain more than 3-4 informational elements. It is of great help that different types of verbal information should be presented by different voices. At the device design side, a user-controlled repeat option should be provided, as due to the surrounding noise the user might misses the system message. Lastly, a wearable speaker should be available to maintain privacy and also not to confuse other impaired visitors. At the end, blind users require auditory feedback that they have reached their destination.

The national Finnish project NOPPA had as goal to show that a guidance system for the visually impaired person is possible to build without laborious and expensive changes in the current infrastructure. The user needs and required functionality were studied [5]. Existing systems and previous research project were analyzed to see the reasons why these systems are not in extensively use. Nevertheless, in studies any specific information needs for the visually impaired were not found. Information needed is either available for the sighted, existing but not accessible, or would be useful for all passengers. However, the means for a visually impaired person to reach the information is different. To produce unbroken trip chain for visually impaired, the system has to switch seamlessly between different modes of operation during the trip (home, transport mode, pedestrian mode, station mode, etc.). This requires that system must be context aware to recognise transition points (TP) and change automatically its mode of operation accordingly.

Among the comments received during the project tests was the need for improving the route plan description to create a mental image of the route, which is an interesting subject for future research. A map and a route plan are difficult to describe with words. Big direction arrows showing possibly next turn or two could also be tested for users who have some vision left. The variety of services, although useful for other travelers categories, makes the menus too complex for visually-impaired users.

4 Information Requirements

According to INFOPOLIS project [6], the travel process sequence consists of three time-based contexts, which determine the main tasks of the system and the traveler, leading, after the assessment, to the specific needs for adapted systems. In other words, infomobility systems have to be tested with real users, to extract the specific adaptation needs of various user groups, as users are the best experts for solutions of their problems and, for example, the user interfaces.

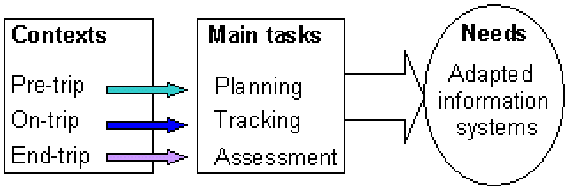

Fig. 1. Travel process sequence, leading to the specific needs for adapted information systems

The detailed type of information, recommended functions and system types are shown in the following table:

Table 2. Trip recommendations in terms of information, functions and system, for the three stages of trip [6]

Pre-trip → Planning	**On-trip → Tracking**	**End-trip → Assessment**
Types of information • trip-planning ticket • ordering/reservation and payment • real time pre-checking info (disturbances, traffic/ weather conditions, etc.)	**Types of information** • localisation and orientation • checking • anticipation	**Types of information** • localisation • orientation
Recommended functions • planning • checking • warning • customising	**Recommended functions** • trip re-conception • signing • overlapping	**Recommended functions** • orienting • signing
Types of system • home terminals	**Types of system** • on-board collective/ individual terminals • portables • public Interactive Terminals • bus stop displays, etc.	**Types of system** • interactive map

Also, according to the TELSCAN project, systems for travelers should include information, which an elderly or disabled person needs, in order to make a journey safely and in comfort. For example, travelers may need to know [7]:

– which buses have a low floor for easier access,
– whether there are reduced fares for people who are retired or disabled,

- how long it will take to walk from one platform to another,
- if there are any stairs to climb.

Using ISO TC204/WG1, "Architecture, Taxonomy and Terminology" Deliverable 3.3 of TELSCAN identified the main system functions where drivers' requirements need to be elicited [7]:

- Pre-trip planning
- Trip Information
- Access to vehicle/service
- Vehicle Control
- Parking
- Dealing with weather and environment
- Emergency warning and driver support
- Ticketing/Payment
- Toll Collection

The Barrier-Free national Japanese project developed a route guidance and wayfinding system, aimed mainly for visually impaired and wheelchair users. Tests that were performed with 16 visually impaired (10 blind and 6 with low vision), 5 hearing impaired, 10 wheelchair users, 10 physically impaired and 5 elderly users, showed [8] that wheelchair users prefer to know the speed of their wheelchair (motored) and the accumulated distance traveled (motored). Also an important comment was that it is useful that the guidance message is received 3 or 4 meters before the turning /destination point. But the information at 20 meters ahead to the points is not required every time.

5 Conclusion

According to INTERNET national UK project [9], social exclusion and the lack, or denial, of access to adequate physical mobility, either by private or public transport, are inextricably linked. The link between social exclusion and exclusion from mobility is two fold:

- Social exclusion can result in lack of access to adequate mobility;
- Lack of access to adequate mobility can result in social exclusion.

Well designed and accessible ICT products, services and applications can open up many new opportunities for participation for people who have restricted mobility, following simply the design-for-all concept. Those people need support both in the pre-trip and on-trip phase of their trip. They need accurate and up-to-date planning information (e.g. current bus timetables, disruptions on route) and better information regarding waiting time at bus/tram stops and train/metro stations - to plan better and to avoid long waiting times.

Specifically designed ICT-based assistive technologies can be of great benefit to older people who are increasingly at risk of having functional difficulties in areas such as mobility, vision, hearing and in some aspects of cognitive performance.

As the needs and capabilities of different users categories vary a lot, each user would benefit most by a system satisfying his/her own requirements and preferences. Thus, a personal needs-oriented approach for (ICT supported) service development is the key for optimal infomobility services for elderly and disabled travellers in the future.

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Aging Well: The Use of Assistive Technology to Enhance the Lives of Elders

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Abstract. Eighty percent of seniors have some type of functional impairment that impacts one or more activities of daily living. This paper focuses on the use of assistive technology devices to support elders with successful aging. A variety of assistive technology devices and their utilization by elders are explored.

Keywords: aging, disability, assistive technology.

1 Introduction

Successful aging has been defined as living on your own terms, adding value to society, family, or friends, maintaining cognitive function, maximizing mobility, retaining function, and reducing the impact of chronic disease/dysfunction [1]. Assistive technology (AT) devices have the capacity to facilitate successful aging; however negative stereotypes and myths surround the acquisition and use of technology by elders. One of the most prevailing myths is that seniors struggle with both technology and change. However, a review of the past hundred years tells us a different story.

Between 1900 and 1910, centenarian's witnessed the first airplane flight, the first Model T car, air conditioning and live radio broadcasts. By the 1920's, the world was experiencing rockets, frozen food and television. The defibrillator was launched in the early 1930's, along with nylon and digital computing. In the 1940's the first jeep was invented, atomic reaction and the atomic bomb, Polaroid camera and the electric guitar. By the 1950's, we were experiencing the heart-lung machine, a cure for polio, and nuclear submarines. By the 60's, men were landing on the moon, the laser; operating systems for the computer and the mini computer were available. In the 1970's we saw optical fibers, Microsoft, video games, bar codes, the Super Computer and human powered flight. In the 80's we experienced the space shuttle, the artificial heart, the personal computer (pc) and genetic engineering. During the 90's we launched the Hubble Telescope. In other words, today's elders have experienced the launch of modern technology, the exponential change and growth of their environment and were in fact, the very architects and change agents who created these fantastic opportunities in our world.

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Population aging is more advanced in the most highly developed countries. Among countries classified by the United Nations as more developed (with a population of 1.2 billion in 2005), the median age of the population rose from 29.0 in 1950 to 37.3 in 2000, and is forecast to rise to 45.5 by 2050 The corresponding figures for the world as a whole are 23.9 for 1950, 26.8 for 2000, and 37.8 for 2050. In Japan, one of the fastest aging countries in the world, in 1950 there were 9.3 people under 20 for every person over 65. By 2025, this ratio is forecast to be 0.59 people under 20 for every person older than 65 [2]. So what does that mean in relationship to the use of assistive technology devices and services?

2 Aging, Disability and Assistive Technology

Eighty percent of seniors have some type of functional impairment that impacts one or more activities of daily living. Examples might include reaching, grasping, seeing, hearing, taste, etc.

2.1 Vision

Even though changes to the eye take place as a person ages, many older people have good-to-adequate vision. Nevertheless, beginning in the late 30s and early 40s, an individual may begin to notice some changes. The flexibility of the eye decreases and it takes an older person more time to accommodate to changes in light. The most functionally important changes seem to be a reduction in pupil size and the loss of accommodation or focusing capability. The area of the pupil governs the amount of light that can reach the retina. The extent to which the pupil dilates also decreases with age. Adaptations in lifestyle and behaviors must be made to cope with this change. An individual might give up driving at night. Placing more lights evenly around the room so that the entire room is lit is also helpful.

Degeneration of eye muscles and clouding of the lens are associated with aging. Several changes in vision result from this. Older people tend to have trouble focusing on near objects, but eyeglasses may correct this problem. In addition, the ability to see colors changes with age as the lens yellows. Red, yellow, and orange are easier to see than blue and green. This is why fabrics in warmer shades may be more appealing to the older person. Serious vision impairments such as cataracts, glaucoma, and blindness affect between 7% and 15% of older adults. If someone you know must learn to cope with blindness or near blindness, you can play a critical role in helping them maintain their independence [3, 4].

There is a wide range of AT devices and strategies to help elders (and others) with visual impairments perform daily activities such as reading, writing, personal care, mobility and recreational activities. Among low-tech solutions are simple handheld magnifiers, the use of large print, or mobility devices (e.g., a white cane) for safe and efficient travel. High-contrast tape or markers can also be used to indicate hazards, what an item is, or where it is located.

Other low-tech solutions include items such as using wind chimes to help with direction-finding, using easily legible type fonts such as Verdana (16pt or larger) and using beige-colored paper rather than white to improve the visibility of text. In recreational activities solutions include beeper balls, three-dimensional puzzles and outdoor trails with signage called “Braille Trails” designed to improve access to wilderness and other outdoor activities.

Brailed text, though less used than in years past due to the advances of computer and other technologies, is still the first choice of many individuals for reading. Many restaurants now provide large-print, Braille and picture-based menus for customers with a variety of abilities.

Books-on-tape are another resource for individuals with severe visual impairments. In addition to commercially available tapes for sale and at public libraries, special libraries provide print materials in alternate formats for persons with visual, physical and learning impairments. Borrowers can arrange to have textbooks and other materials translated into alternate formats. For more information, contact the American Federation for the Blind or theNational Library Service for the Blind and Physically Handicapped (http://www.loc.gov/nls/)

Numerous high-tech solutions exist for persons with visual impairments. Computers outfitted with a speech synthesizer and specialized software such as Jaws™ or WindowEyes™ allows navigation of the desktop, operating system, applications and documents as well as the entire Internet. Any digital text can be heard aloud by the person using this software. For text that is printed such as menus, memos, letters, etc. using a technology called optical character recognition (OCR) allows a page scanner and software to convert print into digital form where it can then be listened to through the computer’s speech synthesizer or converted to Braille or large print.

Another category of high tech aids are portable note takers with either Braille or speech synthesizer feedback for the user. These devices are specialized personal digital assistants (PDAs) with calendars, contacts, memo and document capabilities and can be purchased with either a QWERTY or Braille keyboard.

For individuals with some degree of visual ability, screen magnification software such as Zoomtext™ and MAGic™ enable the user to choose the amount (2 xs to 20 xs) and type of magnification preferred for optimal computer access. Many magnification applications combine enlargement with speech synthesis or text-to-speech. A recent addition to the list of screen magnification software is called Bigshot™. This software is less expensive ($99) and provides fewer features that some other programs. However, it appears to be an alternative for users who do not need access to the more sophisticated computer functions, and it and is highly affordable.

2.2 Mobility

Impaired balance and gait are the two most significant risk factors for limited mobility and falls in the elderly [5]. Mobility impairments caused by disorders such as osteoarthritis might keep an elder from actively participating in social groups with their peers, playing with grandchildren or taking care of routine household tasks. Fear of traversing unknown or uneven terrain often keeps elders at home rather than out in the community.

Upper body impairments that impact reaching, grasping, and carrying objects can interfere with everyday activities such as bathing, dressing, cooking and hobbies.

Elders can become frustrated, depressed and severely isolated by these types of disabilities. Given the importance of computer use in today's world, many AT devices have been developed to give individuals with upper-body mobility impairment such as poor hand control or paralysis access to computers. But, what if someone is unable to use a standard mouse and keyboard?

Alternate computer keyboards come in many shapes and sizes. There are expanded keyboards such as the Intellikeys™, which provides a larger target or key surrounded by inactive space than a standard keyboard. Options such as delayed activation response help individuals who have difficulty with pointing accuracy or removing a finger after activating a key. Individuals unfamiliar with a standard QWERTY keyboard layout, have the option for alphabetical layout. This is often helpful for elders who have never learned to type.

There are also smaller keyboards (e.g., Tash Mini Keyboard™) designed for persons with limited range of motion and endurance. They are also helpful for individuals who type with one-hand, or use a head pointer or mouth stick to type. These keyboards use a "frequency of occurrence" layout. The home or middle row in the center of the keyboard holds the space bar and the letters in English words that occur most frequently, (e.g., "a" and "e"). All other characters, numbers and functions (including mouse control) fan out from the center of the keyboard based on how frequently they are used in common computer tasks.

Voice recognition (VR) is a mass-market technology that has become essential for computer access for many persons with motor impairment. Instead of writing via the keyboard, VR users write or speak words out loud. The computer processor uses information from the user's individual voice file, compares it with digital models of words and phrases and produces computer text. If the words are accurate the user proceeds, if not, the user corrects the words to match what was said. As the process continues, the computer updates its voice file and VR accuracy improves. This software is cognitively demanding yet can offer "hands free" or greatly reduced keyboarding to many individuals with motor impairment.

Another group of computer input methods include devices that rely on an onscreen keyboard visible on the computer monitor such as the Head Mouse™ and Tracker 2000™. The user wears a head-mounted signaling device or a reflective dot on the forehead to select keys on the onscreen keyboard, choose commands from pull down menus, or direct mouse movement. On-screen keyboards are typically paired with rate enhancement options like word prediction or abbreviation expansion to increase a user's word per minute rate. Because so many tasks can be accomplished through computers, elders with disabilities – even those with the most severe motor impairments – can fully participate in everyday activities.

2.2.1 Lower-Body Mobility Devices

AT solutions for individuals with lower body mobility impairments may include crutches, a rolling walker, a powered scooter or a manual or powered wheelchair. Simple environmental modifications or adaptations such as installing a ramp instead of stairs, raising the height of a desk or widening doorways can be critical facilitators for these individuals and may be all that is needed. For other activities or to increase participation, adding automobile hand controls, adapted saddles for horseback riding or sit-down forms of downhill skiing are possible.

There are literally thousands of low-tech assistive devices available for persons with motor impairments. Commonly referred to as aids or adaptive devices for completing Activities of Daily Living (ADLs), these devices include weighted spoons and scoop plates to facilitate eating; aids for personal hygiene such as bath chairs and long-handled hairbrushes; items for dressing such as sock aides and one-handed buttoners; adapted toys for play; built-up pencil grips for writing and drawing; and many others. Many low-tech mobility aids can be handmade for just a few dollars, while others, such as an adult rolling bath chair, may cost several hundred dollars. All share the common goal of reducing barriers and increasing participation in daily life.

2.3 Memory Loss

One of the key concerns of older adults is the experience of memory loss, especially because it is one of the most clearly recognized symptoms of Alzheimer's disease. However, memory loss is qualitatively different in normal aging from memory loss associated with of Alzheimer's disease [2] and not all memory loss can be attributed to a disease process. Recent research has identified mild cognitive impairment (MCI) as a transitional state between the cognitive changes of normal aging and Alzheimer's Disease (AD). Many elders experiencing mild cognitive impairment have a much higher risk of developing Alzheimer's disease. Studies indicated that MCI individuals are at an increased risk for developing AD, ranging from 1% to 25% per year; 24% of MCI patients progressed to AD in 2 years and 20% more over 3 years, whereas a recent study indicated that the progression of MCI subjects was 55% in 4.5 years [6, 7].

Most elders experiencing cognitive decline such as memory loss have not had the benefit of using AT devices because relatively few products have been specifically developed for persons with memory impairments. In addition, caregivers, allied health professionals, and others providing support services for elders with cognitive impairments have generally not been aware of its usefulness. Most have looked to simple solutions for persons with cognitive impairments using strategies like colored highlighter tape, pencil grips, enlarged text, reminder lists, and calendars. Others try low tech adaptations like using a copyholder to hold print materials for easy viewing and making cardboard windows to help eyes follow text when reading.

Recent mainstream technology developments include handheld Personal Digital Assistants or PDAs. Assistive technology software developers (AbleLink Technologies, Inc.) have used this technology and developed software applications (PocketCoach™) that provide auditory prompts for individuals with cognitive disabilities. This software can be set-up to prompt an individual through each step of a task as simple as mopping a floor, up to the complexity of solving a math problem. The latest version of this software combines both voice prompts with visual prompts (Visual Assistant™). The individual setting up the system for a user can simply take a digital picture with the accompanying camera and combine them with digitally recorded voice prompts to further facilitate memory and cognition.

The U.S. Department of Education, National Institute on Disability Research and Rehabilitation (NIDRR) recognizing the need to increase assistive technology development for persons with cognitive disabilities, funded a Rehabilitation Engineering Research Center for the Advancement of Cognitive Disabilities (www.rerc-act) in 2004. Located at the University of Colorado Heath Sciences

Center, this RERC-ACT is focusing on developing a wide range of assistive technologies focused on developing vocational and literacy skills, service provision and enhanced caregiving supports for persons with significant cognitive impairments. This new field of ‘cognitive technologies’ promises numerous advances during the next decade.

2.4 Hearing

About 33% of those between the ages of 75 and 84 have a hearing loss and about half of those over 85 have a hearing loss. Hearing loss affects the older person's ability to talk easily with others. For example, they often have trouble hearing higher pitched tones. They also may not be able to make out sounds or words when there is background noise. Elders may be frustrated or embarrassed about not being able to understand what is being said. As a result, the older person may withdraw from friends and family and outside activities [8].

Individuals who are deaf or hard of hearing deal with two major issues: lack of auditory input and compromised ability to monitor speech output and environmental sound. Assistive technology devices such as hearing aids and FM (frequency modulation or radio wave) systems can be used to facilitate both auditory input and speech output. Other types of AT devices provide a visual representation of the auditory signal. These include flashing lights as an alternate emergency alarm (e.g., for fire or tornado) or the ring of a phone or doorbell.

Another recent adaptation for persons with significant hearing impairments is computer-assisted real-time translation or CART. This AT solution involves a specially trained typist or stenographer who captures what is being spoken on a computer. The text is then is projected onto a display, resulting in close to ‘real-time’ translation. The advantage of this technology is that is can be used by hearing impaired individuals who are not fluent in sign language as well as others who may need listening help such as those who use English as a second language. In addition to use in group environments like conferences or meetings, a variation of this technology can be used to assist a single student or employee in a small setting.

For individuals who wear hearing aids, there are additional technologies that can facilitate hearing in large rooms or in noisy, crowded environments such as a restaurant. The Conference Mate™ and Whisper Voice™ are especially designed for these environments. In the case of the Conference Mate™, the person with the hearing loss wears a “neck-loop” which acts as an antenna and is capable of broadcasting directly to a hearing aid a microphone placed near the speaker, transmits directly to the neck loop eliminating background sound. This is also an excellent solution for office and school environments. The Whisper Voice™ is similar, except it uses a smaller microphone and is more portable. It can be passed from speaker to speaker with sound transmitted to the neck loop and then onto the hearing aid for amplification.

Environmental adaptations can frequently support individuals who are deaf or hard of hearing. For example, a person speaking to someone who has difficulty hearing can take care not to stand in front of a light source (windows, lamps, etc.) and not to over-exaggerate or hide lip movements. In addition, gestures may be helpful.

The world of AT is moving at a very rapid pace fed in large part by the growth in mainstream technologies and the culture of inclusion that is changing traditional concepts about disability and impairment. Space travel, satellite supported telecommunications, wireless networks, new materials with advanced performance properties, miniaturization of integrated circuits and innovation in batteries and power sources are all crossing over into the field of AT. In the United States, Federal funding supports Rehabilitation and Engineering Research Centers for the development and testing of new assistive technology concepts. Funds also support the transfer of technologies from the Federal laboratory system to assistive technology manufacturers. The convergence of these factors is leading to AT products more likely to meet the needs of persons with disabilities, including the elderly.

We know that seniors have unique needs that must be addressed to enable adoption of new and existing technologies. We also know that benefits of technologies for seniors include:

1. connecting isolated seniors to the world around them;
2. easier access to health and care information;
3. providing access to entertainment, recreation and social interaction;
4. enables elders to continue to contribute to society through personal web-sites, email, chat rooms, etc.; and,
5. makes lifelong learning (and teaching) possible through distance education.

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Senior Surfers 2.0: A Re-examination of the Older Web User and the Dynamic Web

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Abstract. Though the Web and those who use it have changed considerably in the last decade, a digital divide between older and younger users persists. Older users still use the Web less than younger users, and more commonly experience significant usability issues when they do. With the emergence of Web 2.0 technologies, we have the ability to close that divide and ensure the Web is universally usable for people of all ages. It requires taking what we know of "senior surfer" requirements and applying them to Web 2.0 interfaces. This paper examines the changing nature of the Web, the Senior Web user, and assesses how Web 2.0 technologies can – but do not yet - improve universal access for everyone. Pilot studies support these hypotheses; future studies are planned to further examine these issues.

Keywords: Older users, seniors, Web 2.0, Rich Internet Applications, usability, accessibility, AJAX, Flex, Flash, DHTML, Web design.

1 Introduction

The Web is becoming both increasingly ubiquitous and dynamic. Web 2.0 offers more interactivity, faster feedback, pageless designs, in-context controls, personalization, and access to social networks. While these new aspects could help narrow the digital divide between younger and older Web users, they have not yet done so. Younger generations have integrated the Web into the fabric of every day life, but older generations are not leveraging the Web's full potential as often or as easily.

According to a Pew Internet and Family Life project report [5], 28% of Americans age 70 and older go online – essentially unchanged from the previous year. Yet access to the internet is commonplace for most other age groups; 89% of 18-28 year-olds, 86% of 29-40 year-olds, 78% of 41-50 year-olds, and 72% of 51-59 year-olds going online. Even 54% of users 60-69 year olds go online.

Though many companies are considering giving their sites a Web 2.0 makeover, older users are far less likely than their younger counterparts to engage in the types of activities typically associated with Web 2.0 in interfaces, including blogs, videos, and

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music downloads [6]. Furthermore, they are much less likely to have high-speed connections [5], which are often required to optimally run rich internet applications. For this reason, companies need to strongly consider how Web 2.0 designs will work for older users. Additionally, as the baby boomers begin joining this "older demographic," companies should begin re-examining their ideas of the older user to better understand the growing diversity within this demographic.

2 The Web - 1.0 to 2.0

The Internet started as four interconnected computers in 1969 as a means to allow researchers to share information [11]. It has transformed into a universal information-sharing medium that allows people to share and access information world wide. As it becomes more pervasive, questions regarding universal access and issues related to digital divides arise.

While some argue the validity of the term "Web 2.0," for purposes of this paper we use it to describe the changes that have occurred in Web design in the last decade, which are manifest in the comparison between Yahoo! in 1997 and 2007.

Table 1. A Comparison of Yahoo! In 1997 and 2007

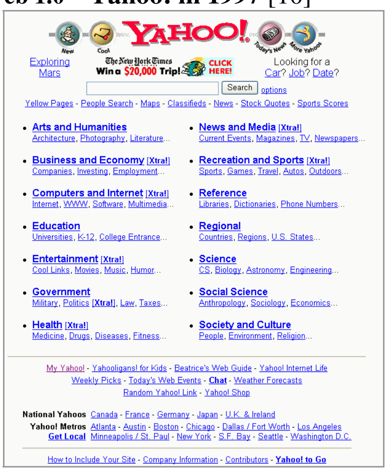
Web 1.0 – Yahoo! in 1997 [10]	**Web 2.0 - Yahoo! in 2007**
	
• Static links	• Fewer links, more actionable elements (sliders, tabs, menus)
• Paging as a means of navigation (backward and forward)	• Pageless navigation (including tabs, expand/collapse, drop-down, widgets)
• Users passively consuming content	• Users creating, refining, sharing and consuming content
• Users customize interface	• Interface dynamically responds to user actions
• Fixed-width designs	• Fluid designs

Table 1. (*Continued*)

Web 1.0 – Yahoo! in 1997 [10]	**Web 2.0 - Yahoo! in 2007**
• Multimedia as "add on" versus integrated into interface	• Multimedia is inherent in the interface
• Information is buried deep into Information Architecture (IA) – requires drill down into site for real content.	• More content is on the home page and exposed by a variety of user actions and settings
• Mainly HTML	• Hybridization of technologies (AJAX, Flex, Flash, etc.)
• Is primarily a solitary experience	• Is a community experience

Web 1.0 provides more linear, paging through related content: link to link and page to page. Though several paths to any destination may exist, those paths are hard-coded requiring users to "guess" the paths provided by the information architect. However, as with many innovations, the Web's original purpose evolved into something else entirely. It became a virtual place of communication, business, expression, information sharing, and social networking.

Web 2.0 is a user experience driven mainly by an "anytime, anywhere" user interaction model where the user dictates how and when he or she can perform actions. Most actions can be done from any page on a site. Paths are dynamically defined by users. The concept of paging is minimized. The interface is inherently multimedia, proactively adapts to the user's actions and preferences, and has become a space defined by community.

In 1997 Yahoo's home page consisted most of links to other pages and minimal customization, even though it was an industry leader in supporting user customization. In 2007, much more content can be displayed selectively as users interact with the screen (mouseover, click, expand, etc.). The page opens with animation and multimedia and enables users to build content and choose UI preferences.

Just as the Web has evolved in the last 10 years, so should the persona/s designed to capture the requirements of the senior surfer.

3 Senior Surfers

The term "senior surfer" has been associated with various age groups including 60+, 65+, and 70+. Ultimately, the term is meant to define how those with physical and cognitive limitations associated with aging fare on the Web. But it's not just age that shapes their requirements and expectations; it's their experiences with technology and the world in general that factor into the design considerations for this demographic.

The first version of the senior surfer concept revolved around older adults with very little exposure to the Web in the workplace. Most had retired before the Web became commonplace, and though often well-educated, lacked computer literacy (e.g. metaphor of desktop, window, file attachment, recognizing and clicking on links, mouse cursor/pointer movement, etc). In focus groups conducted with senior customers, they reported being motivated to use the Web by a need to keep up (with family, hobbies, finances, adult education courses) and/or that their children encouraged them. However, our studies also show that what this group lacked in technical expertise, they often made up for in terms of financial expertise.

We can characterize the Web navigation style of this group as “Deferential.” They dutifully read content provided on pages, exhibited cautiousness when clicking buttons or links, and lacked confidence in their ability to recover from navigating down the wrong path. Overall, they lacked a basic framework in which to fit new lessons about the Web and how best to navigate it, and tended to blame themselves for any issues they experienced online. This made achieving Web literacy difficult.

The baby boomers, however, pride themselves on rejecting these (and other) trends [8]. As they begin to join the retired “senior surfers,” they are redefining this term. At minimum, their sheer numbers will make this group more diverse. They also have different outlooks on aging, technology, and life in general. They do not see themselves as “old”, they love technology, and are happy to try (and demand) new things [9]. The Pew Internet and Family Life group first termed this group as the “silver tsunami” who are more wired and technologically savvy than their older predecessors [7]. This group could be broadly categorized as “Adventurous”. They are more willing to experiment, have a high threshold for frustration, tend to not blame themselves for any gaps in their knowledge, and are motivated by the potential the Web represents and see its exploration as an opportunity to try something new.

With age-related visual, auditory, motor, and cognitive decline remaining constant but the Web and the experience of the older user changing over time, can we apply the heuristics we developed for the first wave of senior surfers on Web 1.0 to improve the experience of the second wave of senior surfers in Web 2.0 designs?

4 Web 1.0 for Senior Surfers

In the last 5 years, we have had over 200 older (65+) adults visit our User Experience labs to participate in a variety of research studies related to web design, usability, and accessibility. Based on these research studies [1] [2] [3], we have defined a set of empirically-based Web design guidelines for older users that we use internally to help shape designs targeted for the older demographic.

1. **Make Text Scalable** –
   - Let users increase text size using the browser’s “text size” controls for a page and/or on-screen controls.
   - If the site is targeted *primarily* for seniors, use a larger default font size (e.g., 14 pt).
   - Minimize the use of graphics for text since they will not scale
2. **Use High Contrast Text** –
   - Contrast between text and background color is a key determinant in legibility.
   - Strive to keep the difference in “gray values” between the text and background greater than 66%; do not allow the difference below 33%.
   - Consider providing a high-contrast option for page designs.

3. **Make Links Visually Obvious** –
   - Older adults have a hard time determining what is a link and what isn't.
   - Be consistent in visual treatment of text links throughout the site.
   - Text links should dynamically change in appearance on mouseover (e.g., turn red).
4. **Make It Clear What Links Do** –
   - Older adults are reluctant to click unless they are very confident about what will happen.
   - Use clear descriptors for links. Include action words (e.g., "View Accounts" instead of "Accounts").
   - Consider including a tool-tip-style pop-up (title attribute on a text link) with a longer description of what the link does if the user pauses over the link.
5. **Simplify Terminology** –
   - Many older adults do not understand web "jargon".
   - Avoid the use of technical terms or other jargon (e.g., Login, Home, URL, etc).
   - When such terms are necessary, define them with an easily accessible glossary
6. **Streamline Pages** –
   - Older adults are more easily overwhelmed by large amounts of content on a page; they read more.
   - Streamline pages, being clear and concise in all writing. Limit the number of points or topics/page.
7. **Make Click Targets Larger** –
   - Arthritis and other conditions can make clicking on small links, buttons, or graphics difficult.
   - Make all "click targets" relatively large and separate from each other. Remember that text links will scale with the text size, but graphical links and buttons will not.
   - When using a graphic as a link, provide a nearby text link to the same place when possible.
8. **Consider Providing Audio** –
   - Many older adults, particularly those with significant vision problems, find it easier to listen to audio versions of pages.
   - Consider providing an option for listening to a spoken version of a page or key page components. This might be done via pre-recorded speech or high-quality text-to-speech.
9. **Provide Memory Aids** –
   - Short-term memory capabilities tend to decline with age.
   - Consider providing "memory aids" in the site that help the user get to the pages they need.
   - Amazon's list of products a user has recently viewed is a good example.
   - Make sure a site map and a good site search is provided (with good recognition of synonyms and common misspellings).

10. **Provide Clear Instructions –**
    - Older users read and benefit from clear instructions, unlike many younger users who tend to skip right over instructional text.
    - Provide clear, step-by-step instructions, especially for complex or multi-step processes.
    - Break multi-step processes into smaller logical chunks.

We are now trying to determine how applicable these heuristics are to the Web as it evolves.

5 Web 2.0 Design for Senior Surfers

The baby boom represents over $8.5 trillion in investable assets [4]. Unsurprisingly, in the last 5 years, many companies have spent considerable time and money attempting to understand their requirements. Accordingly, we have gained good understanding of their requirements of traditional Web 1.0 interfaces. But how adequate are these heuristics when applied to Web 2.0 designs?

Table 2. Our Web 1.0 Design Requirements for Seniors and Web 2.0 Feasibility and Challenges

Web 1.0 Guideline	Web 2.0 Feasibility	Web 2.0 Challenges/Issues
1. Make Text Scalable	• Is richly supported in vector-based development platforms, like Flash/Flex. It can also be supported through CSS and user customization.	• While easy to support, this is seldom done. How such features can be used and supporting large font sizes while keeping the UI intact remains a challenge.
2. Use High Contrast Text	• Color/Style manipulation is easy to support using either via CSS (AJAX) or Flash/Flex.	• While easy to support – at least for some aspects of the UI - communicating how such features can be used can be challenging. Also, it is labor-intensive to “reverse contrast” image-based components.
3. Make Links Visually Obvious	• Easy to ensure that links and other actionable elements have consistent UI.	• While links exist, they are not standardized in their appearance or behaviors. Additional challenges include the variety of user interaction options (onmouseover, onclick, dragging) and widgets (tabs, menus, expand/collapse) that are non-standard across sites (and sometimes within sites).

Table 2. (*Continued*)

Web 1.0 Guideline	Web 2.0 Feasibility	Web 2.0 Challenges/Issues
4. Make It Clear What Links Do	• Easy to accomplish but seldom done.	• There is much inconsistency in how links and other elements look and act. Older users often have no idea what is actionable on a page.
5. Simplify Terminology	• Easy to support but often overlooked.	• New functionality (tagging, dragging, zooming, etc.) introduces more technical terminology that is often not understood (or explained).
6. Streamline Pages	• Pageless design is a primary feature of rich internet applications.	• Offers real advantage potentially but non-standard widgets and interaction still present challenges.
7. Make Click Targets Larger	• Easy to support, particularly when targets are image-based rather than text-based.	• Many widgets have small controls (arrows, +/-, etc.) that are often very difficult to see and with which to interact.
8. Consider Providing Audio	• Flash and Flex offer easy integration of audio components.	• Alerting users that audio is available and how to use it can be challenging. Supporting those who cannot hear either through disability or technology limitations (no speakers) is an issue.
9. Provide Memory Aids	• The dynamic nature of the page supports inherent history tracking (i.e. recently viewed items) and memory aids.	• Providing aids that do not add to the cognitive overload issues on the page.
10. Provide Clear Instructions	• Could easily support layering of interfaces and various complexity levels (i.e. help mode).	• Supporting both the novice and expert user without overloading content on the page.

While Web 2.0 technologies have potential advantages built-in to support flexible, adaptable interfaces, few Web designers and developers create designs that incorporate these features while supporting the requirements of older users. More consideration must be given to design for users of all abilities, embracing the concept of universal usability.

6 Pilot Study and Future Work

To understand more about how senior surfers interact with Web 2.0 designs, we have conducted pilot sessions with 5 older users (age 65+). Participants were asked to perform tasks on interfaces built with Flash, Flex, and AJAX and provide feedback.

Preliminary results indicate that while Web 2.0 designs *could* easily offer usable, interactive experiences for senior surfers, they seldom do. Today's senior surfers often are unaware of which elements on a screen are interactive and miss dynamic changes to the screen. When prompted on how to use various elements, users often do see their value. In general, most report that they would not easily recognize or explore such features on their own. Other issues include:

- Web 2.0 applications are not so dynamic over dial-up. One maps site took 3 minutes to load, and each time users tried to map a new area, the screen lagged significantly before repainting causing users frustration.
- The indicators shadowing the mouse cursor indicating that data was loading signaling were overlooked or misunderstood by users.
- Some users were concerned upon seeing the initial "Loading indicator" that visiting the 2.0 application was downloading software to their hard drive.
- Users often overlooked areas of the page that were interactive. They had trouble grasping what and how to interact with UI elements (determining what was clickable, draggable, or what got revealed onmouseover).
- Terminology specific to the type of data 2.0 applications provide was often unfamiliar. Examples included "zoom bar", "live traffic", "tagging" or rating something.
- Users wanted Help and tutorial content but had difficulty finding them. Once they did find this content, it was helpful and engaging. Demos were sometimes too fast-paced and difficult to follow. One user said he wanted to be able to control the pace.

We are planning a study to learn how Web 2.0 interfaces impact the experience of older users. We will collect both subjective and performance data. The goal will be to understand how effective our Web 1.0 guidelines are in accommodating the needs of older users in Web 2.0 interfaces, and the extent to which additional guidelines are required to address specific nature of user interface issues in 2.0. This new group of guidelines we hope will better enable us to leverage the potential of Web 2.0 and begin closing the digital divide between younger and older Web users.

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Older People as Information Seekers: Exploratory Studies About Their Needs and Strategies

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Abstract. In two studies, we investigated the influences of some individual variables that are related to information search strategies and information access in general for old end-users, and we investigated experimentally the influences of metamemory on their performances and strategies. The first study investigated the Internet access, interests, and information search from the Internet among seniors, by using interviews with a semi-directed questionnaire performed with 47 old end-users (ages from 68 to 73 years). The second study investigated the impacts of a specific cognitive ability, i.e., metamemory abilities, on the information search activities performed by 50 old end-users. Results have shown that the World Wide Web emerged as a major information resource for them, their opinions are modulated by Web experience, locating relevant information among information provided by the search engines emerged as a major problem for the old end-users, and metamemory abilities do not seem to be implicated in the computerized information search activities: No significant result was obtained in the experiment conducted in the second study. Additional research with old end-users is needed to determine the generalisability of the results obtained in our two studies.

Keywords: Information search, Senior, Older people, Metamemory, Cognitive dimension.

1 Introduction

By the year 2030, 21,1% of the world population would be comprised of senior citizens [1]. In this new millennium, individuals aged 60 years and older constitute one of the fastest growing age groups [2]. So, the populations of the developed countries are becoming older while computer use is increasingly affecting wide aspects of life. Thus it is increasingly important to understand specific information needs and strategies used by old end-users to search for information at computer.

First, several studies, exploring computer use among the older adults indicate that the older the individual, the less computer knowledge and interest they are likely to have [3] [4] [5] [6] [7].

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Second, much research supports the idea that various cognitive abilities decline with age after about 40 [8] [9] [10]. Among the cognitive abilities which have been found to decline in older people are as follows: language processing; processes related to the attention, working memory, discourse comprehension, inference formation; interpretation, encoding, and retrieval processes in memory and information processing speed; spatial ability and perceptual speed.

In two studies presented here, we investigated the influences of some individual variables that are related to information search strategies and information access in general and we investigated experimentally the influences of metamemory on performances and strategies.

1.1 Context

An increasing number of older people will need to use computers and computer related systems in the future to avoid social exclusion and so as o be able to live more independently.

There are considerable social and economic reasons why interface designers should rise to the challenge of designing interfaces which are usable by older people [10]. For instance, the number of seniors is growing more quickly than that of all the other segments of the population. This will impact on the cost of social care unless technological solutions can be found to enable people to stay longer in their homes. Designers of interactive electronic products must take into account the special needs of such a significant population who often find current products difficult and complicated to use. Failure to do so will result in this large and growing group of citizens becoming marginalised through lack of access to information and services and also excluded from the use of interactive electronic products such as stair lifts and alarm systems that could help them to live longer in an independent way. As [10] said, even if there is also legislative pressure for the development of systems that are accessible to older and disabled people, unfortunately, the industry sector has not yet recognized the significant benefits of more accessible design most providers continue to produce products that are primarily aimed at younger people.

An important aspect of the older adult population is the proportion having some type of disability. Chronic disabilities include arthritis, hearing impairments, cataracts, hypertension, heart diseases, and diabetes, among others. Unlike younger adult users, there are physiological factors due to the normal aging process affecting older adults' use of the Internet. The normal aging process, including vision, cognition and physical impairments, has an impact on Internet usability. In other words, as adults are aging, their vision, cognition, and physical skills are declining with an important impact on their ability in performing many tasks such as the information search on the Web. Unfortunately, little attention has been paid to the understanding of the impacts of these cognitive and metacognitive impairments on the information search activity performed through a digital environment.

1.2 Metamemory, Aging and Information Search

Metamemory is defined as knowledge of one's memory abilities and functioning [11]. Two levels of metamemory can be identified [12]: monitoring concerns knowledge of the information being processed while control concerns knowledge of the strategies that enable to improve information processing. However, these two levels are strongly dependent on one another.

Poor metamemory appears to be a characteristic of older persons [13] [14]. Some studies have suggested that an older person's metamemory is mostly accurate, whereas others have demonstrated little relationship between memory complaint and impairment. For instance, in the study performed by [14], researchers examined memory complaint in a large national sample of 5 444 older people aged ≥70, by using a longitudinal cohort study with two waves of data collection spaced 2 years apart. Participants were asked if they believed their memory was excellent, very good, good, fair, or poor. They were then administered a cognitive assessment. Results have shown that if people's assessment of their memory matched their actual performance on cognitive measures in general, large portions of the sample inaccurately assessed their memory skills. In other words, poor metamemory appears to be a characteristic of older persons.

Nevertheless, little attention has been paid to the investigation of the searching strategies used by elderly people when looking for information. Nevertheless, some studies have shown that an older adult's performance on working memory tasks decline with age, s/he has a reduced ability to discern details in the presence of distracting information, and s/he has difficulties to search for information accurately and quickly (for a synthesis, see [15]).

According to the recent theoretical model elaborated to describe the cognitive and metacognitive processes involved in the information search tasks [16] [17], the role of metacognitive skills such as metamemory in searching complex environments is crucial. In accordance with these recent models, the information search activity involves several cyclic processes and consists of three stages: preparation, exploration, and consolidation. The preparation stage begins when the end-user prepares to make choices from a menu of links in a hyperlinked system. In the exploration stage, the user navigates and explores the results of the choices and processes the information. After exploring and processing information, the end-user consolidates by evaluating the results against the goals set during the preparation stage. The outcomes of the evaluation stage play an immediate role on recalibration of goals that are carried into the preparation phase of the next cycle. The model is ideally suited for information seeking situations in which goals are emergent, which means that at the beginning of the information seeking task, the user has vague goals, which are refined during the searching process. So, using a vague goal as a starting point, user seeks different types of online information, perhaps beginning with the results from a search engine. With emergent goals, the definition of success in finding the right information evolves during the searching process and the criteria for success vary by different levels of fit between information sought and information found. The user may evaluate the information as 'this is not exactly what I was looking for, but it seems interesting', or 'I will keep this in mind and continue looking for something that fits more precisely into what I am looking for'. Because the user must remember her/his search topic during her/his information searching process and because she/he must decide to begin or to stop one of the three stages (i.e., preparation, exploration, and consolidation), memory and metamemory are essential.

The first study presented here investigates the Internet access, interests, and information seeking from the Internet among seniors, by using interviews with a semi-directed questionnaire. And because poor metamemory appears to be a characteristic of older persons, the second study presented here investigates the impacts of a specific cognitive ability, i.e., metamemory abilities, on the information search activities performed by old end-users.

2 “Why, Where and How Do You Search for Information?”

In this first study, seniors’ perceptions of the Web and of the information searching activity in general were assessed by a paper-and-pencil questionnaire (a Likert response scale) elaborated on the basis of a series of interviews. Questions concerned: perceptions about the nature of information found in the Web; ‘strategies’ of access to the interesting Internet sites and the reliability of different information resources (libraries, television, Web, etc.). One individual factor was manipulated: Web experience (low vs. high).

2.1 Participants

47 seniors volunteers (32 males and 18 females), aged between 68 and 73 years were recruited to participate in this first study. If all the participants were Web users, two groups were constituted according to the frequencies of this use: 24 seniors were considered inexperienced with the World Wide Web (low experience group) while 23 seniors were considered skilled with the Web (high experience group).

2.2 Material and Procedure

A paper-and-pencil questionnaire was created on the basis of a series of interviews with open questions, conducted with six seniors who were not asked to fill it. This qualitative method provides a rich data set for studying seniors’ perceptions of the Web and was appropriate to the exploratory nature of this study. During this interview, the six seniors were asked to explain what kind of information they find on the Web, to discuss the types of electronic resources they had access, and their perceptions and opinions about the information they can find using different information resources. The researcher asked the following questions: (1) Why do you search for information on the Web? (2) How do you find an interesting Web site? and (3) In general, where do you find interesting information?

On the basis of responses obtained from these six interviews, questions for a paper-and-pencil questionnaire items were created (that can be rated on a 0-to-6 Disagree-Agree answer scale). The questionnaire used in this study was a Lickert scale which is a way of generating a quantitative value (numerical) for a qualitative questionnaire (i.e. strongly disagree, disagree, undecided). For an ascending five (or six, or seven or eight, etc.) point scale, incremental values are assigned to each category and a mean figure for all the answers can be calculated. Each participant was asked to grade each item from the 0 (‘strongly disagree’) to 6 (‘strongly agree’) response scale. A forced-choice answer scale with an even number of responses and no middle neutral or undecided choice was used. In other words, the participants were obliged to decide whether they lean more towards the agree or disagree end of the scale for each item.

The first section of the questionnaire consisted of questions related to demographic factors such as age, gender, . . and had questions concerning Web use, such as how long they had been using the Web and the average time they spent on it.

2.3 Results

Eight reasons were proposed to the seniors to describe why they search for information on the Web. Table 1 shows that the 'patterns' of the opinions are similar whatever the Web experience level (low vs. high). From the seniors' perspective, the reasons are (in decreasing order): the interest of the information found on the Web; the quickly of access; the quantity; the recency; the superiority of the Web to give information; the possibility to learn how to search for information through the Web; the aesthetic of information; accuracy and the number of examples

Table 1. *Why do you search for information on the Web?* Average scores of the answers

	Web experience		
	Low	High	*p*
On the Web …			
I can find information in a quickly way	4.3	4	.32
I can find more information	4	3.8	.24
I can find more recent information	3.9	3.8	.18
I can find more interesting information	4.6	4.2	.17
I can find more beautiful information	2.6	2.2	.09
I can find information with clearer examples	2.6	2.3	.11
I can find all the information I need	2.6	2.5	.23

Several multivariate analyses (ANOVA) were computed. There appear to be one general trend: low experienced seniors' scores are always superior to high experienced seniors' scores. So, seniors with a high degree of Web experience could become less confident and more critical than seniors with little Web experience.

Seven 'strategies' to get access to interesting Web sites were proposed. Table 2 shows that seniors' strategies for accessing interesting Web sites are relatively independent from their Web experience (low vs. high).

Table 2. *How do you find an interesting Web site?* Average scores of the answers

	Web experience		
	Low	High	*p*
Through search engines	4.9	4.8	.10
At random	2	1.5	.23
Through TV	3.5	3	.31
Through friends	5	4.8	.18
Through magazines	4.8	4.4	.42
With radio	2.4	2	.27
Through other Web sites	3.7	3.3	.23

Whatever their experience level, the strategies used by our participants can be dispatched into three categories (in decreasing order of preference): (1) friends, search engines, and magazines; (2) other Web sites and television and (3) radio and random. Results show that the scores of the seniors with high experience are always inferior to those with low experience, even if no differences are significant. This means that the reliability of seniors in different ‘strategies’ to get access interesting Web sites tend to decrease with experience, whatever the strategy used.

Table 3. *In general, where do you find relevant information?* Mean scores of the responses

	Web experience		
	Low	High	*p*
District library	4.9	5.3	.21
Dictionary	5	5.2	.18
TV	4.2	3.9	.20
Web	4.3	4	.22
Family and friends	4	3.1	.006
Books	3	3.4	.16
CD-Rom	3.2	3.5	.19

Seven kinds of sources and/or locations of information were proposed to the seniors. Results (Table 3) show that the seniors’ perceptions on the location of relevant information are relatively independent of their Web experience (low vs. high). Whatever the Web experience level, the locations where they found relevant information can be dispatched in three categories: (1) library and dictionary; (2) CD-ROM and books, and (3) Web, family/friends and television. Results show that seniors with little experience are significantly more confident than seniors with a great deal of experience in television, Web and family/friends to obtain relevant information. This result confirms previous results: the confidence of seniors in different location to look for relevant information decreases specially for the ‘nearby’ environment (television and family) and, concerning the Web, seniors with a great deal of Web experience are significantly more critical than seniors with little Web experience.

So, our results support the assumption that seniors with high Web experience became more critical, less confident and less enthusiastic than seniors with low Web experience. In other words, the Web experience can influence seniors’ perceptions.

Moreover, several information needs, or topics of concern, were identified with the questionnaire. In accordance with some previous studies of the needs for information for old users [18] [19], the topics of concern for our participants were (in decreasing order): (1) health, (2) income and finances, and (3) leisure activities (e.g., holidays, hobbies and travels). Other topics included consumer, housing and accommodation, safety, environment, pharmaceuticals, family and personal, education, and services. And finally, for all the participants, being able to locate relevant information among all the information provided by the search engines emerged as a major problem.

3 Impact of Metamemory on the Information Search Activity

This second study investigated the impacts of a specific cognitive ability, i.e., metamemory abilities, on the information search activities performed by old end-users.

3.1 Participants

In this experiment, 50 old French end-users volunteers (32 males and 18 females), aged from 66 to 71 years were recruited to participate. Each of them was individually asked to search for information about three specific topics in the World Wide Wed by using a specific search engine (Google.fr).

The 50 participants recruited for this experiment had a range of experience with computers and the World Wide Web. Participants had been using a computer for an average of 63.7 months (SD=22.67) and they all spent an average of 12.32 (SD=5.71) hours per week using a computer. While all the participants had used the World Wide Web at least once, there was quite a wide range of experience. On average, seniors recruited had been using the Web for 26.34 months (SD=8.21) and spent 5.15 h (SD=3.17) per week using the Web.

3.2 Material and Procedure

- Participants were asked to perform three different information search tasks through the use of Google.fr: these search topics were chosen to provide real life examples that showed relevant to our participants: they focused on health (i.e., ‘can you find three Web sites to get information on the causes, symptoms, treatment and prevention of senior's health’), finance (i.e., ‘can you find three Web sites about the financial planning guidelines to seniors’), and travels (i.e., ‘can you find three Web sites related to an adventure travel tour operator that runs small group for people over 60’).
- A Likert scale elaborated by Fort [20] was used to assess the metamemory of the participants. Each participant was asked to fill this questionnaire before to perform the three information search tasks. This questionnaire is a Likert scale with 40 items about the four dimensions involved in the metamemory identified by [20]: the stereotypes about memory aging, the subject’s beliefs about one’s abilities, his/her knowledge about strategies and strategy uses. Two groups were distinguished: participants with low metamemory skills (M-) and participants with high metamemory skills (M+).
- Moreover, during information search activities, the behaviours and the oral verbalizations of each participant were audio-video-taped. These audio-video-tapes were transcribed verbatim. Finally, an informal interview took place after the participant had finished their information search task at the computer.

3.3 Results

For the two groups (M- vs. M+), three behavioural indicators were analyzed: (1) the average time spent to find the three Web sites for each topic (in min.), (2) the average number of relevant Web sites founded (from 0 to 3), and (3) the average number of Web sites explored (from 0 to 3). The relevance of the Web sites was evaluated by three judges.

Table 4. Impacts of metamemory skills on performance in an information search task

	Search topics					
	Health		Finance		Travels	
	M-	M+	M-	M+	M-	M+
Response time (in min.)	678	702	704	712	416	397
Number of relevant Web sites found	2.5	2.8	2.5	2.6	2.8	3
Number of Web sites explored	17	15	9	11	10	9

Results (Table 4) show no significant differences between our two groups of participants (M- vs. M+), whatever the search topic (health, finances, travels). So, even if poor metamemory appears to be a characteristic of older persons, there is no impact of metamemory abilities on the information search activities performed by old end-users.

4 Discussion

Several main interesting results were obtained in our two studies for our sample:

1. The World Wide Web emerged as a major information resource. Because of the increasing number of the "silver-haired surfer", this result is definitively important;
2. If some pieces of literature assumed that there is homogeneity in use and perception for a same population defined, the results obtained in the first study challenge this idea: if the patterns of the opinions are generally similar, the intensity of these opinions is modulated by individual characteristics such as the Web experience;
3. Health was the number one topic for the old end-users, in accordance with other previous studies. The second topic of concern was recreation and travels, and third was services;
4. Being able to locate relevant information among information provided by the search engines emerged as a major problem for the old end-users;
5. Metamemory abilities do not seem to be implicated in the computerized information search activities: No significant result was obtained in the experiment conducted in the second study.

Because some psychological and neuropsychological research suggests that it is hard for old people to develop new skills and because the ability to use information and communication technology is now assumed to be a prerequisite to living in our societies [21] [22] [23], then understanding more about all aspects of information and communication in relation to older people is becoming increasingly crucial considering the changing demographic profile of communities and the implications for government and society. Moreover, this will require a considerable amount of research in forthcoming years if end-users have specific impairments because the normal aging process, including vision, cognition and physical impairments, has an impact on Internet usability.

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Requirements and Ethical Issues for Sensor-Augmented Environments in Elderly Care

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Abstract. The analysis of the potential for technological innovations to contribute to the prolongation of the independence of the elderly in the care context needs to be situated against a background of change which presents a set of challenges, opportunities and risks. The challenge is to ensure an optimal quality of life and equitable treatment for the growing elderly population. Technological innovations present significant opportunities for meeting these challenges. However, there are also some potential risks associated with the application of technology in this domain. Starting from this apprehension, the paper deals with physical environments and needs of elderly in relation to technical implications and ethical considerations. Two pilot projects in the field of "Ambient Assisted Living" are outlined, dealing with the development of an electronic user terminal and a safety assistant for the elderly.

Keywords: Assistive technologies, elderly, physical environments, user needs, ethical considerations, pilot projects.

1 Introduction

Today, western society is confronted with a profound demographic shift, moving from a world with a predominantly young population to one with a significant proportion of people aged over 65 years [8]. This shift means both, a challenge and an opportunity for the design and development of intelligent technologies. The dramatic increase of the number of elderly people as compared to active workers raises concerns about the society's capacities to maintain existing social and healthcare systems. This also means that there will be fewer young people to help older adults to manage daily life.

In order to cope with this emerging situation, assistive technologies can be introduced to support elderly persons as well as human caregivers and consequently to improve the quality of life of the involved individuals. Technologies, which should be developed according to the needs of their users, will support ageing in place as well as independent living of the elderly. It is obvious that technology can not replace the human factor, which is certainly more important than anything else in the support of elderly people. But technology can provide complementary support, give new opportunities, like homecare and support to mobility. By identifying the needs of elderly people and the derived requirements to support systems, the ways in which

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technology can be integrated into their lives is to be addressed in corresponding research and development activities.

2 Environments, Needs and Independence of Elderly

The World Health Organisation's view of health provides an appropriate framework within which to analyse needs and the meaning of independence in the elderly population [5]. The first section of this framework element comprises the view of health as a state of physical, mental and social well-being and not merrily the absence of disease. This definition recognises the importance of social, environmental and cultural factors in the maintenance of health. The second section defines health as the extent to which an individual or group is able to realize aspirations or needs and to change / cope with the environment. The physical environment, in its broadest sense, is seen as equally important in the promotion and maintenance of health.

In planning of "good" and "age-friendly" living environments, it is necessary to take into account the inter-individual heterogeneity of the elderly. This can be observed especially in the areas of needs and motives. As resulting questions it can be asked, what environmental criteria must be met for the individual to be satisfied with living conditions? To what extent is the individual striving to adapt the environment to his or her goals in life ("proactivity")? It is an important task of environmental gerontology to encourage planners and technicians to be more sensitive to the influence of living environments on competence, well-being and social integration in old age. Creating age-friendly living environments can be understood as a key element of subsidiarity.

In a study of opportunities and limitations of independent living in old age the relation between physical environment and functional competence was analyzed. The analysis showed that greater independence (and thus fewer care needs) was correlated with better housing conditions [7].

For the majority of elderly persons, better housing conditions mean ageing in place, with appropriate changes of living environments supporting independence and enhancement of quality of life. Changes of the living environment are frequently connected with the integration of technical aids and in the near future intelligent technologies for assisted living are discussed as promising (electronic) support for the elderly. To what extent and in which context referring technical systems will be in the position to care for human beings and to provide expected results, is still a matter of investigation.

Preparatory works have been started in various laboratories but only a few of them deal with this matter in "real environments", i. e. in living arrangements occupied by elderly persons. The Austrian Research Centers GmbH - ARC have started a pilot project in assisted living environments, applying a sensor network for activity monitoring as well as intelligent care environments. Preliminary results from these projects (see chapter 3.1 and 3.2) are to provide a basis for planning and design of user-specific assistive technologies, considering given environments and requirements / needs of the regarding elderly persons.

2.1 Age Related Needs and Diversity

It is important to emphasise the heterogeneity of the elderly population independent of the particular place of residence. The elderly is not the homogenous group within any given society. There are large differences between the elderly at different chronological ages and, equally significantly, the variations in levels of ability or needs for a given age range amongst the elderly is much wider than at any other stage of the lifecycle. In other words, ageing of a cohort is associated with a widening variation along a whole range of dimensions. These common experiences of ageing can result in high levels of need among the elderly. Declines in physical health and functioning lead to increased needs for health and social services, especially within the long-term-care category. It is important to extrapolate from the current level of need amongst the elderly to the likely levels of needs in future cohorts.

2.2 Independence and the Elderly

The notion of independence tends to be central to most discussions of the needs of elderly. It is almost invariably expresses as a central aspiration by the elderly themselves and it is increasingly promoted at the policy and service delivery levels for cost reduction and / or quality of care reasons. Concepts of dependence and independence are highly relative and culturally determined. Technologically based interventions can impact on the social relationship, underpinning (in)dependence in various ways. One of the key challenges will be to apply useful technological solutions in a manner which is sensitive to the complexity of these relationships.

3 Implications of Technology

In recent years the debate on independence and self-sufficiency of the elderly has attracted considerable attention and resources. This developed thanks to the greater sensitivity towards the special needs and requirements of this growing segment of the population. The search for new solutions that can guarantee greater independence and autonomy has begun to exploit easily available state-of-the-art technology. Intelligent control and sensor systems, e.g. called “smart homes” or “smart environment system” would go far in simplifying the interaction between the elderly and their domestic environment. A great number of benefits would stem from their implementation: greater safety, autonomy and self esteem and consequently better relationship with others [6].

As it showed in a number of research projects, it was technically feasible to install and operate smart home solutions in laboratory settings. As soon as these solutions are to be operated in real environments of elderly persons, a number of problems emerge, mainly connected to low usability and low acceptance rates by prospective users. As mentioned in a previous chapter, there is a high heterogeneity amongst older people, regarding their needs in different stages of age. Thus, standard solutions for assistive technologies have only small chances for a useful function and for acceptance in households of elderly persons. Again, it should be stressed that the involvement of prospective users is a main prerequisite for planning and development of any technical systems for the support of daily living.

3.1 Electronic User Terminal

Dealing with this situation, the ARCS have been actively involved in a series of pilot projects in the field of Ambient Assisted Living (AAL), in a national as well as in a European context. Two recent projects deal with the acquisition and analysis of user needs and derived system requirements as applied in selected homecare environments. One of these projects puts the focus on designing and testing of a stationary user interface ("electronic user terminal") for elderly persons, which is to be applicable for various purposes, like alarming, communication, structuring of the day, information etc. [2, 3].

Fig. 1. Prototype of an electronic user terminal, showing the menu for a reminder function

In the framework of a qualitative study, prospective users were confronted with a prototype of the terminal, displaying the different functionalities as well as cognitive training software. During and after their active contact with the terminal, users were invited to a dialog on their experiences with the new tool, based on a semi-structured concept of questions. The same experiment was carried out together with caregivers and relatives of potential users. One of the rather surprising results of the trials was that the majority of elderly users had a more positive valuation of the terminal's usability as their caregivers. To get to the bottom of these finding further studies will be conducted.

3.2 Safety Assistant for the Elderly

The second project deals with activity monitoring of elderly persons, living in assisted homes. For this purpose experimental sites have been set up, composed of various sensors (infrared / IR, contact, touch, temperature etc.) for the detection of motions, opening and closing of doors / windows, leaving the bed etc. This system constitutes a sensor-augmented environment, which is unobtrusive for the users. They are living in their homes "as usual", carrying out regular activities, without worrying about the technical installations [4].

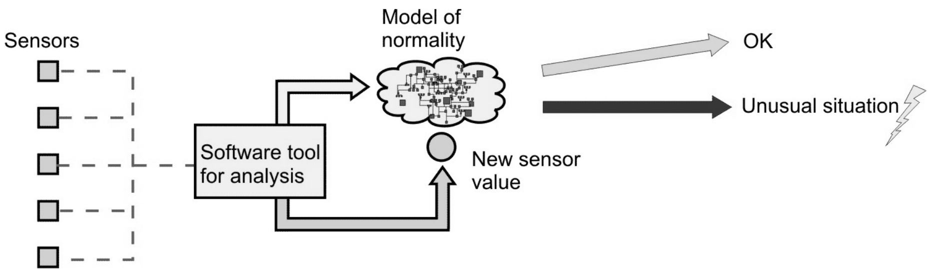

Fig. 2. S.A.F.E. Safety Assistant For the Elderly

The system features several functionalities, which are not activated yet but which are analysed referring to a users´ typical activity or behaviour in his living environment.

- *Safety alarm*: in case of critical situations in the household, the activated sensors should trigger out an alarm warning the person on duty of an imminent danger. It corresponds to the management of hazards brought about by abnormal situations in the patient's setting and / or the behaviour of the aged (running away …).
- *Presence / absence*: in case of elderly people having repetitive habits in their daily life, the system can discover and learn the habits (e.g. the time table, etc) in order to give the alarm to the professionals whenever any abnormality happens on the elderly people's activity.
- *Mobility study*: it relies on the use of IR motion sensors so located as to cover the whole room in different areas to monitor the elderly person. By acquisition and calculation of referring data, the paths followed by the patients are built up so as to be listed and stored. Any abnormity on the elderly´s mobility can be diagnosed to warn professionals.

The "learning" principle is used to account for the changes in the elderly patients´ behaviour, in their physical environment and social setting. The multi-sensor system is installed in her / his apartment to detect presence, motion or walking in / out. The data reflecting the repetitive and representative habits of the user can be identified in a non-intrusive manner without disturbing daily life. These data are recorded as soon as the system is turned on and special software tool are applied ex post for the interpretation of data. In order to get more details for the analysis of users´ behaviour within her / his living environment, it is planned to integrate additional sensor systems, like RFID readers or bio sensors. As a result it should be possible to determine where a person is staying or what household object she / he has used, as well as to get a general sense of her activity level.

For both projects the underlying philosophy is to work in cooperation with end-users and to consider their needs first and foremost. In this framework it is the users themselves who determine which assistive technology to include into their living environment with what priority and the best way to integrate them into the system. In order to satisfy the often conflicting requirements, it is necessary to design modular systems that can be customised in different configurations for different needs. Both projects are intended to contribute to the investigation of questions about human behaviour, among others:

- What influences behaviour of people in their homes?
- How can technology be effective in the home context for long time periods?
- To what degree can activity monitoring contribute to create new computer applications for the home?
- What influences how people adjust to new environments?
  How do people learn in the context of the home?

4 Ethical Issues Regarding the Elderly

Bringing technology with monitoring functions into a person's home also raises important ethical questions with regard to possible conflicts with principles of dignity, independence and privacy. The appropriate choice of technology can help to migrate some of these concerns. For example, monitoring a patient's wellbeing or activity at home might not require video-cameras, but can be done less intrusively through tactile or infrared sensors, as practiced in the above mentioned pilot projects. Technology implementation and careful application of social norms can also reduce a sense of intrusion and loss of privacy.

Another ethical challenge is to avoid the perception that the installation of technologies for "ambient assisted living" means that decision making power is left to a heuristic machine or that it replaces human care and prepares the erosion of social interactions. This perception is a major barrier to the uptake of new technologies. It leads to the important ethical, as well as operational, principle that these services should not aim to substitute existing care networks, but that they should be promoted and implemented as complementary solutions. Smart home devices for example, should be seen as a means to enhancing social care rather than as a substitute for it. Consequently, assistive technologies (especially information and communication technologies) as applied in smart home solutions should not increase isolation; instead they should be tools for maintaining and, ideally, even strengthening social networks and keeping the independence of their users [1].

Other adverse psychological effects of AAL solutions can also be imagined. Having to rely on unattractive technological devices in day-to-day life can do considerable harm to the self-image and confidence of the user. Efforts for better design, discreet ambient integration and the upgrading of conventional home devices with AAL-capabilities can ameliorate this problem. Most importantly, if the personal autonomy of a potential user of supportive technologies is to be fully respected, the user must have the right, to overrule or switch off the technology. These rights must be built into the services. User should also have the right to opt out completely from using the services, if they wish so.

5 Conclusion

Active ageing with the help of assistive technologies, like “smart homes” or “ambient assisted living”, presents a major opportunity to utilize technological progress for individual autonomy and dignity as well as for social inclusion. In order to make the best of this opportunity, it is essential to place users and their needs in the centre of our considerations when designing and implementing novel technical solutions within an elderly persons´ living environment. Consequently, it is decisive to strengthen user involvement and to take better account of user contexts.

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Ergonomic Design of Computerized Devices for Elderly Persons - The Challenge of Matching Antagonistic Requirements

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Abstract. Aging implies a general decrease of physical and mental fitness, which, however, largely depends on training. Additionally, individual impairments occur more frequently with age. Three studies show that most elderly people struggle with the application of modern technologies, although physical communication is only slowed but not impaired and handling characteristics do not significantly differ from younger persons. Most usability problems originate from a lack of understanding the complex interaction of menu control. Former education and missing experience then tend to augment usability problems with time. Using the example of a mobile phone prototype it is shown that, despite the complex and inconsistent needs of elderly, the usability obstacles can be vanquished by considering the hierarchy of cause-effect relationships for design.

Keywords: Elderly persons, usability, input devices, menu control, product design.

1 Introduction

Improved working and living conditions enable a continuously increasing life expectance. In conjunction with low birth rates this leads to a demographic change with a significant increased percentage of elderly persons in many European and Asian countries. For example, in Europe actually more than 77 Mio. persons (equal to 20%) are older than 60 years, and this number is expected to double before 2030.

Manufacturers and service providers hence face a rapidly increasing percentage of elderly customers. To face the particular demands of this group, ergonomic aspects, particularly behavioral and cognitive ergonomic aspects have to be considered. The lacking empathic dimension for younger developers raise the question how to design products accommodating the (specific) demands of elderly persons.

In the following it is shown, that nor physical neither cognitive constraints have to be considered as major drawbacks for the usage to computerized devices by elderly persons, but individual reservations as a consequence of negative experience have to be overcome in order to provide elderly persons access and acceptance of modern technologies.

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2 The Process of Aging

Aging is mostly associated with a decrease in physical and mental fitness. Metabolic changes lead to a reduction of maximum forces and energetic performance beginning from the third decade of life. In a later phase information processing slows down and perceptual and mental performances decrease. Such changes affect all individuals, at varying ages and in varying levels of impairment. The characteristics of such biologically induced effects of aging are widely studied [e.g. 1-4] and build the basis for many ergonomics recommendations and checklists considering elderly persons.

A second type of age-induced variation of performance, which is also relevant for ergonomic design, occurs as a consequence of (mostly chronic) diseases, such as hypertension and rheumatoid arthritis. It is important to notice that the distribution among the population differs from the before-mentioned general gradients: only a part of the population is struck by such impairments, while other individuals are not affected.

A third factor of aging occurs as a consequence of resource utilization. This includes deterioration caused by chronic overload, but also the inverse effect - physical and mental degeneration as a consequence of passiveness. Such (in both directions negative) changes strongly depend on individual behavior, which is often consolidated by a lengthy positive feedback: A decreased performance provokes individuals to reduce or even to avoid corresponding activities, resulting in missing training and accelerated degeneration. This cumulative effect explains the increasing intra-individual variation of performance with age [5-7].

However, aging is not only associated with negative trends. Experience increases with age, affecting social behavior as well as strategic decisions [8]. This has important consequences also for technical products.

From a demographic perspective not only the percentage of elderly persons increases, but also age distribution changes, with important implications on ergonomics factors: improved working conditions and health care allow a life expectancy far above the retirement age. Most seniors are only marginally restricted by health impairments when retiring and during the first and often second decade thereafter. A new generation of "young seniors" with age related impairments but who are still active and demand for challenges (and have time and money) is developing.

Either way, it is desirable but not feasible to distinguish seniors as a special group of population. Aging is a continuos process, starting chronologically and physiologically with birth and ending with death. Thus, no strict classification for ergonomic design for elderly persons may be established.

3 The Impact of Modern Technology for Elderly Persons

Modern technology is not only a comfort feature, but fulfils more and more essential functions for life. Particularly for solitary and needy (elderly) persons communication and (health) supervision devices have a great impact on safety and independent lifestyle, which is identified as being the second most important factor for seniors after health [9].

Furthermore, modern technology becomes more and more an integral part of public organization, e.g. in form of ticket vending machines and mobile information services. This shifts the role of modern technologies from comfort and entertainment towards an element of infrastructure.

The subsequent dependency on modern technologies makes many seniors feel overloaded with daily activities. The assumption of congestion is based on the fast change of technology rather than on the function of technology. A particular problem is the lack of notice about changes and its access. Traditional infrastructure changes very slowly and changes are announced in public media. To keep up with technological change, on the other hand, users are required to update themselves regularly. Many seniors are not aware about this distinction and then react confused when confronted with new interaction requirements. So modern technology often causes uncertainty instead of providing safety and stability.

The role of ergonomics for elderly persons is thus much wider than only considering the pure human-machine interaction.

4 Study 1: Usability Problems of Elderly Persons

Modern devices are much easier to handle than ever. Small and lightweight devices require neither significant forces to be moved and activated nor particular motor skills for adjustment. Extensive functionality, options for individual settings and interactive control allow to adapt each device to very different user and usage requirements. State-of-the-art products are further rugged and almost safe in case of misuse. The decrease of physical, perceptual and mental performance with age thus does not affect usability of technical devices significantly anymore.

However, technical progress often provokes awkward changes for elderly users [10]. For example, the keypads of mobile devices contradict general ergonomic recommendations for keyboard size. They are usable if accepting lower speed and higher error rate. This is true also for elderly users, but more frustrating due to their motor and reaction impairment. Similarly, nearly all age-related deficits of perception, reaction and memorization will reduce performance but do not disable usability.

Considering the fact that any products should keep user requirements low in order to enable access to all levels of users, age-related physiological impairments explain only a minor part of user variance with all its disposition and training impacts. Thus, individual performance is rather a personal than an age-related attribute.

However, many seniors complain of significant problems when faced with modern products (Table 1). In a survey of 130 German seniors between 65 and 91 years more than 60% complained of problems when using technical devices. 30% have devices which they do not use any longer because of usability obstacles, and 40% had already refused to buy a device because it was expected to be to complicated to use. Although such a result is likely to vary between different countries, it draws a picture of significant usage problems for elderly persons.

For ergonomics design it thus raises the question, which factors provoke ergonomics problems and how to overcome such obstacles during product design.

Table 1. Consent rates surveying 130 German seniors (65 to 91 years old) for usability problems of technical devices (% of yes)

all (n=130)	females (n=71)	males (n=59)	<55 years (n=5)	55 to 64 years (n=50)	65 to 74 years (n=49)	75 to 79 years (n=10)	80 to 84 years (n=10)	> 84 years (n=6)
Do you frequently face problems when using technical devices?								
63%	67%	54%	80%	62%	61%	70%	60%	67%
Do you ask for an explanation before buying a new technical device?								
91%	91%	92%	100%	88%	92%	90%	100%	100%
Are you being instructed comprehensible when purchasing a technical device?								
41%	37%	50%	60%	35%	37%	60%	50%	67%
Do you use the manual when start operating a new technical device?								
97%	96%	100%	100%	98%	100%	80%	100%	83%
Does the manual helps you for problems operating a new device?								
60%	55%	72%	60%	68%	53%	70%	60%	33%
Do you have a possibility to receive help in case of trouble with technical devices?								
68%	68%	67%	60%	70%	69%	50%	50%	100%
Do you have devices which you do not use anymore because of usability problems?								
30%	33%	23%	60%	32%	29%	10%	40%	17%
Did you ever refused to buy a device because of its complicated usage?								
40%	41%	38%	80%	38%	37%	20%	60%	50%
Would you appreciate an individual instruction to get new devices operated?								
82%	84%	79%	100%	90%	80%	60%	80%	67%

5 Study 2: Usability of Input Devices

Operation of menu controlled devices becomes more and more common. The handling of such devices requires skilled motor control, with fast and precise movements and visual feedback. Such operations are expected to be more difficult for elderly persons in general, but with different characteristics depending on the type of movement required. This raises the question whether or not different types of input devices would be more suitable for elderly persons than for younger persons.

In a laboratory test the performance characteristics of six different types of input devices (see Table 2) were evaluated for younger and older users. The task consisted of a two-dimensional selection movement, which corresponds to many menu selection movements and puts similar requirements to the different input devices. In a 5x5 field matrix an indicated field had to be selected and then confirmed by pushing a button on the input device (see Fig. 1). Visual distance was 5m, the field size was each 3x2° with 0.5° spacing between the fields.

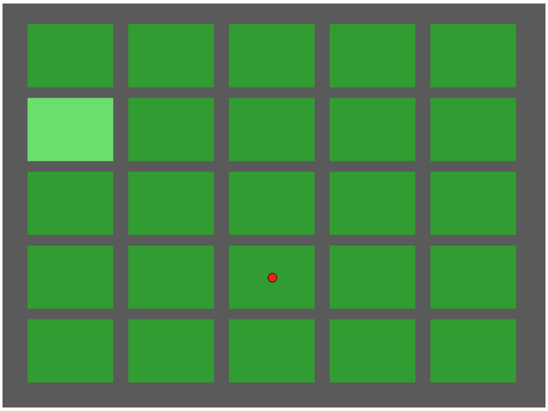
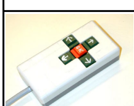


Fig. 1. Experimental task: The cursor (in form of a red dot) has to be moved to the highlighted field and then the mouse button has to be pressed

Each input device was tested for one minute repetitively (order of input devices permuted between subjects), and the whole set of 6x1 minutes was repeated 3 times (with a 15 min rest break in between) to check adaptation. The tests were performed with n=60 seniors (30 females and 30 males) with ages between 55 and 90 years and a control group of n=20 persons (10 males and 10 females) of 25 to 40 years.

Analysis was processed for execution speed, error rate, and learning function. Additionally a subjective preference was requested (detailed results in [11]).

Table 2. Rank order of handling attributes for different types of input devices evaluated for younger persons (25 to 40 years, n=20) and for elderly (55 to 90 years, n=60). Age groups and ranks are only separated for significant differences (p<.05).

<table>
<tr><td rowspan="2">Input device</td><td colspan="2">Keypad</td><td>Trackball</td><td colspan="2">Lightpointer</td><td colspan="2">Drawing-table</td><td>Computer-mouse</td><td colspan="2">Touchpad</td></tr>
<tr><td colspan="2"></td><td></td><td colspan="2"></td><td colspan="2"></td><td></td><td colspan="2"></td></tr>
<tr><td>Speed</td><td colspan="2">4</td><td>4</td><td colspan="2">1</td><td colspan="2">1</td><td>1</td><td colspan="2">4</td></tr>
<tr><td>Error rate</td><td>6 ≤40 yrs.</td><td>3 ≥55 yrs.</td><td>1</td><td>3 ≤40 yrs.</td><td>1 ≥55 yrs.</td><td>1 ≤40 yrs.</td><td>3 ≥55 yrs.</td><td>3</td><td>5 ≤40 yrs.</td><td>6 ≥55 yrs.</td></tr>
<tr><td>Subjective preference</td><td colspan="2">3</td><td>5</td><td colspan="2">1</td><td colspan="2">3</td><td>1</td><td colspan="2">5</td></tr>
<tr><td>Moved extremities</td><td colspan="3">Finger</td><td colspan="5">Wrist</td><td colspan="2">Lower arm & fingers</td></tr>
</table>

The result showed a general decrease of speed and increase of error rate for seniors (average 1.5 s versus 2.3 s processing time and 2.0% versus 5.6% error rate). However, the ranking of the different input devices did not differ for speed and subjective preference between young persons and seniors (see Table 2). Error rate differed in detail between young and old, but general characteristics also corresponded for both age groups. Considering work experience with computers as a covariate showed that this factor is more effective than age for performance.

Input devices which are controlled by wrist movements (light-pen, computer mouse and drawing table) tend to provide the best overall performance.

Although keypads allow a discrete control and required less accurate movements its performances ranged below average.

6 Study 3: Usability Obstacles of Complex Electronic Devices

This study was intended to understand which problems occur and which strategies seniors apply to solve usage problems with complex electronic devices. It was expected to obtain a set of typically reported interaction problems of elderly persons (e.g. [12-13)

60 seniors (55 to 91 years old, each n=20 in the age groups 55 to 64, 65 to 74 and more than 74 years; complemented by a control group of n=20 aged 25 to 40 years) were asked to adjust the ring volume of a mobile phone. Three different types of common mobile phones were used (Nokia 3310, Motorola Timeport L7089, and Mars Trium), and subjects were not instructed for any specific usage in order to discover their exploration strategies. Interaction was stored on video tape and subjects were retrospectively asked to explain their behavior.

As a general result, button control and visual perception caused problems for 19% and 25% of all seniors. The 25% visual perception problems in this case were mostly associated with difficulties to recognize symbols and abbreviations, only few problems (4%) were caused by optical obstacles (seniors used reading glasses if convenient). The 19% button control problems occurred due to difficulties to identify buttons and selective activation without pressing a second one; some few problems were caused by insufficient feedback. However 84% of seniors faced problems with the logic of interaction (menu control), 70% got stuck without finding a way back (almost equally assigned to each of the three mobile phones).

A first conclusion could be drawn in a way that a major problem has to be seen in the complexity or inconsistency of the menu logic. A detailed study, initiated by a randomly observed incidence, showed that this interpretation would be mostly wrong: during one test, an senior held the mobile phone in a way that he covered a central part of the display with his thumb. Under normal circumstances menu control would be disabled due to the missing visual control. However this person continued typing to fulfil the task (adjusting the ring volume). When he was subsequently asked if he would not feel restricted, he reacted visibly confused by the question and denied.

Checking the background of his reaction it turned out, that he did not expect displayed information for menu control, but only tried to figure out a successful sequence of keystrokes to adjust the ring volume by chance. A retrospective inquiry of all seniors showed that almost all persons struggling with menu control (66% of total) did not use display information for navigation, but only sought for a suitable key sequence. They expected young persons to memorize the appropriate key sequences and themselves being too old to keep this information stored. Observing other persons using their mobile phones they just realized how fast they pushed the button, but the visual control use of the display was not observable. Many of the seniors wrote down important commands for the use of their TV-sets by noting the sequence of buttons to be pressed.

Thus, a more general problem of menu control has to be seen in the interactive character of activating functions by selecting from the options on the display than in the consistency of the logic itself. In fact, neither memorization capabilities nor intelligence have ever been limiting factors to access menu controlled devices (except considering extremely bad designs).

Persons who are aware how menu navigation works in principle mostly figure out an individual set-up and cannot imagine other persons not knowing the interactive character of this type of interaction. This might be the major reason why developers (and in this case even ergonomics researchers) do not expect this case being relevant (but in this study was for more than 60% of the senior users).

7 Discussion and Interpretation of Studies

The three studies mentioned before show that the interaction with modern technical devices is somewhat slower, less comfortable and sometimes require additional aids for elderly persons (e.g. lenses), but there is no objective barrier for use. However, many seniors complain extensive problems when trying to use modern technology (see Table 1).

The barriers to use modern technologies are obviously not caused by decrease of perceptual, motor or cognitive performance. Experience of modern technology rather seems to be a key factor. Experience again largely depends on individual attitude to modern technologies.

There is no reason to seek the difference in open-mindedness to new technologies between young and old persons in constitutional factors. Hence, cultural environment and educational factors should cause such effects. Elderly persons formerly experienced a different type of technology and means of accessing it. Some decades ago modern technology was associated with extensive power (e.g. motor vehicles) and/or it was mechanically sensitive. Either way, technology was expensive and sensible to damage. Already now seniors report fear of damaging technical products in case of misuse - however the usage of today's products is mostly explored by trial.

With time, demureness and trepidation are recursively boosted: careful and distant behavior to modern technology isolates from new developments in a way that users avoid to get in touch with it. When using modern technologies the likelihood of usage failure is quite high because of the missing experience. The resulting frustration provokes an even more distant behavior to modern technologies. This is particularly apparent after retiring from work life, suspending the necessity to cope with new developments.

Experiencing a reduction in performance with age decreases self-assuredness and confidence of control, e.g. for physical stability and mental reliability. This experience additionally amplifies the feeling of uncertainty to use modern devices.

The increasing sanity is recognized as a positive attribute of aging [8]. However, being more rational may result in a more conservative behavior which again constrains openness to explore new technologies.

Thus, the formation of technical skills depends much more on experience with new technologies than on age. It seems to exist one offensive group of seniors which almost does not face any usability problems at all, and another defensive group of seniors who have shaped a more negative attitude to modern technologies.

8 Conclusions for Ergonomic Product Design

The physical, perceptual and mental restrictions of aging touch elementary ergonomics requirements and are still important to consider. However, any particularly visible emphasis of ergonomics attributes (e.g. large buttons, striking colors) provokes to stigmatize the user of such a product as an impaired person needing particular equipment (examples in Fig. 2). In this respect ergonomics requirements and social categorization need to be subtly balanced.

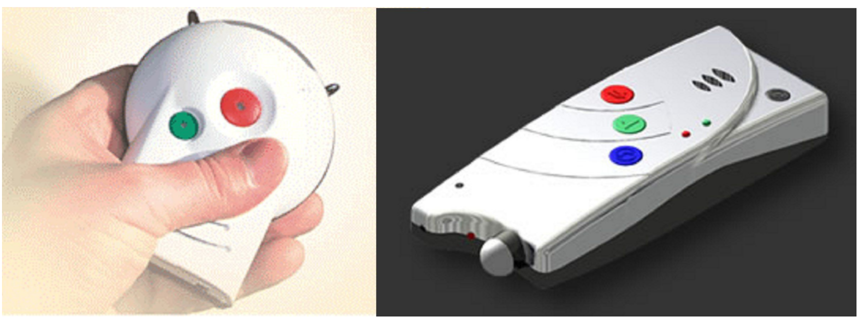


Fig. 2. Commercial communication products designed for elderly users lack acceptance because they often provoke a stigmatization

In order to overcome a lack of user experience it is not sufficient to provide a product design which is only easy to use. Additionally such a product shall help to overcome fears and reservation in order to explore and experience new technology.

Thus products for elderly persons must not address interaction performance deficits in a way they become visible (although this might imply some performance deficits, but not disable usage). Rather they must support older users to explore new options and functions by shunning fears of inexperience and incompetence.

This is a particular challenge for the design process, as most developers may not have an emphatic insight to this problem and those effects may not be illustrated by functions or characteristics. A suitable form of participation is thus a key for product development, particularly during the conceptual phase. But users again may not easily express their demands at this stage, but focus mostly on device requirements. During the studies performed by the author, user representatives only concentrated on interaction deficits which turned out not to be the key ergonomic deficits. Introduced forms of participation in product development (e.g. [12]) thus provide only limited access or require extensive prototype building and re-engineering. Advanced forms of user participation for this issue still have to be developed [14].

An application example, a mobile phone prototype, shall show how to meet the (partially inconsistent) design requirements for a final product (Fig. 3, [15]).

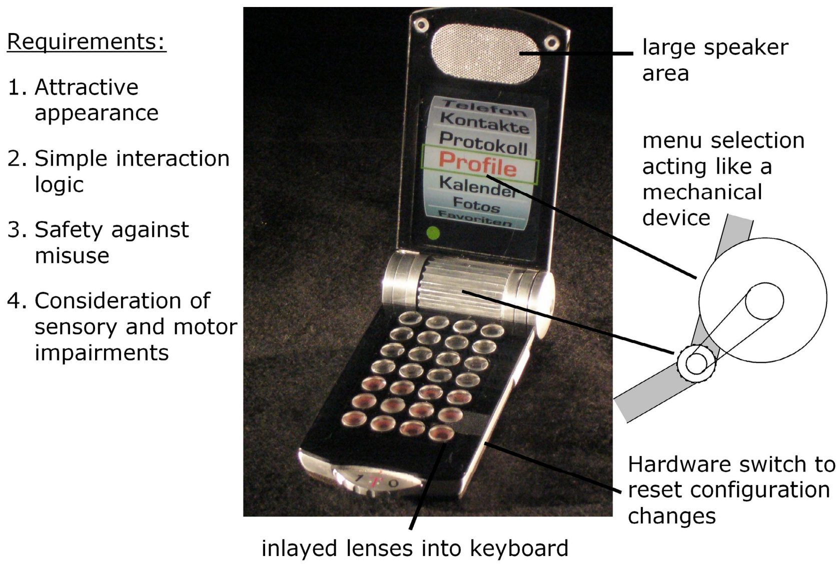


Fig. 3. Requirements and prototype of a mobile phone addressing the needs of elderly persons

Product aesthetics is the first and often singular attribute enabling to attract a potential user's interest, because a product receives no further attention if this is not achieved. It is thus essential to be attractive in the users perception (which are mostly sportive attributes even for seniors) and must not risk to stigmatize the user. For the mobile phone it was aimed to create a shape which is conform to the aesthetic demands of seniors and is equally assumed to be attractive for their children and grandchildren.

A product then has to convince potential users for its safety against misuse. In the mobile phone example a simple hardware switch was added to reset any changes in configuration to a previously defined state. A selectable time range for undoing changes (e.g. to come back to the configuration used the day before) may be applied as an extension.

The proposed mobile phone uses a mechanical correspondence to access its functionality by menu control: A rotary cylinder moves a correspondent virtual cylinder on the display in a way as they would be coupled mechanically. Selection is then performed by pressing on the rotary cylinder. In order to avoid overload when not being already familiar with all functions, options for a stepwise reduction of functionality (starting with a simple number selection and connect/disconnect function) are provided. The physiological particularities of seniors are further addressed, e.g. by inlayed lenses into the keyboard. So button description can be read without using lenses. However, the size and the appearance of the phone does not differ significantly from common mobile phones.

This example shows that the consideration of the hierarchical cause-effect structure of physical and psychical aging may help to design products being usable and attractive for elderly as well as younger persons.

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Web Access for Older Adults: Voice Browsing?

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Abstract. We report on a study exploring the use of voice commands by older adults browsing the Web. We sought to develop an understanding of how such commands might make Web navigation and access to Web accessibility transformations easier. The results suggested a number of surprising difficulties in using spoken commands. Some were due to general confusions about how to use the browser. Some were due to mismatches between what was natural to say versus what was natural to do with a mouse. We review some of these difficulties and discuss possible underlying reasons. Finally, we suggest interface changes that would make an otherwise well-engineered user interface better suited for voice commands.

Keywords: older adults, Web, conversational interfaces, UI.

1 Introduction

Access to information is critical in today's society. Once the realm of only technologically sophisticated users, today's Internet is a vital tool for societal participation. It is used not just by college students and workers in information technology professions, but also by older adults eager to connect with extended family members and to look up information about leisure activities. Importantly, as key government services move to online administration, ability to access the Web is not a luxury, but a necessity.

Older adults face a number of challenges in using the Internet. Issues related to decline of sensory, motor, and cognitive abilities are compounded for these users by the fact that in many cases they are trying to use a technology for which they have no experience [1], [2]. These difficulties have lead to calls for the creation of alternatives to a traditional browser that take into account the needs and experiences of older adults [3].

In work we have been doing for the past few years, our approach has been to provide adaptations to better accommodate the needs of older users. This has the virtue of providing full browser functionality to users, rather than limiting them to a subset of function. Although the full range of browser functionality can be daunting for novices, we decided to address the issue of access not limited to novice users, but rather to find an approach that would address accessibility needs of both novice and advanced users [4] [5].

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2 A Broader View of Web Accessibility

The work on Web adaptations for older users goes beyond traditional discussions of Web accessibility. There is often a tendency to equate 'accessibility' with the needs of blind users, and, in some cases, users with motor limitations. In part, considerations of these user groups dominate because the needs of these groups can be articulated. While the solutions are technically challenging, the needs are understood.

Less well understood are the needs of older adults. We've argued, however, that the notion of Web accessibility should be expanded to meet the needs of a more diverse user population [4]. An interesting characterization of older adults is the phrase 'dynamic diversity' [6]. This encompasses the fact that the needs of individuals in the population are very diverse, as well as the fact that needs of individuals fluctuate. Designing a system that will meet the needs of users with diverse and changing needs is challenging, however, as the system must be flexible and easily changed in the face of changing requirements.

The Web accessibility requirements of older users can be grouped into a few general categories. That is, older adults express the desire to have content on Web pages 'bigger,' 'more legible,' and simply to have less of it on a page [7]. They also ask for help in using the mouse and keyboard, often asking to be able to "talk" to the computer rather than pointing, clicking, and typing. Many consider that speech will be a more natural interface and will make the task of Web browsing easier.

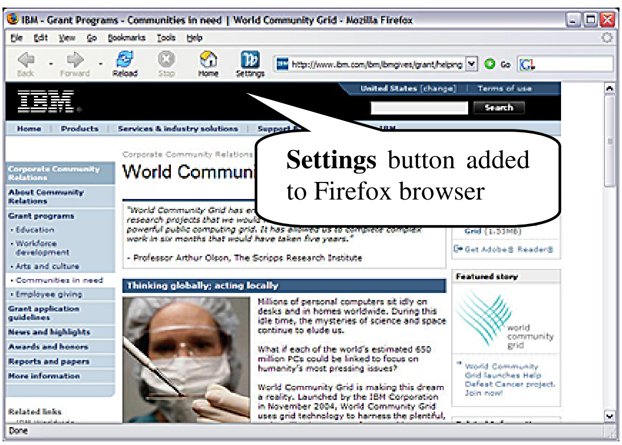

Fig. 1. The Firefox browser with software extension that allows users to personalize their Web experience

Previous research on talking browsers suggests, however, that speech interactions may not be as easy as expected [2], [8]. This work has determined that cognitive limitations associated with aging limit the ability of older adults to deal with the complexity of speech interactions, particularly when the task of Web browsing is new.

2.1 Making the Web More Usable

By way of background, our work has involved the implementation and testing of browser adaptations for the Internet Explorer[tm] and Firefox browsers [4], [5], [9], [10]. The software allows users to set a number of options to personalize the browsing experience to meet their own needs. Figures 1 through 5 are sample screenshots from the Firefox version of our software.

As can be seen in Figure 1, this is the Firefox software, with the addition of a single Settings button in the toolbar. By clicking that button (or pressing the F12 key), the user brings up a panel at the bottom of the screen that allows them to cycle through and try various options for transforming Web content. One of the panels, **enlarge text**, is shown in Figure 2.

Fig. 2. A sample panel from the Firefox extension. Users can cycle through various options for setting their preferences by clicking the forward and backward arrows.

The software provides a variety of ways in which users can change the page. Popular options for older adults have been enlarging content (text and images) and browser controls (menus and scrollbars), improving text legibility (changing text and background colors, expanding white space between letters and lines of text, and reducing the overall complexity of Web pages (e.g., converting multicolumn to single column layouts and removing non-essential page content) [10]. Non-visual changes include easy (sometimes automatic) adjustments to keyboard and mouse function, and the ability to have page content read aloud. In some cases, our software simply makes features in the browser or operating system that users may not be aware of or have difficulty setting more obvious and easier to adjust [4], [11].

Users may combine these features in any way they wish. For example, Figure 3 shows the same Web page as in Figures 1 and 2, but with the text greatly enlarged. In fact, the text is so enlarged that the page becomes navigationally complex due to that fact that part of the page no longer fits on the screen. Off screen content is difficult to keep in mind and requires tedious horizontal scrolling to read.

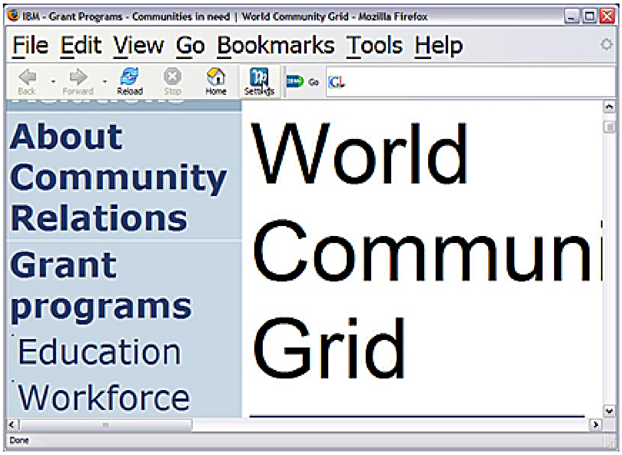

Fig. 3. An example of much enlarged text. Menus and input fields are also enlarged. Notice the horizontal scroll bar indicating that some information does not fit within the screen width.

To remedy this navigational problem, we created the '**one column**' features in our software. Shown in Figure 4 is the page from Figure 3, but with the **one column** adaptation applied. In this case, the page content is put into a single column and the user no longer has to engage in horizontal scrolling and the associated task of integrating on-screen and off-screen information.

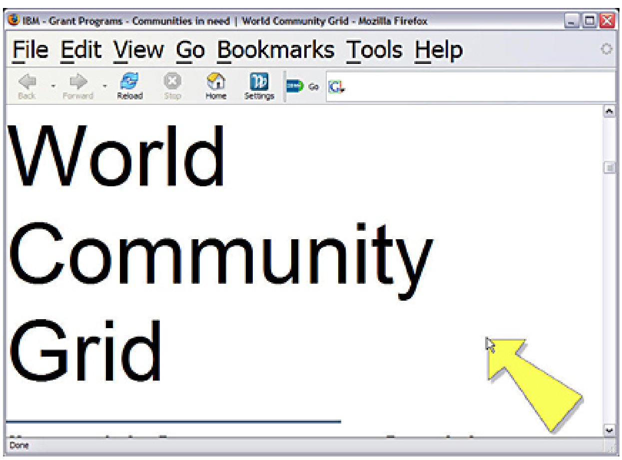

Fig. 4. Screenshot with the same text size as in Figure 3, but with the **one column** feature being used. All the text now fits on the screen, as indicated by the absence of the horizontal scrollbar. Also shown here is the **large cursor** option.

3 Voice Browsing

When working with our users, we are frequently asked if they can use speech to control the computer. They say they wish they could simply talk to the computer, rather than fussing with the mouse and keyboard. Conversational speech interfaces, with their promise of being able to 'just talk to' the computer are alluring [12] and seem to offer a more 'natural' means of interaction. While useful in many situations, there are reasons to wonder how successful such a feature would be with an older population.

Although not widely explored, we know that problems may arise for older users at two levels: problems with recognizing the speech of older voices and problems with the complexity of command vocabularies. There is reason to believe, however, that older users, despite difficulties, are positive about speech interfaces [1], [13].

3.1 Cognitive Demands

The task of Web browsing is not a trivial one. In fact, it can be very cognitively complex for older users. In some cases, older users have only partial and often incorrect models of the Web browsing task [2]. What is often considered by younger people to be a simple task of rapidly clicking through choices can be a daunting task for older users new to the Web. A simple example of this can be seen in the case of scrolling. Skilled Web users know that to see additional content that is off the bottom of the computer display, they must 'scroll down'. What is taken for granted by these skilled users becomes a challenge for older users who have a different mental model. Older users new to computers are likely to associate text with paper. To see something on the bottom of the paper, it may be necessary to move the paper *up*. Indeed, designers of interfaces aimed at older novice users have reported success replacing the scrollbar with buttons with labels to be more consistent with user expectations [14]. The mismatch between expectations and task demands may be even more daunting in a voice browser where users direct the computer with commands *based on* a faulty mental model.

Successful attempts at voice browsing have been reported for younger adults [15], [16] and have been incorporated into Web browsers [17], [18]. We can wonder whether older adults find the interaction natural. We note, for example, that the list of commands that will work must be enumerated for users [17]. Skilled computer users can understand this need to limit the command vocabulary. Novice users may not understand that and assume, instead, that the computer will simply *understand* them.

We can think of a number of aspects of a Web interface that could be more or less difficult to control with speech. Certain browsing tasks might be anticipated to be easy, such as going 'Home' and 'Back'. More difficult might be how to select a link on a navigation bar or in the main content area of a page. Even more difficult would be entering urls. Some urls might be relatively straightforward, such as 'CNN', but even this straightforward url would need to map properly to a full url and, failing that, require a complex editing or selection operation. Extremely problematic would be long or complex urls.

As we set out to explore these issues we began by not constraining or suggesting commands. We started, instead, with an open-ended task in which participants could direct the computer using any command vocabulary they chose. Our primary goal was to learn what commands our participants would naturally use to control browser activities. We were interested both in general browsing commands, as well as what commands people might use to control our IE and Firefox adaptation software.

3.2 Wizard of Oz Study for Web Navigation

To determine how older adults would navigate the Web using only voice commands, we conducted a small 'Wizard of Oz study'. In this study, the experimenter served as the speech recognizer. This eliminated errors due to faulty recognition. Thus, problems with browsing could be attributed to task demands or user misunderstandings. Although not a controlled study, the results from our participants were illuminating.

The study participants were seven English speaking older adults who lived near the IBM Research facility in New York. They were recruited through advertisements requesting paid participants for research on computer usage. Before beginning the study, all participants met with the experimenter, signed consent forms and completed a background questionnaire about personal characteristics and computer experience. Participants included five women and two men. All but one rated themselves to be experienced Web users. With the exception of that one person, all reported regular Web browsing, ranging from 3 to 4 times per week to daily Web usage. Participants ranged in age from 65 to 75. On the whole, this was a well educated group of individuals and all were retired from professional jobs, many of which had required computer use as part of the job.

Fig. 5. Screenshot of the **speak text** panel

Each experimental session was videotaped. A session began with the explanation that we were trying to learn how people would browse the Web using speech. Participants were generally aware of speech recognition as a technology and were positive about the possibility of being able to use it for Web browsing. The experimenter then introduced them to our IE or Firefox software. Participants were guided through the basics on how the software worked and were given an overview of the features that allowed them to change settings. This overview lasted about ten minutes. After that, they were given about five minutes to explore the Web on their own, using our software. Following this, they were told that they would be trying to navigate the Web using only speech. That is, the experimenter would control the mouse and keyboard and the participant would control the computer by speaking commands that the experimenter would execute. An entire session lasted approximately one hour. We looked both at commands to control the preference settings in our software and at commands to control basic browser navigation.

To anticipate, the task proved to be more difficult than we initially imagined. The participants varied a great deal in terms of their computer experience: The least experienced was just learning to use a computer, while the most experienced reported having used computers for 20 years. All others reported some number of years of experience with computers. Not surprisingly, the two participants with a great deal of computer experience fared reasonably well. The more novice the user, however, the more difficult they found the task. Despite the fact that speech was considered a more 'natural' means of interaction than using a mouse, it became immediately clear that these users, particularly the more novice users, had no idea how to direct a Web browser verbally. Pointing to the screen to indicate their preferences was much easier than being able to compose a verbal command. In this sense, the mouse was a better controller than was a spoken command.

3.3 Setting Preferences by Voice

Because our settings control interface had proven to be quite simple to use with a mouse [5], we had anticipated that our participants would have little difficulty in speaking commands to set preferences in our software. We learned we were mistaken.

Prior to our study we suspected that participants would readily say "forward" or "next" to move to the next panel in our set of control panels. We also believed they would naturally say button names (such as "faster" in Figure 5) in lieu of a mouse click. While the more experienced users were more inclined to behave in this manner, less experienced users had more difficulty. In many cases, the users wanted to describe what they wanted to do in long sentences, rather than short, recognizable commands. It is reasonable to assume this behavior was somewhat exacerbated by having a live person present. In large part, however, this behavior was due to the fact that the users did not have enough experience to understand that short commands were needed.

The task of naming buttons in the panels was particularly difficult in the case of buttons that acted as toggles. For example, the button for 'one hand' keyboarding in our software uses a toggle – clicking the button once turns the computer's StickyKeys feature on and clicking the button again turns the feature off [9]. Users who had no trouble saying "one hand" to turn on the feature were confused as to what to say to turn it off. This is somewhat surprising since clicking to turn on a feature and clicking again to turn it off is *logically* equivalent. Seemingly, the changed interaction modality changed the task enough to make this interaction awkward.

It also became clear that it was tedious for users to have to say "forward" several times to move through panels for features they wanted. While the interface worked well with mouse clicking, it seemed unwieldy with voice commands. Participants quite reasonably wanted to simply say what they wanted to do.

In sum, it became apparent that a number of modifications to the interface design would be needed to have an optimal design for use with voice commands.

3.4 Internet Explorer and Firefox Controlled by Voice

Other research has explored possible voice command sets to be used for controlling Web browsers [15], [16], [17], [18]. This work has not, however, specifically looked at use of these commands by older adults. For our purposes, it was, therefore, important to determine commands that might be most acceptable to these users.

As was true with our accessibility software interface discussed above, we were not very successful when being non-directive with browser navigation commands. Participants generally had no idea of what to say to the computer to navigate the Web. In some cases they were reduced to silence. In other cases, they gave long descriptions of what they wanted to do. In one case, we observed the confusion that the user said they wanted to go "up", by which they meant that they wanted to scroll down. In some cases, participants were so unclear as to what they wanted to do that the experimenter could not understand their request. In other cases, it required long conversations to clarify what the participant wished to do.

After two participants, we switched to having a printed list of commands to see how well the participants could use them. We asked participants to suggest better words if they did not like or feel comfortable with the suggested ones. This approach worked much better than the open ended approach, although the participants did constantly refer to this list, even after several uses of specific commands.

Participants were able, generally, to do the basics of scrolling and moving back and forward. "Home" turned out to be a confusing term in that sometimes participants meant to go to the website's home page (such as CNN home after having drilled down a few levels) and sometimes meant to go "Home" meaning the browser's Home button. With voice, there was no clear distinction in these two uses of the word Home. With a mouse click, this would not have been a confusion.

We did not try having participants using numbered links to indicate a link they wished to select [16]. We anticipated that participants would read the text of links in order to select. This, too, was more difficult than we had anticipated, with participants more often than not unsure about what to say. There was a tendency to continue to draw on mouse analogies even though they were not necessary. For example, our participants tended to say "click weather" to select a weather link, and "click go" to select a Go button. Interestingly, one participant felt most comfortable navigating by saying "mouse left", "mouse down" and so on to move the mouse around the page to targets.

Participants in this short study tended to go only to websites well known to them. They found it natural to say things such as "go to google.com" or "go to yahoo.com". There was a tendency to want to fill in forms by speaking whole words, although users seemed to have no trouble spelling the words for forms when the experimenter requested this for text entry.

4 Discussion

It is important to keep in mind that our participants attempted to use voice browsing for less than an hour. It is quite likely that with more practice they would have improved greatly in their facility to use commands for browsing. Indeed, one of the experienced users was able to maneuver quite rapidly. For novice users, however, the voice commands seemed quite daunting and it is likely that initial reactions to a voice browser would be quite negative: they simply could not use voice commands without having a better model of how browsers worked. This experience is reminiscent of the work of Zajicek in finding that novice older users had a great deal of difficulty using screen reader technologies due to limited mental models of the tasks [2].

Participants in our study were often positive about the idea of using speech commands despite difficulties. After their experience with trying to use to control browsing, however, some spontaneously complained that they wished they could just use the mouse which was ‘easier’. Most did not have any dexterity limitation, so were not strongly motivated to use speech by an inability to use the mouse and keyboard. The one participant who did have a great deal of pain in her hands wanted very much to have a speech alternative to the mouse and keyboard. For such users, speech offers the potential for easier access. For many, however, the cognitive complexity of using these commands will be a challenge to be overcome.

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How Can We Make IT Devices Easy for Older Adults? Effects of Repetitive Basic Operation Training and Help-Guidance on Learning of Electronic Program Guide System

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Abstract. Older adults have difficulties in using unfamiliar IT appliances because they look poor to learn operations in trial-and-error fashion. To find a different way for older adults to learn operations effectively, an experiment like usability testing with Electronic Program Guide (EPG) system on a HDD/DVD recorder was executed. Unfocused general information was not helpful for learning new operations. Repeated practice of basic operations with timely help-guidance messages facilitated the acquisition of targeted elementary actions and made them easy to learn new elementary actions as well as new complicated operations. It was suggested that older adults could learn better from successful operations than from trial-and-errors, which may induce harmful error spiral. It is necessary to investigate how to avoid error spiral in self-learning environment in home use.

Keywords: Help-guidance; Repeated practice; Usability testing; Electronic Program Guide (EPG) system; Error spiral; Errorless learning.

1 Introduction

Although older adults are said to have difficulties in using unfamiliar IT appliances [1-4], appliances in daily life, e.g. TV sets, which have been used by most old adults without serious difficulty, are getting more difficult to use because their design concepts are now based on information technology. Electronic Program Guide (EPG) system of TV sets and HDD/DVD Recorder is a typical new function implemented in the common daily appliance. The program schedule data of all available channels are provided with the broadcast and displayed on call on the screen as a table. Many extended functions such as scheduled recording of a selected program are also available. EPG is a quite new system with many useful but complicated functions. The user interface of EPG system is quite different from that of conventional TV set and similar to the GUI of PCs, since its operation depends on the information displayed on the screen.

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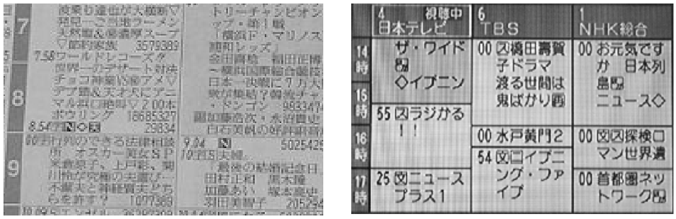

(a) (b)

Fig. 1. Shows a TV program table in Japanese newspaper (a) and in EPG system (b). It is provided in a format of 2-dimensional table of channel and time.

In our previous study [5], the usability test of EPG system was performed with older and young adults of different experiences on personal computers. Young adults learned GUI operation by trial-and-errors. On the other hand, older adults, especially those without PC experience, could not learn GUI operation in trial-and-error fashions. The observation of them suggested that error itself makes it difficult for older adults to learn operations. Uncertain understanding of the basic operation induces errors, and the errors prevent older participants from learning the basic operation. This harmful error spiral finally results in deadlock or loss of motivation to use new appliances.

Evans et al. reported that errorless learning is an effective training/rehabilitation method for memory deficits patients [6], and it is also proved effective in psychological memory tasks for healthy older adults [7,8].

In this study, we tried to find methods for older adults to learn operations apart from trial-and-errors. Our strategy was to keep users away from serious errors with guidance and repeated practice.

2 Methods

2.1 Participants

Participants were 5 older adults (68-73 years, average 69.8) and 5 middle-aged adults (51-65 years, average 59.6) totally 10 without substantial experience of PC operation and cellular phone mail and with experience to use VCR. All participants were voluntary and paid for this experiment.

Half of them were assigned to "early-support" group and other half was to "late-support" group. The familiarity with VCR was equalized between both groups by prior easy operation test.

2.2 Procedures

Three-days consecutive usability testing was executed with ten older adults, which was done individually. Before the experiment, pre-test session was held for each participant, which was consisted the explanation of the objectives of the experiment, the interview about personal background and experiences with IT-based systems. In addition, their experience on VCR operation was confirmed by easy operation test.

On the first-day of the experiment, they heard instruction and saw demonstration of thinking-aloud method, and then they had some practice of thinking-aloud with Tangram puzzle. After some conceptual explanation about the functions of EPG system, the usability test was executed task by task. At the planned timing in and the end of each day, participants were interviewed by experimenter. The experiment lasted 1.5-2 hours a day. Utterances and behaviors of participants were recorded by an IC sound recorder and 3 video cameras aiming the remote controller, the TV screen and participants. All button actions on the controller were logged at the infrared receiver.

A DVD/HDD recorder (EH-60) with TV monitor (TH-32D30T, Matsushita Electric) equipped with EPG system, and a standard remote controller was used. Some buttons on the remote controller were hidden to decrease confusing factors.

2.3 Help-Guidance

During the usability test, two types of help-guidance were provided by the experimenter. The messages were given to both early-support and late-support groups at different timing.

General message: the following messages were given to the early-support group just before tackling the tasks for which the message was helpful. The same messages were given to the late-support group at the end of the day.

- The screen consists of various areas including TV program table, commercial messages, and operation instruction area.
- The system has two separate storage areas: HDD and DVD.

Context-dependent guidance messages: the following help messages were given as needed. The early-support group was given with these messages immediately when they were applicable. The late-support group was given after they showed difficulties.

- Invalid operation: e.g. the button you are pushing is invalid now.
- Current status: e.g. the TV program table is shown now.
- Hint: e.g. please pay attention to the on-screen message.
- Answer: e.g. please push the red button.

During the test, participants often forget the final goal. In such case the goal maintenance message was given for both groups: e.g. please confirm the target of your operation.

2.4 Tasks

To use the EPG system functions with the remote controller, users must acquire the following 4 elementary actions:

- Direct button action: e.g. “power on/off” and “channel selection” which are directly associated to fixed basic system functions

- Cursor action: selecting an item shown on the screen with “up”, “down”, “left” and “right” keys followed by pushing “execute” key
- Color button action: “blue”, “red”, “green” and “yellow” keys are defined in the EPG specification, whose function is context-dependent and shown in the operation instruction area on the screen
- Menu selection action: some complicated functions are organized to multi-layered menu tree structures and the users should make step-by-step selection at each layer

The direct buttons are simple and familiar to older adults. Cursor action and menu selection action are derived from IT operation and quite new to the participants of this report. Color buttons are characteristic of EPG system. Video game players will be familiar with these buttons but older adults will not.

The system operations are performed with combined sequences of the elementary actions. The following basic operations represent the fundamental functions of the system. It is easy for users to imagine what happens with these basic operations. These basic operations were repeated several times.

- Examine TV program table
- Setup scheduled recording
- Review recorded programs

The system has more complicated functions e.g. program search and dubbing. The operations of them, i.e. complicated operations, are also performed with elementary actions. Fig. 2 shows the operation schema of EPG system.

The tasks given were as follows. The name of each task is shown as Task <date>-<sequential number>.

The tasks of the first day were as follows:

1-1: Turn on the TV set.
1-2: Display the program table and examine the TV programs.
 – Provide information on layout of program table only to the early support group.
1-3, 1-4: Display the program table of different days and examine the TV programs.
1-5: Setup scheduled recording for three assigned programs.
1-6: Review recorded programs.
1-7, 1-8: Setup scheduled recording for favorite programs.
1-9: List the table of the scheduled-recording-programs
1-10: Cancel the specified scheduled-recording-programs

Task1-2, 1-3 and 1-4 were tasks to repeat practice of basic cursor operation and to be used to information on the screen such as functions of color buttons. Task 1-5,1-7 and 1-8 were tasks to repeat practice of the scheduled–recording to use cursor, enter and color buttons. On task1-1 to 1-4, programs are specified, but after Task 1-7, users had chance to select their favorite programs. The subjectivity and their will for their operations could be improved by having targeted their favorite programs.

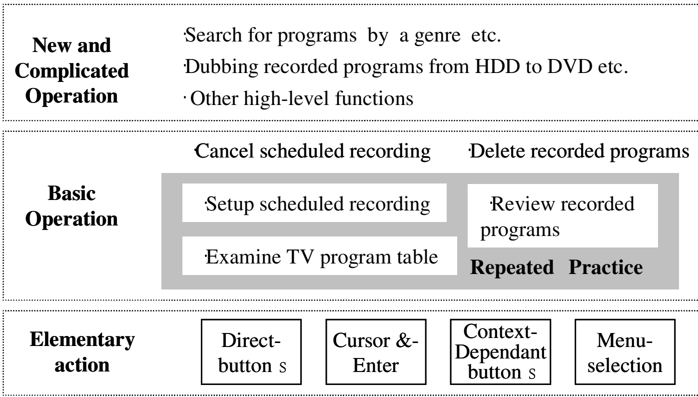

Fig. 2. Shows the operation schema in EPG system. Both of basic operations and new and complicated operations are performed with combined sequences of the elementary actions.

The tasks on the second day were as follows:

2-1: Turn on the TV set and setup scheduled-recording
2-2 to 2-4: Operations related to review of recorded contents.
2-5 to 2-9: Operations related to scheduled-recording.
2-10, 2-11: Operations related to review of recorded contents.
2-12: Search for assigned movie programs.
2-13: Search for programs of favorite genre.
– Provide information on HDD and DVD only to the early support group.
2-14: Review the program on the DVD.

The tasks on the third day were as follows:

3-1: Turn on the TV set and setup the scheduled-recording.
3-2, 3-3: Operations related to review of recorded contents.
3-4, 3-5: Operations related to scheduled-recording.
3-6: Review the programs on the DVD.
3-7: Dubbing of three recorded programs from HDD to DVD.
3-8: Operations related to scheduled-recording.
3-9: Operations related to scheduled-recording and cancel double-reservation.
3-10: Start recording on the screen at once.

2.5 Analysis of the Behavioral Data

The achievement of each participant was coded as 3 categories: "success by oneself", "success with hints" and "failed", depending on the help-guidance provided. When the user completed the task without "hint" and "answer" messages, his/her achievement was coded as "success by oneself". When "hint" message was given before completing the task, the achievement was coded as "success with hints". Otherwise the achievement was coded as "failed". The number of participants coded as each category was counted.

In this report we mention the results of the previous study, where the help-guidance above was not available before the users gave up or were in a deadlock. Otherwise the test conditions were similar to that of this study. Please note that the previous study was performed with young and old PC users and non-users, but the results with older participants without PC experiences are referred in this report as previous study.

3 Results

The first obstacle for the users was the cursor action in Task 1-2, where the users were requested to display the program table and examine the TV programs. All users of both groups (5/5 in each groups) needed hints to complete the task, suggesting that all users were equally not familiar with system operation at the start of the test. The result was almost the same as older adults without PC experiences in the previous study.

3.1 Effects of Unfocused General Information

The second obstacle for the users was the color button action in Task 1-3, where the color buttons have function to change date of the TV program table. Only early-support group was informed of the general screen layout just before tackling the task. Table 1 shows the number of participants who completed the task by themselves, i.e. who found the color button function shown on the screen. The performance was not different in two groups. Although very clear message focused on color buttons was not given, the general information given can be a good hint to understand the color button action. But it turned out to be ineffective..

Table 1. Number of participants who found the color button function shown on the screen

	te ete	l te	t l	e t
N. of participants	4	6	10	7
ne el (k)	2	3	5	1
ne el (k 4)	4	4	8	1

Another general information regarding HDD and DVD was given to early-support group before Task 2-14, where the users were requested to review the programs recorded in the DVD. However, the number of users succeeded by themselves in Task 2-14 was 2 / 6 and 2 / 4 in early-support and late-support groups, respectively. Again unfocused general information was not helpful.

3.2 Effects of Repeated Basic Operation with Help-Guidance

In this study, basic operations were incorporated to different tasks, offering repeated practice of basic operations. One of basic operations, scheduled recording, was incorporated as Tasks 1-5, 1-8, 2-1 and 3-1. The performance of these tasks is shown in Table 2. At the first trial in Task 1-5, performance was almost the same between two groups. However, the performance was better in early-support group in Task 1-8, suggesting early support facilitated learning of the basic operation. Users in early-support group seemed to acquire elementary actions more effectively. On the next day the performance was worsened back. On the third day the performance was improved.

Table 2. The number of participants who achieved "scheduled recording"

ou	e u o e		Su o e	
	h eve	e ve o	h eve	e ve o
				4
			6	

As a whole, the performance was improved during other repeated operations. The performance in Task 1-4 was better than in Task 1-3. Similar improvement was also observed with other repeated basic operations but was not in the previous study, where help-guidance was not available before giving up or deadlock. These results suggest that older participants learn by repeated successful practice with timely help-guidance but not with trial-and-errors.

3.3 Improvement with New and Complicated Tasks

The last obstacle in this study was menu selection action. Task 2-12, TV program search, was quite new to participants. For this task, 4 steps of menu selection action were required. Specifically, at the root menu, action type {search for program, scheduled recording,...} was to be selected first. At the 2nd step, the method for search {by category, by keyword, ...} was to be selected. Then, category {movie, sports, ...} {Japanese movie, foreign movie, ...} was to be selected. At the final step, sub-category "Search task" needs to be selected. The performance at each step was shown in Table. 3. Note that the first step, select action, can be skipped if the users came from alternative path. Five participants in this usability testing could notice alternative path.

Surprisingly, the performance of both early- and late-support groups was far better than that in the previous study ($p<0.01$). The menu selection action was new to all participants in the present as well as previous studies. This result suggests that it was easy for the users after acquisition of two new elementary actions, cursor and color button actions, to learn another new elementary action, menu selection action, in the new complicated operation. The search operation lead to a list of TV programs found with a new screen layout. The participants were requested to change date with color buttons and to setup scheduled recording with cursor action. Most users had no difficulties in using appropriate buttons even on the new screen. They found appropriate actions with trial-and-errors at this and later tasks. This was never observed in the previous study.

Table 3. The number of participants who passed the each step on menu structure

ou	u o e	e u o e	o	ev ou S u
N. of participants	4	6	10	7
1. Action "Searching for" e ve h	(	)	)	
2. Method "By category"				
3. Category "Movie"	4	6		4
4. Sub-category	4	6		4
h g		6		
h r r g r		4	6	

4 Discussion

This study suggested that general information without clear focus on the target operation was not so helpful for older adults even if it was provided just before tackling the task. It seems to be difficult for older adults to understand general information in relation to actual operation before becoming aware of system behavior. It can explain the reason why the printed guidance manuals are not so helpful for them.

Timely help-guidance was proved to be helpful for older adults. Once they gave up or fell into deadlock, help-guidance was not effective at all. It was also shown that older adults learn elementary actions with repeated successful basic operations with timely help-guidance and become easy to learn other new elementary actions as well as new complicated operations at the same time. Help-guidance could not a rescue of error spiral. So, it is important to avoid falling into error spiral.

It was observed that a user proceeded to next operation before good comprehension, got confused by new operation. For example, a participant learned the operation of scheduled recording followed by program review. Then, she forgot what she learned first. It is important, but is not clear in this study, how to tell whether the user has reached to complete acquisition of the operation after repeated practice.

We felt that once several basic operations were completely understood, older adults may be able to learn new and complicated operations in trial-and-error fashions. It should be really important that the users successfully learn the basic operations first.

Among the help-guidance messages given in this study, “invalid operation” and “current status” messages can be implemented in the system with ease. The “hint” and “answer” messages depend on what the user want to do and are difficult to be implemented in the system. It is necessary to investigate how to avoid error spiral in self-learning environment in home use.

Many appliances targeted to older adults are equipped with large fonts and large buttons. They just compensate the deterioration of the sensory and motor functions, and are not enough to improve usability of IT appliances. Not only these peripheral functions, but the cognitive function based on the central activity of brain and memory is also impaired in accordance with aging. This factor is to be considered for user interface design of IT appliances. So, it is important to investigate the learning process of older adults as well as appropriate learning environments.

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On Some Aspects of Improving Mobile Applications for the Elderly

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Abstract. Improving the quality of life of elderly people is an emerging issue within our information society for both research and development. This paper addresses some issues on the development of applications for mobile devices, which have been designed to enhance the quality of life of the growing number of elderly people, and how they can be made more acceptable to the target population. We summarize some relevant issues in order to devise a research methodology to cover more than just the technological and physical aspects of user interfacing but also psychological and sociological aspects. One aspect of achieving this aim is to confront designers and developers with those problems that the elderly face daily and which are not easily understood – especially by younger designers and developers. Finally, we present some issues on how to simulate certain physical constraints of elderly by using the AgeSim, which is a simulation suit. However, not only physical but also cognitive impairment cause problems amongst elderly and result in fear, anxiety and consequently in rejection. The main goal of this paper is to raise awareness amongst developers on which problems are to be taken into considerations during design and development of mobile applications for the elderly.

Keywords: Usability, Mobile Interfaces, User-Centered Design, Age Simulator.

1 Introduction and Motivation

There is no doubt that the application of mobile devices can improve and support the lives of the elderly, given the willingness on the part of those concerned to use these devices. Increasing *acceptability* must be based not only on a thorough knowledge of the requirements of the elderly but also on their misgivings.

Facilitation of usage is only one aspect of the problem which must be dealt with. In order to bridge the widening digital divide [1] that has grown up between the technical experts and the increasingly older generation, who were adults before the

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electronic revolution, it is also necessary to understand their *uncertainties* and *difficulties*. Research is therefore also aimed at investigating ways to *increase motivation* and *improve acceptance*. It will be geared towards analyzing the fears, problems and requirements of the target group, particularly taking such factors as previous profession and gender [2] into account and using the results to make the design more elder-user-friendly. For example, the same technology which has made miniature digital hearing aids possible has also made other technical devices, such as mobile phones, so much smaller and more compact that the use of these devices has become difficult for the elderly. However, designers and developers need to understand their needs, which need not necessarily be just bigger brighter virtual keyboards and larger script. Their motivation is different, their frustration level is lower and they may have to overcome previous, negative experience. We are of the opinion that the design and development of mobile applications for elderly must support the users to overcome their fears and enable them to accept technological aids and mobile devices without reservations. The design must then reflect this acceptance and not be the cause of new biases.

2 Background: Problems of the Elderly

Problems of the Elderly can be categorized coarsely into *Cognition* (Attention, Memory, see section 2.1.), *Motivation* (Attitudes, Beliefs, Fears, Anxiety etc., see section 2.2), *Physical* (Movement, Balance, Locomotion, Joints (Fingers) etc., see section 2.3), Force Control, etc.) and *Perception* (Vision and Audition, see section 2.4). Cognitive and Motivational Issues are difficult to simulate (see section 4), however, we are able to simulate some physical and perceptual impairments by use of an Age Simulator (see section 5).

2.1 Cognitive Complexity as Barrier

The use of technological applications requires a certain level of *procedural knowledge*. Certain knowledge procedures, stored in the long-term memory permit the required human-computer interaction in a certain situation. The usability of the application essentially supports the acquisition of new knowledge procedures in order to operate and interact with the application properly. The Cognitive Complexity Theory (CCT) by Kieras & Polson (1985) [3] is a formal approach in order to analyze the complexity of an interactive application. The end users' knowledge of how to use a system to accomplish various tasks is represented in a procedural notation that permits quantification of the amount and complexity of the knowledge required. This results in a definite quantification of the *cognitive load* involved in using a system [4]. This implies that making a system more usable could be accomplished by altering its design until the knowledge is adequately simplified. By representation of the device behaviour, it is possible to *simulate* the user-application interaction to obtain rigorous measures of user complexity [5]. Since *cognitive performance* slows down with age, lowering the complexity of applications or the user-application interaction for (novice) elderly users could be a vital factor for design and development of mobile applications. Ziefle & Bay (2005), [6] found that the benefit from lower complexity was much larger than theoretically predicted. This means that simply defining cognitive complexity by the number of production rules does not account for the *real difficulties* which the users experience in real contexts. In the experiment of Ziefle & Bay it was interesting that elderly users had a lower navigation performance than younger users, however, their performance matched the younger users when using *mobile applications with low complexity.*

This was reinforced by the research on Learning done by Midford and Kirsner [7], which confirmed that the implicit learning ability is not reduced by aging, however that older people were at a disadvantage compared to young adults in their ability to perform accurately when complex material was repeated.

2.2 Motivational Issues of the Elderly

We can put such issues as beliefs, attitudes, anxiety, fear, computer literacy, acceptability, etc. under the terminus *motivational issues,* whereby motivation is described as a psychological construct. Therefore, it is interesting that motivation can be stimulated by the use of technology and that motivation is essential for learning.

It is noteworthy that most people attribute the elderly with a reluctance to use modern technology. While it is generally acknowledged that older people are less apt to accept new and unknown technology than their younger counterparts [8] and that it tends to make them feel uncomfortable, some researchers found that older adults are actually motivated to use mobile applications – when they are sufficiently informed as to the resulting benefits [9], [10]. That could mean that the reduced usage rates by the elderly is also the result of poor understanding of the benefits that mobile applications could have for them, as well as their reluctance to learn a skill, which they feel requires a highly specialized form of expertise or special knowledge that they lack.

Basically, computer literacy is highly related to computer anxiety [11]. It is therefore essential to ensure not only a high *learnability* [12] but also a high recognisability content in order to advance a feeling of security. Although the ability to understand and benefit from technology is far less dependant on age than those affected are disposed to believe, it does require flexibility and effort, which many elderly people are unwilling to invest unless the benefits offered clearly outweigh the disadvantages. Some research showed that older adults tend to loose concentration easily and become bored with the subject, one possible cause of this apparent rejection may be due to the form of anxiety that is based on the mistaken distrust in one's own capabilities [13].

Other research indicated that most participants felt less anxious and more confident about using technology after being taught computer-based skills [14]. For the developers it is a must that they understand the attitudes of the elderly towards technology, a good chance to achieve this is the application of User-Centred Development (see section 3).

2.3 Physical Impairments of the Elderly

Clearly, the physical effects of aging cannot be universally quantified; however studies show a number of common illnesses which can be classified as age-related. rheumatoid arthritis, while not being exclusively age-related, has been shown to cause isolation and depression in the elderly [15] and sometimes hinders the use of technological innovations, such as mobile telephones and the internet, which could help reduce the isolation caused by lessened motor activity.

However, in most cases the effects of aging are less drastic. They include slower response times, coordination reduction and loss of flexibility [16] Age-related macular degeneration can be the cause of restricted eyesight without complete blindness, while deafness may be preceded by years of gradual loss of hearing. But this combination of partial loss of vision, hearing, memory and mobility contribute to a loss of confidence, which leads to difficulty in the absorption of information.

The impairment of fine motor skills is also often a factor in older peoples' unwillingness to use a PDA or a laptop with an integrated mouse. For example, the standard setting for desktop icons is small and few older users are aware of the possibilities of user customization, neither do they possess the necessary knowledge for their implementation. Various studies have found that older people have greater difficulty in using a mouse to track on a screen and that, even after some practice, their performance on a computer is generally slower [17]. Basically, there are five distinct human factors which show measurable disparities between older and younger people:

(1) learning time (=time to perform task)
(2) speed of performance
(3) error rate
(4) retention over time
(5) subjective satisfaction

In order for modern technology to be of assistance, it is essential that it takes these differences and the associated difficulties into consideration.

2.4 Perception (Vision and Audition) as Barrier

Changes in vision and audition are the most obvious causes of restrictions to which the elderly are subject. One cause of visual impairment is age-related macular degeneration (ARMD), a disorder that the Rotterdam Study in 1995 [18] cited as being the most frequent cause of blindness in the elderly and has been seen to increase in frequency with people over 65 [19]. However, in the main, this disorder *restricts* the eyesight resulting in partial impairment. With the correct interface design this should not be an obstacle to using modern technology. Other age dependent changes in vision, which must be taken into consideration in design and development, include:

(a) those where ability decreases with age:

(1) visual acuity (ability to resolve detail);
(2) visual accommodation (ability to focus on close objects);
(3) colour vision (ability to discriminate/perceive shorter wavelengths);
(4) contrast detection (ability to detect contrast);
(5) dark adaptation (ability to adapt quickly to darker conditions);
(6) glare (susceptibility to glare);

(b) those where the necessity increases with age:

(7) illumination (required light – increases with age); and

(c) those where an age dependant reduction can be observed:

(8) motion perception (motion estimation);
(9) peripheral vision (width of field narrows).

Presbycusis, which is defined as *an inevitable deterioration in hearing ability that occurs with age* [20], is a multifactorial process that can vary in severity from mild to substantial [21], [22]. Auditory facilities which noticeably decrease with age include:

(1) auditory acuity (ability to detect sound),
(2) auditory localization (ability to localize sound),
(3) audition in noise (ability to perceive speech and complex sounds).

Although, language is closely related to cognition and is often treated as a separate subject, there are many issues which can influence the language comprehension of elderly people [23]. Understanding this is necessary, in order to design both textual and auditory content for mobile applications properly – when designing text-based materials the limitations of the working memory of the elderly must be taken into consideration [24].

3 Some Design and Development Issues for the Elderly

Although touch screens have proved to be very good for older adults [25], [26] touch screens on mobile devices are extremely difficult for older adults to use due to the small size of the targets and the difficult handling of the stylus (see fig. 2).

Jog dials/thumb dial, for example, could be an solution; or if touch screens are used with small devices the application must be optimized by increasing the target areas in order to use rather their fingers than the awkward pointing device (stylus), because (as described in section 2.3) elderly have difficulty in making accurate, movements requiring fine motor skills or even fast movements with their fingers – for example, a double-click with the mouse – is problematic. The elderly are less sensitive than children to tactile feedback [27].

Cognitive Performance can be supported by placing information in the task environment, which reduces cognitive demands on the end user. Perceptual declines can be coped with, to some extent, by improving the physical stimulus in order to perceive and recognize that stimulus. Display information consistency – consistency is required for learning and cognitive performance support. Recognition and incorporation of previous knowledge can increase interest and motivation, which in turn can improve performance levels.

Experiments have been made with the use of speech systems to counteract some of these difficulties, primarily those caused by restricted sight. Menus and usability interfaces have been simplified to minimize the amount which needs to be memorized in order to use the applications and special mobile phones have been designed with only 3 buttons to simplify the connection to emergency services in case of emergency.

Emergency bracelets are available in many countries, which automatically contact an emergency address when the wearer either looses consciousness or presses a button.

However, all these systems are basically designed as emergency backup for invalids or severely disabled people. The question of selective disability – that is elderly people who are otherwise fit – needs to be addressed with insight, not only into what is required to enable older people to remain independent of full time nursing but also their preferred lifestyle and minor incapacities. When the use of a modern cell phone is hampered by partial arthritis, speech control might well be the answer but it is also worth investigating the optimum size of of 12-button cell phone keypad.

In order to develop both useful and usable mobile applications – especially for the elderly – a particular method brings benefits: User-Centered Development (UCD) proved to be very effective [28]. Some key principles of UCD methods include *understanding the end users* and *analyzing their tasks;* setting *measurable goals* and involving the end users from the very beginning. Based on the experiences within previous work [25], [29], [30] we found UCD of particular importance to realize usable and useful applications, especially for mobile devices. However, sometimes the work with end users is not always possible and most of all the issues of the elderly are not totally understood and accepted by the developers, in this case simulation of some of the restrictions, to which they are subject, can make difficulties clear to developers and raise awareness in design issues.

4 Simulation of Cognitive and Motivational Impairments

The main slant of interest in cognitive impairments has been to try and understand those affected from a psychological viewpoint. The HCI approach aims to use simulation to explore ways and means of decreasing difficulties of use caused by assumptions in design. Due to the danger of cognitive overload, applications should be developed in order to achieve cognitive congeniality; further we (designers, developers, engineers, researchers) should target towards *adapting information to people's individual needs and levels of expertise* in order *to enhance cognitive performance.* Ideally the system should learn with the user, offering less and less assistance as the user progresses. It should present an optimal level of relevant information, thereby holding the user in a state of optimal arousal, minimize and optimizing cognitive load and reduce the number of distracting elements.

5 Simulation of Physical and Perceptual Impairments

The main difficulty facing researchers, designers and developers lies in envisioning the difficulties which could arise from a minor physical disability, which they themselves do not possess. During software design, the end users must be included in the specification and testing of any new product. However the variety and extent of physical disability, for example, a partial sight and speech impediment, makes this extremely difficult. We are of the opinion that, in order to actually understand the difficulties of the end users it is necessary for the developers to feel and experience these difficulties during the first design iteration. An American idiom says *"don't* *judge a man until you have walked a mile in his boots"* This metaphorical advice has been taken seriously in the development of AgeSim, which is a device designed to permit a developer to experience the restrictions caused by various types of impairments, whether from age or other causes (see figure 1).

The AgeSim is a current project at the University of Applied Sciences JOANNEUM in Graz and was originally developed by Alexander Nischelwitzer and his students Nina Tomasch and Jasmin Wundara. The AgeSim suit was created to simulate physical restrictions of different groups of people. So it is possible to feel how an elderly, a disabled, an overweight or a pregnant person feels. If you wear the suit you are able to identify barriers more easily. Possible simulations include: old age; overweight; pregnancy and disability. The logger and the AgeSim have to communicate with a headset. We are also able to simulate hardness of hearing with this headset and the test leader can communicate with the AgeSim test user.

The AgeSim suit resembles a boiler suit with some rather shrewd additions. The under arms and leg joints are webbed, thereby restricting the height to which the arms can be raised and the length of the stride. A number of weights fit into the pockets of the suits trouser legs, gloves, designed to simulate arthritic joints and the decreasing sense of touch, and a helmet, which reduces sensory perception. The helmet restricts the mobility of the head and has a number of accessories, one being exchangeable visors to simulate various eye disorders the other is a mountable camera for recording what the user sees during usability tests. The logger and the AgeSim user communicated via a headset. It is also possible to simulate hardness of hearing with this headset and the test leader can communicate with the AgeSim test user.

Fig. 1. AgeSim let designers feel how certain physical impairments feel to the end users

The test person in figure 1 was an engineer, in the best of health. After putting on the suit and gloves, he was weighted and fitted with a helmet, the sides of which hindered sound waves while the visor reduced his vision by more than half.

He was given two exercises: to walk up 3 flights of stairs and to use his mobile telephone. The stairs were less of a problem than we expected, possibly our subject was a little too healthy. But the second exercise caused a total rethink. Not only was it almost impossible to use the stylus to make a connection, the reduced sight made it difficult to see the number being “dialled” and the sound control on the mobile device was insufficient to compensate for the reduced hearing. It is an experience for designers and developers and especially for computer science students, to feel the limitations in fine motor skills and movement during the use of a mobile application – add the visual impairments and auditory limitations (see figure 2) and the necessity for a complete rethink is made clear.

Fig. 2. It is astonishing for developers to feel how complicated the use of a mobile application actually can be for people with physical impairments (movement, eye, etc.)

6 Conclusion

The increasing ratio of older people to younger people in the western world makes it essential that elder people remain fit, independent and secure well into advanced or high age. Medical Informatics undertakes to improve the standard of living for this growing population of elderly people, for people with disabilities, general health problems or ongoing conditions, such as diabetes and epilepsy, but this multimedia information must be presented so that their actions can be supported – particularly in emergencies – with the help of mobile, ubiquitous technology.

Given a sufficiently high acceptance level, mobile technology can help to achieve this goal. However, for any end user to accept innovation, a clear benefit must be offered, whether in a physical, medical or emotional respect. This must be achieved on a number of levels: The design needs to be adapted to the end user’s physical impairments; the interface must offer a relative degree of familiarity to overcome any reservations felt by the end user; the benefit of using the device must be appreciable, in order to provide a motivation for its use and the balance between intuitive use and practicable teaching methods, designed for learning needs of this age group, must be established. This can be as complicated as an ergonomic, *fits-the-hand,* mobile phone or as simple as supplying the mobile with a wrist strap to *decrease the user's fear* of dropping it. The application of AgeSim and similar simulation opportunities can give the designer a closer knowledge of the difficulties facing end users and help answer some of the questions arising around usability optimization for older people:

A further aim is to discover some of the parameters of complexity reduction for information technology by applying Human–Computer Interaction and Usability Engineering (HCI&UE) methodology to the problem of how to optimize information presentation, in order to enhance the design and development of interfaces that will also satisfy the requirements of non-technical generations and simplify interaction with sophisticated devices.

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Touch Screen User Interfaces for Older Adults: Button Size and Spacing

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Abstract. This study investigated the optimal button size and spacing for touch screen user interfaces intended for use by older adults. Current recommendations in the literature are aimed at general audiences and fail to consider the specific needs of older adults. Three independent variables, button size, button spacing, and manual dexterity were studied in two experiments that measured reaction time, accuracy and user preferences. Design recommendations for touch screen button size and spacing for older adults are stated based on these experiments. The paper also discusses the role of manual dexterity in designing appropriate touch screen interfaces for older adults.

Keywords: older adults, usability, touch screen, user interface design.

1 Introduction

Touch screens are widely used in applications such as information kiosk displays, ATMs and home systems for environmental control, security and health care. The intuitiveness and ease of operation of touch screens has made them popular in products for older adults. However, to achieve these benefits, it is critical for the designer to trade off the target size and target spacing associated with the control buttons in the touch sensitive area of the display. This is especially important when the screen space is very limited. While recommendations and previous studies exist in the literature, these are aimed at general users rather than older adults.

For systems using touch screens, the ISO [1] recommends that the size of the touch-sensitive area should be at least equal to the breadth of the index finger distal joint for the ninety-fifth percentile male. The EIA [2] recommends that the minimal touch-sensitive size should be 19.05 mm [2]. Pfauth and Priest identified key size as an important factor in touch screen use when the interface involved a hierarchical menu display [3]. Other studies revealed that larger key sizes led to better performance in touch screen interfaces that support numeric keypad entry or menu entry [4, 5, 6, 7, 8, 9,10].

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For a matrix of buttons such as an iconic navigation panel or numeric keypad, the size of the spaces between adjacent buttons must also be considered. For touch-sensitive screens designed for first-contact touch activation, the ISO [1] recommends providing an inactive space at least 5 mm wide around each touch target. The EIA [2] recommends that the spacing between touch sensitive areas should be at least 6 mm. Previous studies revealed some interesting results with spacing. For example, Scott and Conzola's [11] results support the use of compressed (2mm or less) inter-key spacing in keypad designs. Martin [6] recommended compressed 6 mm inter-key spacing for square keys. Colle and Hiszem [8] recommended that 1 mm spacing should be used if sufficient space is available and spacing as small as 0 mm might be acceptable if space is very limited. Sun's study [9] with firefighters also indicated that the size of button spacing usually did not affect performance. However, when the button size is very small, such as 20 x 20 pixels (6 mm on Sun's display), zero-inch spacing decreased performance. Sun's experiment also showed that there is a tradeoff between speed and accuracy that depends on spacing. Larger spacing resulted in fewer errors, but increased the reaction time. Beaton and Weiman [4] also found that users preferred vertical spacing of 5 or 10 mm and horizontal spacing of 10 mm.

The studies described above set some general guidelines for touch screen button size and spacing, but they do not consider the special characteristics of older adults that might affect the use of touch screen interfaces. Carmeli, et al. [12] provides an extensive review of changes in the aging hand that affect manual dexterity. Goggin and Meeuwsen [13] found age-related differences in the spatial aiming and pointing movements commonly associated with manual dexterity, with older adults emphasizing accuracy over speed. Pratt, et al. [14] found that hand pointing movements of older adults were qualitatively different than younger adults. Ketcham, et al.[15] had younger and older adults perform a similar aiming task, varying target size and position on a screen. They found that decreasing target size caused older adults to make more corrective movements than younger adults as they propelled their hand toward the target, which resulted in slower reaction times.

The study reported here sought to determine the optimal control button size and spacing for touchscreen-based user interfaces for older adults. Two experiments were designed to test researchers' hypotheses. Experiment 1 was a touch test with only a single button. The test simulated a device that has only one key or two or more non-adjacent keys. Experiment 2 was a touch test with multiple buttons and simulated a device in which adjacent keys are laid out in rows.

2 Experiment 1 – Single Button Touch Test

2.1 Design

Subjects. Twenty-six older adults (13 female and 13 male) aged from 53 to 84 years (mean = 71.81, SD = 6.91) gave their informed consent to participate in Experiment 1. All subjects were right-handed. Subjects were recruited from Social Welfare of Shanghai-PuTuo Area (13 persons) and the elder college of East China Normal University (13 persons).

Experimental Design. The experiment used a 2 x 9 repeated measure design. Pegboard performance had two levels, high PB and low PB, and was treated as a between-subjects factor. Button size was treated as a within-subjects factor and had nine levels: 6.35 mm, 8.89 mm, 11.43 mm, 13.97 mm, 16.51 mm, 19.05 mm, 21.59 mm, 24.13 mm, and 26.67 mm). The only dependent variable was reaction time (RT).

2.2 Procedures

Peg Board Test. All subjects' were tested using the Peg Board Test published by The Morrisby Organisation [16]. This test measures manual dexterity using a straight-forward task that requires candidates to assemble pins, washers and collars and place them in holes.

Single Button Touch Test. After the pre-tests, all subjects were asked to perform the single button touching test. Before the formal testing, they were given a 12-trial practice. During the test, a single target button appeared in a random position within a designated 160 mm x 160 mm area at the center of the screen. The subjects were asked to touch the target button as quickly and accurately as possible. Within 500 ms after the subject touched the target, the next target would appear. Subjects were asked to place their finger in a standard ready position, the lower right corner of the touch screen. All stimuli in each condition appeared randomly to avoid ordering effects. A total of eight repeated trials were measured in each condition for each subject.

Equipment. The experiment was set up in a room with daylight lamp lighting. An ELO 17 inches Touch Screen LCD (Model number ET1725L-8uWF-1, 442072-001) was used at a resolution of 1024 x 768. The subjects were asked to sit in front of the touch screen and adjust their position relative to the screen until they were at a comfortable viewing distance. Also, they were allowed to adjust the tilt of the display screen for a comfortable viewing angle, typically 75° relative to the desk.

2.3 Results

Peg Board Test. Based on Peg Board Test scores, each subject was assigned to one of two groups, a High PB (Peg Board Test) group and a Low PB group. Subjects were scored on two Peg Board subtests, preferred hand and both hands. Higher Peg Board Test scores indicate greater manual dexterity. Subjects whose PB Score (Right Hand) was greater than or equal to 12 and PB Score (Both Hands) greater than or equal to 18 were placed in the High PB group.

Single Button Touch Test. By design, accuracy on this test was 100%. A trial began only after the button in the previous trial had been touched. The buttons were touched on every trial. Therefore, only data on reaction time was recorded and analyzed.

Figure 1 shows the mean RT for the entire sample of 26 subjects as a function of button size. Repeated measure analysis revealed that the main effect of button size was significant, $F(8, 192) = 27.770$, $p^{***} < .001$, indicating that RT decreased as the button size increased.

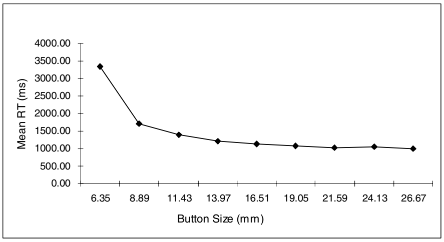

Fig. 1. Mean RT (ms) on a single button touch test for all subjects at different button sizes

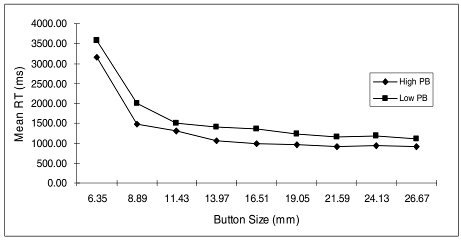

Fig. 2. Mean RT(ms) on a single button touch test for the High PB group and Low PB group at different button sizes

One way ANOVA revealed that the Mean RT at size = 6.35 mm was significantly longer than the mean RT at sizes > 6.35 mm. The mean RT at size = 8.89 mm was significantly longer than the mean RT at sizes >= 13.97 mm. No significant difference was found between the Mean RTs at 11.43 mm, 13.97 mm, 16.51 mm, 19.05 mm, 21.59 mm, 24.13 mm, and 26.67 mm. Also shown in Figure 1 is a slight increase in the Mean RT at size = 24.13 mm which suggests that faster RTs could not be obtained by increasing button size further.

Figure 2 compares the RT performance of the High PB to the Low PB group at various button sizes. Analysis showed no significant group effect of PB level, $F_{(1, 24)} = 2.900$, $p > .05$, and no significant interaction of PB x Size, $F_{(8, 192)} = .203$, $p > .05$, even though the High PB Group (Mean =1074.05, SD = 373.07) was 21.83 % faster than the Low PB group (Mean = 1373.91, SD = 480.22). This indicates that manual dexterity as measured by the Pegboard test does not significantly affect the performance in touching an isolated button on the screen.

3 Experiment 2 – Multiple Button Touch Test

3.1 Design

Subject. Fourty older adults (22 female and 18 male) aged from 50 to 85 years (Mean = 70.08, SD = 6.39) participated in Experiment 2. All subjects were right-handed. Subjects were recruited from Social Welfare of Shanghai-PuTuo Area (23 persons) and the elder college of East China Normal University (17 persons). All 26 subjects who participated in Experiment 1 also participated in Experiment 2.

Experimental Design. The experiment used a 2 x 6 x 5 repeated measure design. Peg Board performance had two levels, high PB and low PB and was a between-subjects factor. Button size was treated as a within-subjects factor and had six levels: 11.43 mm, 13.97 mm, 16.51 mm, 19.05 mm, 21.59 mm, and 24.13 mm. Spacing also was treated as a within-subjects factor and had five levels: 0 mm, 3.17 mm, 6.35 mm, 12.7 mm and 19.05 mm. Dependent variables were reaction time (RT) and accuracy.

3.2 Procedures and Equipment

As in Experiment 1, all subjects' were tested for manual dexterity using the Peg Board Test. Following the pre-tests, all subjects were given a 12-trial practice on the multiple button touch test and then asked to perform the formal test.

The multiple button touch test worked in the following manner. A button with a picture on it appeared at the top of the screen. A 3 x 3 matrix of buttons with pictures simultaneously appeared directly below it on the screen. The subjects' task was to select the button from the 3 x 3 matrix that matched the button at the top of the screen, e.g. had the same picture as the one at the top. Subjects were told to use their finger to touch this button in the matrix as quickly and accurately as they could. Within 500 ms after touching a target in the matrix, the next trial would appear. Subjects were asked to place their finger in a standard ready position, the lower right corner of the touch screen. After the touch testing was completed, the subjects were asked to choose the most comfortable and preferred button size, horizontal spacing, and vertical spacing. All stimuli in different conditions appeared in random to avoid ordering effects. A total of 5 repeated trials were measured in each condition for each subject.

3.3 Results

Peg Board Test. As in experiment 1, all subjects were separated into one of two groups based on their Peg Board Test scores. Subjects whose PB Score (Right Hand) was greater than or equal to12 and PB Score (Both Hands) greater than or equal to 18 were placed in the High PB group. Those scoring lower than this were placed in the Low PB group.

Multiple Button Touch Test. The data of 40 subjects were analyzed using a 2 x 6 x 5 repeated measure analysis, with the factors PB Level (2), Button Size (6), and Button Spacing (5). Reaction Time (RT), Accuracy and Preferences were analyzed. The first and second responses and the extremes (over 1.5 SD) were excluded from the statistical analysis. Excluded data comprised only 0.033% of all data collected.

Reaction Time. *Size and Spacing Main Effects.* Figure 3 shows the Mean RT for each combination of button size and spacing. Repeated measures analysis of RT revealed that the main effect of button size was significant, $F_{(5, 190)} = 32.443$, p***< .001. The Mean RT decreased as the button size increased. One way ANOVA analysis of size revealed that the mean of RT at size = 11.43 mm is significantly longer than the mean of RT at size > 11.43 mm. The mean of RT at size = 13.97 mm is significantly longer than the mean of RT at size > 13.97 mm. No significant difference in RT was found between the sizes 16.51 mm, 19.05 mm, 21.59 mm, and 24.13 mm.

The effect of button spacing was also significant, $F_{(4, 152)} = 7.682$, p***< .001. The subjects showed the longest mean RT at a spacing of 19.05 mm (Mean = 1881.73, SD = 846.8) and achieved the shortest mean RT at a spacing of 0 mm (Mean = 1732.01, SD = 737.78). One way ANOVA analysis of spacing revealed that the mean RT at spacing = 19.05 mm was significantly longer than the mean RT at spacing < 19.05 mm. The mean of RT at spacing = 12.7 mm was significantly longer than the mean RT at spacing = 0. No significant difference was found between the mean RT at other spacings: 0 mm, 3.17 mm, and 6.35 mm.

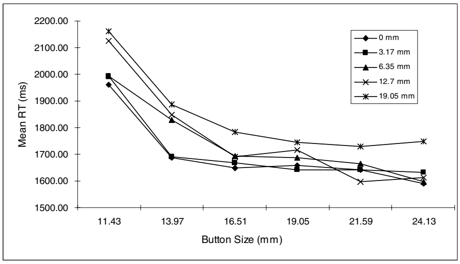

Fig. 3. Mean RT (ms) for all subjects at different button sizes and spacings in a multiple-button touch test

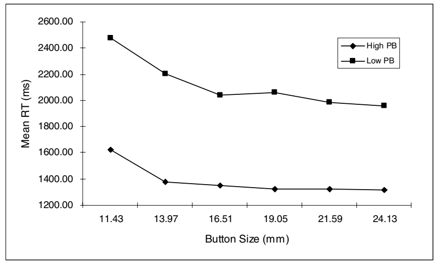

Fig. 4. Mean RT (ms) of each group for button sizes in a multiple-button touch test

Effects of Manual Dexterity on RT. Figure 4 shows the significant main effect of manual dexterity as measured by the Peg Board Test, $F_{(1, 38)} = 25.545$, $P^{***} < .001$. Reaction Time of the High PB group (Mean = 1384, SD = 422.5) was 34.69% shorter than that of the Low PB group (Mean = 2119, SD = 890.4). No significant interaction was found, but there was a trend for the interaction effect of Size x Peg Board Test Level, $F_{(5,190)} = 2.739$, P*(Sphericity Assumed) = .021 < .05, P(Low bound) = .107 > .01.

For the High PB group, a one-way ANOVA revealed that RT at button size = 11.43 mm is significantly longer than at sizes > 11.43 mm. RT at size = 13.97 mm is significantly longer than at sizes = 19.05 mm or 24.13 mm. There were no differences between button sizes of 19.05 mm, 21.59 mm, and 24.13 mm. For the Low PB group, a one-way ANOVA indicated that RT at size = 16.51 mm is significantly longer than sizes > 11.43 mm. RT at size = 13.97 mm is significantly longer than sizes > 13.97 mm.

Also, for the High PB group, the RT curve becomes flat at 16.51 mm, while the RT curve for the Low PB group becomes flat at 19.05 mm. This might explain the trend for an interaction effect on RT between size and Peg Board level. There was no significant interaction of size x PB, space x PB or size x space x PB.

Accuracy. *Size and Spacing Main Effects.* As Figure 5 shows, as a whole, the subjects performed the multiple button test with high accuracy (average correct responses = 98.85%, SD = 0.05). Repeated measure analysis of accuracy revealed a significant main effect of Size, $F(5,190) = 5.237$, $p^{***} < .001$. Accuracy tended to increase with button size from 11.43 mm to 19.05 mm, where it was highest (Mean = 99.6 %, SD = 0.002). Accuracy decreased a little for larger button sizes of 21.59 mm, and 24.13 mm. However, even at these button sizes, accuracy was still 99.4% and 99.2%, respectively. There was no significant main effect of spacing on accuracy, $F(4, 152) = 1.612$, $p > .05$.

Effects of Manual Dexterity on Accuracy. The effect of manual dexterity on accuracy was not significant, $F(1,38) = 1.049$, $P > .05$. However, Figure 6 shows that for all button sizes smaller than 24.13 mm, the High PB group tended to perform with higher accuracy than the Low PB group. However, the differences were not statistically significant. Also, there was no significant interaction on accuracy for size x PB, space x PB or size x space x PB.

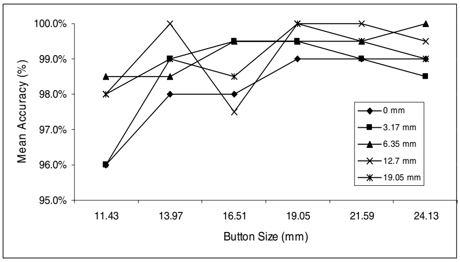

Fig. 5. Mean accuracy (%) for all subjects at different button sizes and spacings in multiple button test

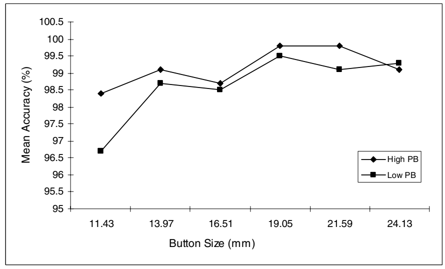

Fig. 6. Mean accuracy (%) of each group at different button sizes in a multiple button touch test

Subjective Preferences. *Overall Button Size.* Chi-Square Tests of expressed subject preferences revealed a significant difference at different button sizes, $x^2 = 14$ df = 4, P** < 0.01. The subjects favored button sizes of 16.51 mm and 19.05 mm.

Manual Dexterity and Button Size Preferences. Analyzing the preferences of each PB group separately revealed a statistically nonsignificant, but rather clear trend in preference for a button size of 19.05 mm in the High PB group, $x^2 = 8.155$ df = 4, $0.05 < p < 0.1$. In contrast, the Low PB group's preferences were distributed across a range of the larger button sizes: 16.51 mm (31.8%), 19.05 mm (22.7%), 21.59 mm (18.2%) and 24.13 mm (27.3%). Low PB subjects thought large buttons were better and made the touching operation easier. Some High PB subjects also mentioned the comfort and ease of use of larger buttons, but were concerned that very large buttons are less convenient because a large space that must be searched in order to use them.

Overall Button Spacing Prefernces. A Chi-Square Test revealed a significant difference in preferred button spacings, $x^2 = 35$ df = 4, P*** < .001. Fourty-four percent of the subjects preferred a spacing of 6.35 mm, 17.5 percent preferred 3.17 mm and 21.25 percent preferred 12.7 mm. Note these are all in the middle of the range of spacings tested.

Analysis also revealed no significant difference between the preferred horizontal spacing and the preferred vertical spacing, $x^2 = 0.512$ df = 4, P > .05.

Manual Dexterity and Button Spacing Preferences. Analyzing the preferences of each PB group separately revealed a significant difference between High PB group and Low PB group, $x^2 = 26.713$, df = 4, P*** < .001. Compared to High PB group, the Low PB group preferred larger button spacings. The High PB group preferred spacings of 3.17 mm (30.56%) and 6.35 mm (58.33%). In the Low PB group, spacings of 6.35 mm (31.82%), 12.7 mm (34.09%) and 19.05 mm (25.00%) were significantly preferred over the other spaces.

4 Recommendations and Discussions

4.1 Button Size

It was hypothesized that older adults would have shorter reaction times with larger touch-sensitive buttons was supported by the experiments, which is consistent with previous studies [4,5,6,7,8,9]. Accuracy of performance presented a noisier and slightly more complicated picture. The older adults in Experiment 2 did not perform with significantly more accuracy as button size increased. However, they were most accurate with buttons that were 19.05 mm square. In addition, consistent with previous studies [4,5,6,7,8,10], the majority of the subjects expressed a preference for buttons that were large, but not too large, 16.51 mm and 19.05 mm square.

What design guidelines for sizing touch-sensitive buttons can be stated based on the results of these two experiments? First, if one is designing a separate button with no adjacent buttons, and a reaction time of around 1400 ms is acceptable, then an acceptable minimum button size is 11.43 mm square. A larger button size, such as 19.05 mm square, should be used if the task requires better performance. Second, if the user interface design uses rows of adjacent buttons and screen space is limited, then a button size of 16.51 mm square is acceptable. Again, if faster response performance is required, then a larger button size, such as 19.05 mm square, should be used. The experiment results show that buttons of this size also produce the highest accuracy of response and are quite preferred by older users.

4.2 Spacing

It was hypothesized that larger spaces between touch-sensitive buttons must improve the touch screen performance of older adults generally was not supported. The subjects had longer reaction times with larger spaces between buttons. This is consistent with Sun's [9] findings with younger subjects. Martin, et al. [6] have explained similar findings in terms of Fitts' Law [17].

What guidelines for touch-sensitive button spacing can be derived from these experiments? If the user interface design uses rows of adjacent buttons on a single screen, then the buttons should be separated by a space of 3.17 mm to 12.7 mm. Older adult subjects preferred a spacing of 6.35 mm for this kind of button layout and also were most accurate with this spacing. Large spacing (19.05 mm in this experiment) will only increase the time for searching the screen and moving to touch the target button. Designers should be cautious of using no space between buttons. Although zero spacing did not affect response speed in these experiments, it was associated with the lowest accuracy and the lowest preference ratings.

4.3 Manual Dexterity

Manual dexterity will not significantly affect the performance of touching an isolated button on the touch screen, but it has a significant effect on speed and a slight effect on the accuracy of selecting and touching a target button embedded in a row of adjacent buttons. Scores on the Peg Board tests were an effective way to categorize older adults according to their manual dexterity. The High Peg Board Test subjects were able to touch the target button more accurately and more quickly and preferred relatively smaller buttons and spacings. Subjects in the Low Peg Board Test group touched the buttons more slowly and preferred relatively larger buttons and spacings.

These results suggest that a designer who applies these button size and spacing guidelines needs to be cognizant of the target population for his or her design. If the target is older adults with relatively normal manual dexterity, then a button size of

16.51 mm and spacing of 3.17 mm to 6.35 mm should be appropriate for screen layouts that require rows of adjacent buttons. However, for older adults with poor manual dexterity a larger button size, at least 19.05 mm and a larger spacing, 6.35 mm to 12.7 mm, is required.

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Creating Home Network Access for the Elderly

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Abstract. Wireless broadband networks for home environment present us with many challenges unfamiliar in more public settings. At home, we encounter the end-users with little ICT experience. Probably among the most challenging members of the home network are the elderly, who may have demanding needs for ensuring accessibility. Either living in a joined community as in a home for the elderly or at home on their own, the possibility to have a remote connection to the homes of their extended family may become important by e.g. decreasing mobility. Interconnectivity between various heterogeneous networks across multiple homes means for example situations where the family shares a photo album or web server with various pieces located at different homes. In this paper, we identify usability challenges presented by internetworking multiple homes, with a special focus on universal accessibility.

Keywords: Home networks, accessibility, usability, user interface design, security, accessibility, authentication.

1 Introduction

In this paper, we identify usability challenges presented by internetworking multiple homes, with a special focus on universal accessibility. The analysis was conducted in order to find out, on basis of analyzing existing user behaviours and needs, what kind of user needs the elderly, as part of an extended family that includes their children and grandchildren and other relatives, may have in connection to home networking. Either living in a shared, yet private community of a special home for the elderly or in their own home, the additional connectivity offered by the emerging home network may prove to provide for true enrichment of the daily lives all family members. The study included a perspective on using these future connections for creating increased value for their own personal habitats inside the elderly home by having their own network access, of having connections to the other inhabitants of the home for the elderly, as well as of having access to and being accessible from the homes and networks of their relatives and friends elsewhere.

In a typical home for the elderly, there are several "user groups" that make up the community and have quite differing roles and amount of involvement in the daily routines of the home. Firstly, there are the inhabitants, the elderly, who for one reason or the other no longer wish or can live on their own. Secondly, there is the personnel,

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for whom the home is a working place. Thirdly there are the family members of the inhabitants and friends, who visit the home on a more or less frequent basis.

We were especially interested in seeing what type of *contents* the elderly would be most interested in sharing with others. Also, we were interested in any *privacy* issues involved in getting connected with both the elderly home's inhabitants and personnel, as well as with the family members and friends outside the elderly home. We were not so much focusing on how the connectivity could be utilised for monitoring the health of the inhabitants of the elderly home as often is the case with studying the elderly, but more on how it could enhance their lives by enabling them to be more involved with others, both inside and outside the home. Thus, we were not concentrating on the life-enhancing technologies and their usability or accessibility.

The work was done as part of a project focusing on wireless broadband home networks, where the goal is to build interconnectivity between several home networks through broadband access networks in an easy-to-use and secure fashion. This research aims at ensuring reliable and secure broadband end-to-end connectivity between peer devices within one home. The peer devices can also be in multiple sites in several wireless home networks. This is a challenging environment to begin with, since the target recipient is a consumer without technical expertise.

A further challenge is created by the multitude of end devices, legacy and new ones, entering and leaving the home network at any moment, and the number of technologies provided for enabling the connectivities both within the home and between the homes. In addition to developing system architectures and internetworking solutions, the project will also analyze business value systems: identifying future service possibilities for the vendors in the field based on the discovered user needs.

The work at hand was a natural continuation of user studies conducted with families with children earlier. That work was done in order to gain a basic understanding of the current situation of the home networking in families. Families with children were selected, since the family members might have interestingly conflicting interests in sharing and withholding information from other family members. This work is reported in [7]. We wanted to probe further into understanding the user needs of the extended family as these questions were constantly raised during the initial interviews, in the case of families of divorced parents, and especially in regard to the needs of the elderly.

The paper is organized as follows: First, we will present an overview on the approach to building a home network in our project. We will proceed by describing the different use scenarios identified earlier in the project. Then, we will present relevant work done in the area of usability work in home networks, especially in relation to the elderly, including some work on the accessibility issues. We will then present the method, study setup, and the results of the user need analysis conducted. On basis of the analysis of the findings, we will present enhancements to both the usability and accessibility of our proposed user interface solution for home network management, as well as an analysis of the possible future uses of such network in the context of a home of the elderly and its individual inhabitants.

2 Home Network and Its Users

2.1 The Home Network

What constitutes a home network in practice is not a simple question [3]. In order to identify the challenges embedded in building internetworking via broadcasting

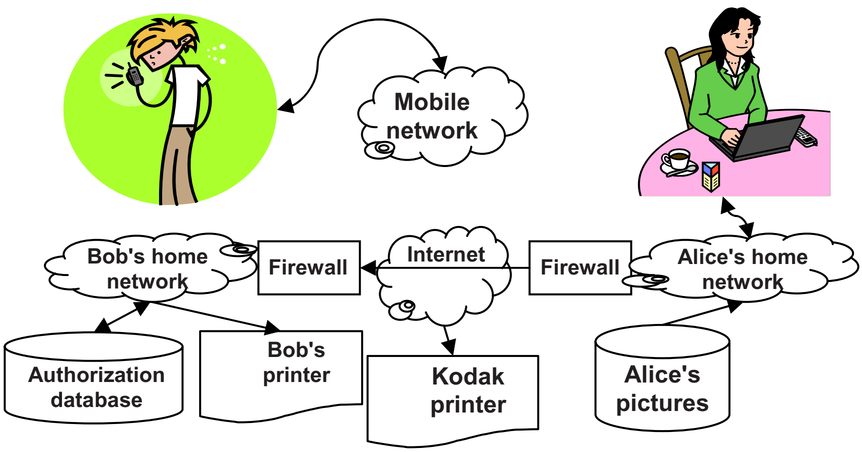

Fig. 1. An example of home network content sharing

between multiple homes in a secure and easily manageable way, we first need to understand what kind of totality of devices, applications, and information we are to manage. The basic concepts of "home", "network", "internetworking", "user" etc. are ambiguous – in order to proceed we need to build working definitions of the basic concepts we are dealing with.

One of the main advantages of wireless home network is that it allows the creation of totality where different kinds of terminals can be used together for accessing any content and services that are part of the home network. The home network can be used for *sharing content*: photos, records, or videos can be accessed both within home with own or visiting terminals, or remotely from outside the home, enabling a wider audience of this type of personal content, but with restricted access that enhances the privacy as compared with completely open ways of sharing, as e.g. by using flickr.com or similar services for sharing photographs with others online. Sharing photos – and thus sharing memories and experiences – is one of the key uses that will have core place in the emerging home networks also. For example, in one family in the user study we have reported in [7], a grandson had placed a "home server" in his grandmother's apartment, allowing easy access to the joint digital photo collection of the two for the grandmother.

Home networks also allow mixing of content coming from different sources. A typical example of this could be interactive television. In the home networking scenario, members of the family could share and join experiences by interacting with their personal devices on the TV show, competing against each other or against the others as a team. In the future, it will also become possible to enrich the contents by tagging and marking, enabling the *sharing experiences of the content* as well. A simple example is music sharing, where it is already possible to add tags to the streams for others to look up as “interesting parts”.

Of course, a fully-fledged home network could also be utilised for surveilling purposes. For example, the parents might want to check if their kids already arrived home from school and how they are doing while still at work. In the case of the elderly, the possibility to monitor the users with special needs and, possibly, also stay alerted on any changes of a fragile state of health may become an important addition of the possibilities enabled by the home network.

One more possibility is to control the home devices when away. A good example of remote control user needs is in [6], who report on the users’ expressed wish to “take care of the home” remotely in their study. In case of progressing memory loss, an elderly person might want to access their home from a distance, in order to “make sure the stove was turned off”.

The above scenarios illustrate some cases of how the home wireless network can be used. To realize these visions, further development is required on several technology areas. For example, novel circuit and radio technologies are required for the implementation of the network itself. In addition, terminals must be able to work in heterogeneous networks, which must be made secure too. Finally, the applications and the content have to be interchangeable between the different devices.

On basis of these observations, we have defined the home network in the following way: *Home network is a constantly changing totality of devices – computer, A/V systems, mobile devices – that can be connected to each other, together with the internet and broadband connections, and that is used by a non-technical user group, typically a family, for personal needs.*

2.2 Home Users

Analyzing the user needs of the household inhabitants is not an easy task, since these needs may vary substantially. Defining different user roles with corresponding privileges and restrictions clearly is a must. Also, what users understand as home, network and its boundaries may is not be self-evident.

According to [5], currently most broadband adopters typically have several computers in their household and these early adopters are also more familiar with the networking than the majority of home users. So the level of understanding and know-how about technology and security issues among the current users of home networks is likely to be higher than average and inferences from their experiences must be made with caution [2].

An important issue to understand when trying to create a home network with security features is that *perceived* security might differ from the actual security. [1] make an excellent point in examining how people experience security in their everyday lives. People make mistaken inferences about what is secure and what is not, and for them, the boundary of computer or network security may not differ from physical security, or at least the boundaries of these areas is unclear and ill-defined for them. This will have major repercussions on building the security, since people may not feel safe if we only provide them with the technological answers, without really understanding their needs.

Continuing in the lines of study of [10], [2] point out that some devices are of more individual nature than others clearly intended for collaborative usage, so user expectancies about their usage may also vary accordingly from device to device. This became evident also in [6], where the initial attitudes towards the various devices also changed during the study phase of six months of actual usage. This study on couples living in a smart home is reported in [6]. In this work it was evaluated how the usage behaviours and UI expectations will develop in a smart home environment with several users over extended period of time (6 months). Three devices, PC, mobile phone, and a media terminal, were tested, and UI prototypes for these devices were designed and adjusted according to user feedback. It became clearly evident that the user expectations for each device were different, mobile phone becoming the most used device to control the smart home functionalities despite initial reluctance and suspicion towards it as suitable for operating the home. Initial emotional response may affect the adoption of usage for extended periods. The recent work of e.g. Donald Norman on the importance of affective responses to inanimate objects also enlightens this point [11].

2.3 Managing the Home Network

Usually, in the homes studied by [3], one household member had the major responsibility over managing the network, and the other household members did not need to be as knowledgeable about the network. This seemed to be the case in the homes studied by us as well [7]. Grinter et al [3] have identified three themes potentially causing trouble in home network maintenance. These are: 1) the myriad of networks that exist in households, 2) the household tensions that emerge due to different personalities and individual needs 3) the collective challenges met with in network administration and troubleshooting. They identify also the invisibility and (in)comprehensibility of the networks as problematic issues in home network management.

In regard to the special needs of different household members of varying ages and capabilities, the [4] presents a good report on the current level of understanding of the behaviour of the teenage members of the families. [4] also presents nicely the current state of existing home network usage practises, the telephone still dominating home communications. Yet, they report on increasing awareness of households on Internet technologies, and the family becoming a source of recreational computing. This increased usage of computers at home has also been the source of research studies, especially email and the World Wide Web (WWW) (e.g., [9], [12], and [15]). They further report on the findings of Kraut et al. [8] on how households tended to prefer *communication* activities over *information* activities. According to the authors, this ability to use the computer as a communication appliance may require not only personal access but also that members of our social circle have this, as well. In case of the elderly, this might have big impact in affecting communications between the elderly, since they might have asymmetrical access to computing and networking resources between them.

Edwards and Grinter [2] have presented seven challenges that home environment presents to ubiquitous computing technology. These include the deployment of such technologies; technical questions in interoperability, manageability and reliability; social issues in adoption of domestic technologies, as well as design issues. We will now consider three of these challenges from the accessibility point-of-view, on basis of our observations and the user studies reported in [7].

3 Analysis of Three of the Challenges in Home Networks from Accessibility Viewpoint

The three challenges are chosen as examples of how accessibility issues may affect how the home networking should be realized and communicated to the users in the case of the elderly users.

3.1 Challenge One: The "Accidentally" Smart Home

The general question of the first challenge by [2] is how the occupant-users adapt to the idea that their home has suddenly reached a level of complexity at which it becomes unpredictable. A specific question this scenario raises is how will they begin the process of making sense of what has happened. From an accessibility point-of-view, the analysis is two-fold. On one hand, an elderly inhabitant may in fact be used to uncontrollable changes, and accept them *as is.* The elderly tend to have to give some amount of their privacy and self-control away as they grow older. Having the home change in the same way, in an uncontrollable fashion may be experienced as a natural continuation of this process. On the other hand, the new situation may raise fear and resistance to change may occur, as more control is taken away from the users. With the wireless nature of this new technology, the invisible actions of the network may cause the incontrollability to seem unbearable.

3.2 Challenge Five: Social Implications of Aware Home Technologies

How the new “smart home” or “networked home” may affect its inhabitants social awareness also. The privacy issues may become pending when the home becomes aware and connected to the outside world in ways that cannot really be detected and monitored by its inhabitants. In the case of the elderly, it may be hard to judge, what is left from the privacy of the life led in the networked homes. What these implications may be is not clear and cannot be foreseen for any home users. However, the difference between the elderly users is, again, in that of level of the control that these users probably have about finding out and deciding on just how aware the home may become.

3.3 Challenge Seven: Inference in the Presence of Ambiguity

Challenge seven deals with the levels of smartness that the home should, in the end, achieve. Where are the boundaries, what should be monitored, for whom, and how? [2] present a thought-provoking example on how the smart environment can infer that some state exists by aggregating a number of other factors. For example, if a number of people are gathered together in a meeting room, the system might assume that a meeting is taking place. This type of inferences is unforeseeable and uncontrollable – and probably undesirable, too, for all users. Will the new technologies of the networked home be seen as tools for extended monitoring and surveillance by the elderly inhabitants and thus resisted by them, depends to a great extent on the ethicality of those embedding the connectivity and its controls in these domestic environments.

4 Conclusion

On basis of the analysis conducted on the challenges presented by the home networks from an accessibility point of view, we can clearly see that a lot needs to be achieved before the home network can become a desired reality to the elderly users also.

4.1 Future Work

As continuation of the theoretical work presented in this paper, and the already conducted user studies with families, we are in the process of testing our prototype UI implementation for pairing the home devices and personal devices, such as mobile phone and laptop, for example, with each other to form connections between them in a secure fashion in order to exchange contents such as digital photos between them, also with the elderly in order to detect accessibility issues and the special usability needs and user acceptability issues that these users may have with our current solution. We have already tested this type of connection forming between two mobile phones [13] and between a laptop and a mobile phone [14] with tens of users within the age range of 18-60.

However, the user base for these studies needs to be extended. Such initial connections form probably the most personal and graspable part of the emerging home network for all users, also the elderly for whom the mobile phone may be more of an asset in the less than perfectly private homes and lives that the new technology may mean to them. Assuring the accessibility and usability issues for these users is key enabler for safe, trusted, and successful communication for this special group of users – for staying connected, without becoming the new "Johnnys"[16] of the home networking world.

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Contextual Research on Elderly Users' Needs for Developing Universal Design Mobile Phone

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Abstract. As the aged society and digital convergence have been progressed, 6most of elderly users are having difficulties in using mobile phone with complex functions. It is necessary to develop mobile phone with easy and convenient usability for universal users including elderly based on concept of universal design. We conducted qualitative & contextual research on elderly users' contextual experience and interaction difficulties in using mobile phone in everyday life. Based on elderly users' need figured out in this research, we tried to retrieve User Interface Design implication for universal design mobile phone, which can be used easily by anyone regardless of age and ability.

Keywords: contextual research, elderly user, universal design, mobile phone, UI design.

1 Introduction

As the age of digital convergence and ubiquitous computing has been arrived, the function of mobile phone has become more and more complex and various. Because mobile phone becomes more important and necessary in everyday life in Korea, the increased complexity causes severe inconvenience to people with physical or cognitive disabilities such as elderly users who are come up as a main consumer group by the progress of the aged society.

Therefore, it is necessary to develop mobile phone with easy and convenient usability for universal users including elderly. In order to develop universal mobile phone, research for elderly users' difficulties and needs in using mobile phone in everyday life should be preceded.

The objective of this research is to retrieve User Interface Design implication for universal design mobile phone, which can be used by anyone regardless of age and ability, through figuring out elderly users' difficulties and particularities in using mobile phone in everyday life.

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2 Contextual Research Method

2.1 Characteristics of Contextual Research Method

The first challenge of design is to understand the customers: their needs, their desires, and their approach to the work. Yet work becomes so habitual to the people who do it that they often have difficulty articulating exactly what they do and why they do it.
Contextual inquiry uncovers who customers really are and how they work on a day-to-day basis. The cross-functional design team conducts one-on-one field interviews with customers in their workplace to discover what matters in the work. Team members observe people as they work and inquire into actions as they unfold to understand their motivations and strategy. The interviewer and customer, through discussion, develop a shared interpretation of the work.

Contextual research method is differentiated with usability test since it is a site visit to understanding how the client actually does. While usability test is a device-oriented evaluation process, contextual research method is a user-oriented discovery process. While usability test focuses the relationship between device or service and user, contextual research method focuses more on user environment including physical, psychological, cultural circumstances. Therefore, contextual researchers should have a wide perspective to look out over more various users' experience, not only interaction experience. Also, they should try to understand users' feelings and psychological problems more deeply and try to interpret cultural meaning of a device to users.

Team interpretation sessions bring the design team together to hear the whole story of each interview and capture the insights and learning relevant to their design problem. An interpretation session brings all team members' unique perspectives to the data, sharing design, marketing, and business implications. Through these discussions, the team captures issues, draws work models, and develops a shared view of the customer whose data is being interpreted and their needs.

2.2 Contextual Research Process

Survey for Recruiting Users. In order to recruit various level users, we implemented survey to 83 elderly people who uses mobile phone. The questions on survey were included to ask interest and level of usage on mobile phone. We selected 8 basic level users and 3 intermediary users over 60 based on survey result. Each level user can be categorized to the first groups who have intention to learn and use and the second group who give up to learn or who don't have intention to use.

The following table shows gender, age and model no. of the mobile phone, the participants were using.

Table 1. Profiles of elderly users

Users	Don't have intention to learn & use	Have intention to learn & use
Basic level Users	Female, 61yrs, LG SD330 Male, 68 yrs, StarTAC 2004 Male, 61 yrs, PS-K2500	Male, 61 yrs,SCH-X430 Male, 61 yrs, SPH-X4209 Male, 63 yrs, LG-SD9230 Male, 65 yrs, SPH-X4909 Female, 67 yrs, SCH-E560
Intermediary level users	Female, 72 yrs, SCH-X130	Male, 65 yrs, SPH-X4909 Male, 69 yrs,SCH-X700

The following figure shows contextual user research process applied in this study.

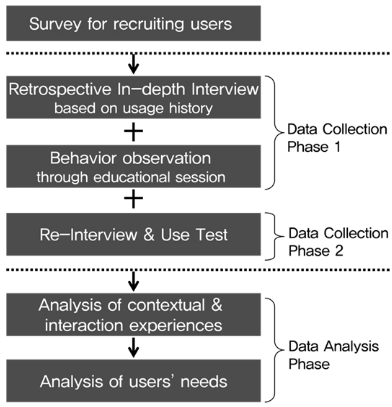

Fig. 1. Contextual research process applied in this study

Data Collection Method. First, we did retrospective in-depth interview to 11 elderly users regarding their perception of mobile phone, usage pattern and difficulties in using main functions in everyday life. Especially, we interviewed them with checking usage records (stored history on their phone) – in and out calls, sent and received text messages, phone number list on phone book, photo album, alarm and other settings. This method could help to inspect users' past experience with very concrete situation including usage context.

Second, we taught 8 basic level users with intention to learn major functions-inputting phone number on phone book, making a call by searching phone book, sending out text message, receiving and deleting text message, taking and saving a photo, checking and deleting photos. We intended to observe their perception, understandability, learnability, and error situation from their behavior during intimate, one-to one educational session.

Third, we re-interviewed and did usability test to 3 active users one month after the educational session, in order to examine how much and in what context they utilize newly learned functions in their everyday life, and what caused difficulties if they couldn't utilize them. The usability test could help to find error situation and analyze cause for the error.

All the interviews, educational sessions and tests were recorded under usability testing equipment to capture users' reaction and word and users' interaction with mobile phone.

Data Analysis Framework. Collected video data was reviewed and special episodes' video that shows elderly users' Contextual Experience (cultural, psychological factors) and Interaction Experience (difficulties in usage) were clipped. Each video clip was categorized into 7 usage situations – general perception/usage pattern, making/getting calls, using phone book, sending/getting text message, using camera,

Fig. 2. Scenes from user interview & interaction with mobile phone

using additional functions and et cetera. Almost 200 episode video clips were collected and each video clip was transcribed and added by observer's interpretation with notion of user factors and design factors. The following table 3 shows analysis form for episode video clips.

Table 2. Data Analysis Framework for episode video clips

Situation	*Category of 7 usage situation*	
Contextual / Interaction experience	*Explanatory title for the episode*	
Observed Fact	 *Title of video clip*	*Transcription of user's word*
Interpretation	*Interpretation or note for the episode*	
User factors	*User related cause for the situation-physical, cognitive, and psychological*	
Design factors	*Design related cause for the situation*	

Tables to describe each episode were re-categorized to draw out categories of needs. Development directions or solution ideas for universal mobile phone were generated based on the interpretation of categorized, related situations (related episode video clips). The following chapter will describe the detail of the elderly users' needs in using mobile phone.

3 Elderly Users' Needs in Using Mobile Phone and UI Design Implication

Elderly users' needs were mainly categorized into 3 factors such as physical factors in product design, cognitive factors in UI design and cultural, psychological factors in usage context of mobile phone.

3.1 Physical Factors in Product Design

Need for vision

Need for vision in screen. Elderly users were having vision difficulties in screen in the following cases; reading text in menu and text message especially when font is not gothic, and when color contrast between text and background is not obvious / identifying icons in upper part of the screen, whether text message is arrived or how much battery is left/ checking time in phone screen (they consider this feature very important) /identifying photo in album. They need bigger screen with big font size, gothic font type, obvious color contrast, obvious design or way to add text for status icons, big obvious clock setting, and a way to check photo with other big display equipment because of vision problem.

Need for vision in buttons. They were having vision difficulties in button in the following cases; identifying consonants and vowels of Korean and English on the button because they are layout so densely on small button/ finding side button's function. They need bigger button, separating design between number and text part on buttons, and more obvious clue for functions of the side buttons.

Need for Hearing

They missed calls because they couldn't hear ring tone and don't know how to change bell to vibration, so they selected the loudest ring tone, not the most favorable one. Many elderly users speak loud during call because they can't hear the counterpart. They need louder setting for ring tone with better speaker.

We found that a look of the mobile phone can influence to some elderly users' psychology regarding hearing. They associate better sound functionality to length that can cover from ear to mouth and to more or bigger holes on speaker. This misconception can be a reference to design appearance of mobile phone for elderly.

Need for Manual Dexterity

Need for manual dexterity in buttons. Elderly users become all thumbs, so we could find many times that they push wrong buttons (the very next button) or push buttons with finger nail because the button is too small and too close. They liked more obvious textual feedback and even auditory feedback by calling numbers. They prefer pushing less buttons. Especially, they couldn't control differentiating short push and long push on one button. They were also too slow when typing text message to complete a letter, because the cursor automatically moves to the next letter space. They need buttons with more obvious textual and auditory feedback when pushing buttons or navigating menus. Memorized number dialing should be provided with easy access. More than one function on one button should be restricted. Text making time should be set longer.

Need for manual dexterity in battery. They are having hard time when taking battery out or putting it in. The control part should be bigger and the manipulating way should be simple and clear. Graphic design on surface should give affordance to guide.

Need for manual dexterity in camera. Elderly users often block lens with their fingers when they use camera first time. We found that many pictures were out of focus because their hands couldn't be still. For supporting manual dexterity in camera function, lens should be layout away from users' hand position, and it is better to have steady shot function and handler or finger supporting design.

Need for Convenient Carrying. Elderly users prefer small and lightweight phone because of power weakness. Specially, male users appeal for inconvenience to carry mobile phone when it is thick. Their hands are easy to slip things because grip power becomes weaker. They need thin, lightweight phone with bigger screen and button ironically. Male users need a way to carry phone more conveniently. They need better grip with non-slippery material and body design for grip support.

3.2 Cognitive Factors in UI Design

Need for Function Restriction vs. Usage Evolving. Elderly users need restrict functions to the extent that they often use. They feel that mobile phone has too many functions they don't use. They are interested in functions that are not related to their everyday life. They need that mobile phone should support well only its main functions such as phone call with phone book, text message, camera, clock and alarm and basic setting for screen theme and ring tone. However, some elderly users had more interests and questions regarding infrequently used menus after educational session.

Need for Alternative Method Restriction. During educational session, some elderly users couldn't understand the difference between making calls from phone book and from call history. They insist to use the first-time learned method even though there is more convenient way. Supplying alternative method made them confused. They don't want alternative methods when they learn first time. They need simplified and authentic method to learn simply and to remember easily.

Need for Feedback for Current Mode. Elderly users are having difficulties in identifying current mode, especially when the screen design looked similar such as phone book and call history or shooting mode and album mode. Some users were confused whether they were deleting text message or photo. They need more obvious clues or feedback where they are. The screen design should be distinctive when some pages could be looked alike. Deleting functions could have consistency.

Need for Easy Access (Shallow Depth). The major reason of failure for most tasks was the access failure. Elderly users couldn't find functions in navigating menu. They couldn't find where "input phone number" menu or "send message" menu is. They couldn't know where they change screen theme. They feel stressful when the depth becomes deep. On the other hand, they like direct call with memorized number button, even when they never understand phone book functions. They want frequent menus in shallow depth so that it can be accessed directly.

Need for Simplification of Process. The other major reason of failure was that process needed too many steps to finish. Some users can't send text message because she can't follow the steps to complete sending message out. Elderly users don't want to use voice mail because it needs annoying verification steps. Many elderly users understand phone book as to store a phone number per name. They couldn't finish inputting phone book because phone book page has so many rows to input such as address, e-mail, memo, photo and etc. They need simplified process with least pages, steps and options. Especially, voice mail should be more convenient so that it can replace the role of text message when elderly are too old to read text message in LCD screen.

Need for Clue What To Do Next. Elderly users can't recognize things unseen on the screen. They don't try scroll down to find menu 4 or 5 when the menu box shows up to 3 menus. They don't know way to check text message with left, right arrow keys. Some couldn't find shooting button when they are taking pictures. One of them didn't know what to do when alarm is ringing while the folder is close. On the contrary, another user didn't know what to do when phone is ringing while folder is open. They need clues what to do at the moment in the specific cases, or what to do next in the process.

Need for Task Oriented Label. Some label with English word, abbreviated word, Chinese word, or inconsistent word makes elderly users confused. They need Korean, task-oriented and consistent label with clear meaning.

Need for Text and Number Key than Icon. The most obvious distinction between elderly and young users was whether they navigate menu with number keys or with arrow keys. Most elderly users were using number keys. When the number key was gone or didn't work, elderly users were confused. They can't identify meaning of icons, so that number keys and text menu can be more efficient to deliver meaning. Especially, number key should be supplied anytime in any page and it shouldn't be gone or blocked.

3.3 Cultural, Psychological Factors in Usage Context of Mobile Phone

Need for Creating Usage Culture For Text Message And Camera Phone Among Elderly Users. Elderly users want to learn text message and how to take a picture with camera phone, but they say that there is no counterpart to send message and that they feel shy when using camera phone. It is social perception of them for mobile phone as exclusive possession of young people. If universal design phone for elderly users is developed, it should be promoted to create natural usage culture among elderly users.

Need for Normalization (Feeling Envious of High-End Function Phone). Most elderly users want to have high-end mobile phone even when they think they don't need high-end functions. Some users who have camera phone tend to show off their phone's ability. Some users who have outdated phones feel envious of high-end phone. Most of them feel negative for special function phone for elderly users exclusively. They said that they don't need complex functions, or special treatment as if they were old, handicapped people.

Need for Sparing Expenditure. Most elderly are very sensitive in saving expenditure because they experienced hard time in their young ages. Some of them were kind of obsessed by saving battery or charged electricity. They were also sensitive in saving calling rate. The quick charged and long lasting battery will be appeal to elderly users and saving cost plan should be supplied with hardware at the same time.

Need for Provision Against Emergencies. Elderly people are very cautious, so they need mobile phone to support emergencies such as when they are lost, when they have an accident, when weather becomes bad, and et cetera. They need someone else to call their home or family or hospital when they are unconscious. They need direct call function in emergency. They also want information service for abrupt weather change and where they are.

Need for Emotional Connection Or Self Verification. We found that many elderly users called missed calls back. They feel one call very precious because it is rare. They hesitate to call or mail to their sons and daughters, worrying they are not welcomed. Elderly users are likely to be lonely and want to be connected emotionally with family and friends, so that to verify their self-existence to others. Communication equipment should help to increase connectivity between people.

Preference to Old, Analog Things. Elderly users feel difficulties to adjust new equipment. Some of them insist to use same company's phone. Most of users bring memo pad, even when they knew how to use phone book inside of mobile phone. Most of them don't understand desktop metaphor in computer related product. The metaphor in mobile phone is targeted to young people. They prefer old, analog things in metaphor.

Need for Privacy. Some elderly users want to send secret text message only for recipient. It is universal need to be able to send secret message by sender.

4 Development Strategy for Universal Design Mobile Phone

Development strategy for universal design mobile phone can be divided into three categories based on target users and phone features. *Silver phone* has minimal HW features by eliminating features (barriers) elderly users do not use. Barrier Free Design concept is applied to this direction. Barrier free design pursues special solution to remove elderly or disabled people's difficulties. Silver phone targets only elderly users, so has minimal HW & SW features that reflect elderly users' needs directly. *Simple UI phone* has minimal SW features and has simple UI that reflects elderly users' cognitive needs while it has high features such as Camera & Color LCD. Universal Design concept is applied to *Universal Design Phone*. Universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design The intent of universal design is to simplify life for everyone by making products, communications, and the built environment more usable by as many people as possible at little or no extra cost. Universal design benefits people of all ages and abilities. Therefore, considerations for elderly users are reflected on universal design phone to the extent that do not cause discomfort to young users. It targets universal users regardless of age and ability, while considering elderly users' needs.

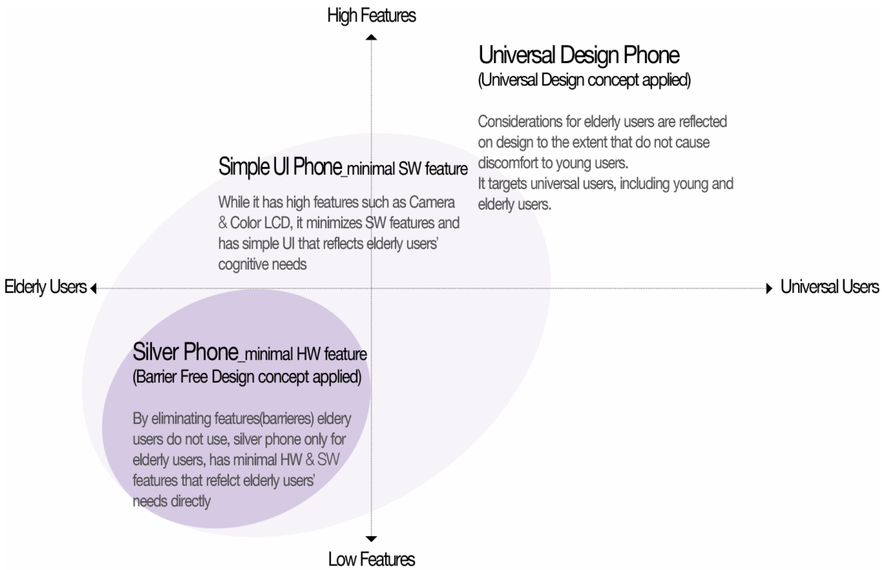

Fig. 3. Development strategy for universal design mobile phone

Elderly people's cognitive needs of eliminating functions to their frequently used functions can be taken care by supplying customization features to simplified menu in universal design mobile phone. Also, default setting should be simplified to fit to elderly users' behavior pattern, because young users can change settings easily. Appearance is very important factor in achieving universal design. The look should be targeted to young people or it should not have any generation orientation even though it has big buttons, big screen and large font.

It was suggested as the result of this research that development direction for universal design mobile phone in Korea should be Simple UI phone with simplified menu and UI based on elderly users' normalization needs.

6 Conclusion

The contextual and qualitative approach to elderly users makes to collect rich and substantial experience data in using mobile phone from their everyday lives. Especially, the episodes users describe their difficulties help to imagine the real situation vividly. Also, cultural, psychological understanding sought from contextual research makes to set the marketing strategy and to generate service ideas in addition to UI design implications.

This study shows a representative process of contextual research method that can be adapted to user experience research for mobile phone. The elderly users' need resulted from this research should be used to draw out UI design guidelines to develop universal design mobile phone. In this research, we select users from elderly people over 60. Since they are not accustomed to computer, they will be very different to computer-minded elderly users. In order to accomplish universal design mobile phone, the research to other groups of users including computer-minded elderly, children, teenagers, and the handicapped should be followed in the future.

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Design of Interactive Technology for Ageing-In-Place

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Abstract. In this paper we describe work directed at exploiting existing consumer electronics to present just-in-time reminder cues to assist ageing-in-place. We describe our methodology which first employed a series of structured interviews to gain insight into older people's opinions and expectations of consumer electronics and of the notion of autonomous and persuasive reminder systems. We then discuss our initial efforts to design and evaluate (using a Wizard-of-Oz methodology) a system which can make use of the existing programmable and wirelessly-networked, technology within the home, to provide a rich messaging service to older people as they conduct their everyday activities. Our research has the long-term aim of providing just-in-time, appropriate cues via multimodal displays to aid safer ageing-in-pace for the older population.

Keywords: Aging-in-place, persuasive technology, smart homes, pervasive computing.

1 Introduction

The UK and world's population is "ageing", that is the proportion of older people within the total population is increasing and the trend is set to continue. In the UK it is estimated that there will be 27.2 million people aged 50 and over by the year 2031 and by this time 3.8 percent of the population will be over 85 [1]. This increase in the aged population will place an inevitable strain on health services and support networks.

Maintaining an independent lifestyle, and living in their own homes – so called ageing-in-place - is often an integral social need of many older people and could also have direct cost benefits for the full-time care sector. There is also evidence to suggest that older people are healthier and report a genuinely higher quality-of-life if they remain independent [2]. However, independence can, at times, lead to vulnerability and this can also put increased demands on other sectors of the healthcare sector as well as on supporting families and other caregivers. Deterioration in older people in areas such as cognitive ability, memory, and physical dexterity lead to concerns around such issues as the neglect of nutrition and medication, physical well being (falls) and social isolation. Autonomous, and intelligent assistive systems which

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support independent living by providing reminders and other pertinent information that can assist in decision-making processes – particularly in a just-in-time fashion - have the potential to make a significant positive impact on the lives of older people and their care-givers [3]. However, to-date, the requirements of such autonomous systems, and particularly their interface and social acceptability to older users is not well understood. Despite this, a striking number of "smart home" technology demonstrators have appeared in recent years which are aimed specifically at the deployment and evaluation of context-aware and pervasive technology to support ageing-in-place. Many such demonstrators have been built around conventional houses where the walls, floors and appliances are all used as displays and/or input devices for a controlling computer [4, 5]. A number of groups are even exploring the use of augmented reality (AR) technologies within the home, such as in the 'kitchen-of-the-future' scenarios described variously in [6, 7 and 8] or by deploying numbers of smaller devices to form distributed displays [9]. While undoubtedly impressive, such interactive installations at present would be extremely difficult to recreate in real homes, often requiring significant amounts of custom hardware, software and special infrastructure such as cabling [10], whilst also remaining, for the time being at least, prohibitively expensive.

A slightly alternative research agenda to develop persuasive computing systems to support healthy ageing has been put forward in [11]. In this, it is concluded that current research effort should be directed at exploiting emerging consumer electronics to "motivate healthy behaviour as people age by presenting just-in-time information at points of decision and behaviour". The research presented here is conducted in this spirit in that we have chosen to exploit only consumer electronics that are readily available in most homes as the displays to provide reminders about particular in-home tasks. The remainder of this paper firstly discusses relevant previous work in persuasive and reminder-based technology for older people, before going on to describe our own work in firstly assessing older peoples' attitudes to some of the technology that already exists in their home. We go on to describe our efforts to design a system which can make use of the existing programmable and wirelessly-networked, technology within the home, to provide a rich messaging service to older people as they conduct their everyday activities. We then outline a short series of evaluation experiments in which we recruited a number of older people to engage with our prototype system and we finally describe our findings and future directions.

2 Persuasive Reminders and Older People

Intille [11] stresses that technology can have a positive impact on the lives of older people in that it can contribute towards them being able to live in their homes for longer than otherwise possible. His reasoning for this is that health related messages can be given at appropriate times – "specifically (at) a point of decision or behaviour where when an easy to understand message might have an impact on behaviour". There are in fact many recent studies showing that context aware technology can indeed have a *persuasive* and positive effect on user behaviour (e.g. see [12]). Unsurprisingly, a number of researchers are already investigating the potential of information appliances as vehicles for persuasive reminders. Recent research by a number of groups worldwide has given rise to the development of many experimental systems, or devices, which can give users obvious reminders and unavoidable information about their daily activities. These include the development of active medicine bottles [13], "aware home" appliances such as the now infamous Internet Fridge, specialized reminder/memory aids [14, 15, 16, 17], and, for the longer term, plans for holistic systems to give us reminders about almost everything to do with our daily-lifestyle [18]. In fact some aids to memory (such as pill bottle alarms) are readily available through local health professionals responsible for deploying general assistive technologies. Some researchers refer to all such developments as *cognitive orthotics*, though such a term has previously only generally been applied to devices developed for people with severely impaired memory function [19]. It should also be be pointed out that good deal of earlier activity (e.g. [20], [21]) was ongoing in this area long before the field of pervasive and mobile computing became as widely investigated as it is today

Many of the systems developed above are still very much in their infancy and much has to be learned about their efficacy as well as their acceptability by older people – indeed many systems by their own design will mark their owners out as being unusual in some way – a common criticism of much assistive technology. Emerging technologies such as AR could, in future, provide an ideal medium for persuasive messaging – however at present we are wary of adopting such technology as a platform to build experimental systems for reasons of cost and also sheer strangeness, and novelty, in a home setting. In our research we are striving towards systems which do not intrude into older peoples' everyday lives but provide flexible and socially acceptable persuasive messaging and which assist with an everyday activity in an effective manner.

3 Exploration of Older Users' Attitudes to Technology

At the outset of our work we were interested to determine older people's attitudes towards the technology that already exists in their home and also towards the notion of exploiting that technology as a medium for delivering just-in-time persuasive messaging. We were also keen to explore whether older people from different backgrounds and within different age-groups viewed such technology and ideas differently. We also wished to determine if findings from previous studies (e.g. [22]) held for our sample and also which devices and services were liked already and thus desirable to augment or emulate in further research.

We conducted a series of semi-structured interviews on a targeted group of older people from within our local region (the rural, largely agricultural, English county of Lincolnshire) but from different socio-economic and professional backgrounds. In total, 16 older people were recruited locally, from Age Concern day centers and elsewhere in the community and an attempt was made to obtain a distribution of participants across age, gender and background. A sample of responses from our participants when discussing in-home technology and the notion of reminder systems is given in Fig. 1.

Subject A -

1. ``I had a little trouble with it [a video recorder] --- as a new thing''

2. ``I can't hear the phone in the kitchen, so I was offered something on the wall [a strobe] that flashed. I said "wouldn't it be better if I had a cordless phone" ''

3. ``It [the remote control] looked a bit complicated to me....[I prefer] anything that's not too complicated''

Subject B -

1. ``I've had it [an old mobile phone] given to me - a cast off from my children''

2. "Would you actively avoid buying one [a mobile phone] with more features (cameras etc)?"

``Yes, as they're more expensive...I wouldn't mind experimenting with them wasn't so expensive''

Subject C -

1. ``[Devices don't annoy me] once they're set up. It's getting them to work in the first place!''

2. (on call centres and mechanistic technology in general) ``Even people who know the technology under certain circumstances want to talk to someone...a problem is lack of training for people on the end of the phone - they've got a script and if you ask a question off the script they don't have a clue what you're talking about''

3. ``If it [the phone] is flashing for no reason it doesn't seem important''

4. ``My wife writes them [appointments etc] down so I don't have to, really''

Fig. 1. Selection of responses from participants during structured interviews when discussing in-home technology and the notion of reminder systems

Our interviews revealed that our participants rarely purchased or set up their own technology, particularly in the case of entertainment systems which were often bought by relatives. This indicates that any further development of this technology must target older people, their relatives and the healthcare professionals who provide deployment advice. Subjects generally liked telephone services such as banking as this meant they could receive the service at home and did not need to use a computer. Most had no desire to use computers and no experience of interactive television despite wide ownership of digital TV or cable equipment. The familiar interaction idiom of the telephone may be preferred to the unfamiliar interaction idiom using the TV. We expect that the level of familiarity with technology will change as time passes – for example people still in work will be more familiar with computers than the current older population.

4 Evaluation of Consumer Electronics for Persuasive Reminders

Following our structured interview process, we then went on to develop a prototype ‘living-room’ system featuring a wireless network of typical home devices of telephone (both conventional and cordless), RF remote control device, analogue radio and TV. This is shown in Fig 2. Through use of open-source software technologies and standards such as Asterisk [23] SIP and MPlayer we were able to program these devices in such a way to allow them to behave like conventional consumer electronics, but also so that they could be interrupted to present synchronised persuasive messaging to a user. A number of scenarios were developed in consultation with local care professionals to capture everyday behavior. Four scenarios in Table 1 were selected to script an experiment to evaluate older peoples’ reactions to our system.

Table 1. Scenarios chosen for reminders to be issued during evaluation

	Critical	**Non-Critical**
Time Dependent	Attend an appointment	Watch a particular television programme
Time Independent	Take medications	Water household plants

We devised a Wizard-of-Oz (WoZ) [24] based experiment to evaluate older people’s reactions to our persuasive reminder system. Hence we utilized a human ‘wizard’ for real time analysis of user activity, generation of appropriate visual and aural cues, and the appropriate means of directing them, via our system, to the user in a given scenario. This is shown schematically in Fig. 2 below.

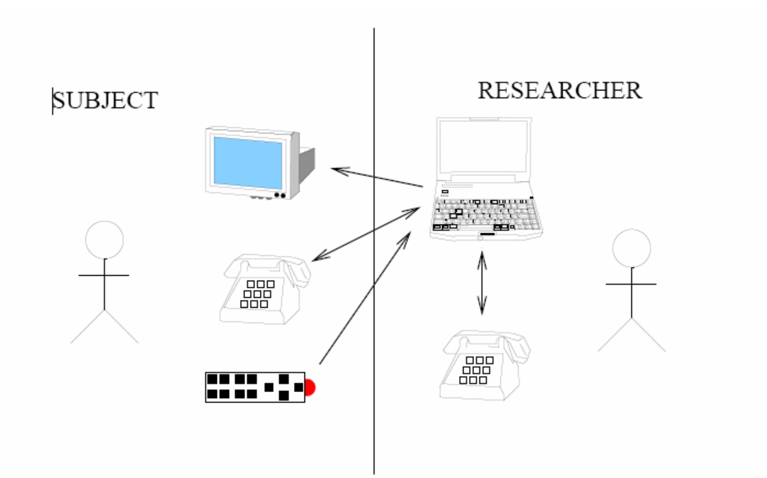

Fig. 2. Schematic of Wizard-of-Oz (WoZ) [24] approach to evaluation experiments

The system was evaluated with 8 of the participants who previously completed our structured interview process: 3 male and 5 female, 3 from professional backgrounds and 5 from non-professional backgrounds. We defined "acceptable reminders for each scenario and an order of escalation, plus "success" & "failure" conditions. Subjects were not instructed in the use of the system though paper documentation was present and the use of the remote control explained. This simulated a system placed in the home without explicit instruction, as is the case with much commodity technology.

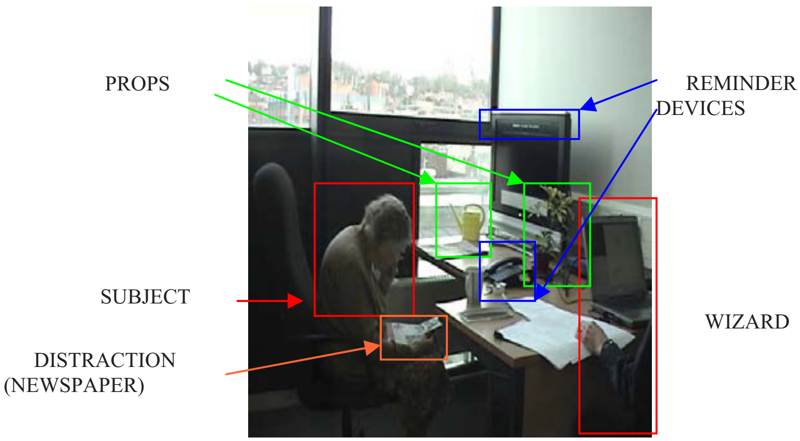

Fig. 3. Participant taking part in WoZ based evaluation of reminder system

Fig 3 shows our prototype system under evaluation. The participant is performing a distraction task, in this case reading a newspaper, intended to simulate everyday routine while they are exposed to various reminders. Unfortunately the Wizard is visible as we lacked a second experimenter to record responses etc; we believe this affected the suspension of disbelief required for effective WoZ evaluation. Two reminder devices can be seen: a telephone and the television; the latter displaying a reminder. Throughout the experiment, the participant is questioned about the reminders shown to them and subjectively rates them based on their persuasiveness, intrusiveness etc. The intention is to discover which reminders work well for each scenario.

5 Results and Conclusions

Our WoZ based experiment revealed that, as expected, participants reacted very differently to reminders depending on the context. Several stated that they would feel annoyed if "phone call" reminder interrupted them for a trivial task but found such reminders persuasive nonetheless. Similarly, most subjects expressed distaste for the synthesized voice when played from speakers but liked the same reminder delivered via the phone. The voicemail reminders confused some subjects. Voicemail had two "alert" modes: the first caused the phone display to flash and the second rang the phone once. Neither made what was happening clear to the subject, indicating that the well known adage of "discoverable design" [25] must be a priority when implementing such systems.

In general, reminders issued in a different "mode" from the distraction task succeeded, for example receiving a spoken-voice reminder when reading. Focus of attention was also important; for example the on-screen reminder (though non-intrusive) was effective if the user was watching TV as their distraction task. Similarly, users often noticed an active "phone-flashing" reminder only when they interacted with the phone for other reasons despite the phone flashing for some time previously. Differences in reaction between subjects to the same reminder indicate the need for the system to be tailored to particular users and their habits in any future implementation.

The exploratory nature of this study limits the conclusions that may be drawn from our work and the small sample size is an additional drawback. Two priorities are a statistical study to reexamine the interview findings with a statistically valid cohort and further controlled experiments with specific successful reminder modes to determine what makes each mode persuasive and how their efficacy may be improved. Thereafter, a second WoZ, or even real, system can be built and evaluated based on such findings.

Acknowledgments

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Difficulties on Small-Touch-Screens for Various Ages

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Abstract. Digital products with small-touch-screens are increasingly affecting daily life, and most especially that of the elderly population in Taiwan which, at present, is over 9.9%. As people age, they find it increasingly difficult to operate digital products with small-touch-screens. The main purpose of this study was to investigate and categorize these difficulties for three groups of adult users. The fifteen participants in the investigation were classified into three groups: young adults, middle-aged adults and elderly adults. All of the adults were requested to accomplish different tasks using three digital products with small-touch-screens and then to provide their opinions on the kinds of difficulties they had encountered. The experts classifying the results found that the elderly adults were the group confronted with the most difficulties in the operation of small-touch-screen digital devices. In the digital dictionary experiment, the greatest difficulty for the three groups centered on cognitive ability; the majority of problems were related to motion in the PDA. In fact, the most notable problems for each of the participants were related primarily to motion in the PDA and to cognition. The results also indicated the common operational problems with the three digital products with small-touch-screens, including the impact of space or position of handwriting and button size on motion ability; and the impact of the size and color of the fonts or icons and screen brightness on perception ability. Lastly, regarding the difficulties with cognition, most of the participants were confronted with complex information, inconsistent with the interfaces of the digital products. Results of this study were based on the opinions from the three adult groups and, could be used in future designs for small-touch-screen interfaces.

Keywords: small-touch-screen, motion, perception, cognition.

1 Introduction

Digital products with small-touch-screens are increasingly affecting daily life, and this is particularly the case for the elderly population in Taiwan which, at present, is over 9.9% (CEPD, 2006). Young adults are no longer the sole focus of consumer product markets; more and more attention has been given to the design and development of products for elderly adults. Studies show that human ability includes three segments: perception, cognition and motion (Hotta, 1997; Okada, 1997; Fisk, et al., 2004, p15.). Elderly people often suffer degeneration in their physical abilities which affects their

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lifestyle. The current generation of digital products is noted for compactness, making them easier to carry, but also with the problem of small-touch-screens.

Owing to the degeneration of human abilities, elderly adults have more difficulty operating small-touch-screen digital products than do the younger users for whom they were originally intended. For example, elderly users find it hard to press minute buttons because of the degenerated dexterity in their fingers or to operate more complex interfaces due to memory impairment（Lee & Kuo, 2001 . It is important, therefore, to design accessible interfaces on digital products for elderly people. Also, additional consumers would reduce the production costs for the development of universal digital products which are easy to use by both young and old.

The main purpose of this study was to investigate and categorize the difficulties encountered by various aged users of small-touch-screens. Results of this study were based on the participants' opinions, which could be used for future designs of small-touch-screen interfaces.

2 Methods

Thinking aloud was used in this study. The first step was to request participants to operate three digital products with small-touch-screens and to describe their difficulties. The second step was to categorize these difficulties, which were recorded using a digital video camera by two experts. The experts in this study had three or more years experience studying interface designs for elderly people. These two experts categorized the difficulties in operating small-touch-screens for all users according to three human abilities: perception, cognition and motion.

Table 1. Experiment instruments

			
	Digital dictionary (CD826 pro)	**PDA** (ASUS A730)	**Cell phone** (Dopod 818)
Product Size(mm)	137.5 x 82.8 x 18.9	117.5 x 72.8 x 16.9	108x 58x 18.1
Screen Size(pixels)	3.8'',320x240	3.7", 640x480	2.8", 320x240
Weight(g)	250	170	150

2.1 Participants

There were fifteen participants: five young adults (between the ages of 21 and 35; mean age: 27.9 years, SD: 5.2 years); five middle-aged adults (between the ages of 45 and 58; mean age: 52.1 years, SD: 3.9 years); and five elderly adults (65 years old and above; mean age: 67.9 years, SD: 3.8 years). All of the participants in this study had some experiences in operating digital products before the experiments.

Table 2. Tasks of three experiment instruments

Digital dictionary	PDA	Cell phone
• Task 1: consulting a dictionary	• Task 1: calculating machine	• Task 1: dialing someone
• Task 2: setting some individual information	• Task 2: setting some individual information	• Task 2: setting some individual information
• Task 3: multimedia	• Task 3: multimedia	• Task 3: multimedia

2.2 Experiment Instruments

Each participant was requested to accomplish tasks with each of the three experiment instruments: a digital dictionary, a PDA (personal digital assistant) and a cell phone. Table 1 shows the specifications of each of the experiment instruments, whose main input methods were tap buttons or handwriting on a touch-screen with a stylus.

2.3 Tasks

Table 2 shows the main tasks handled with each of the instruments. For the digital dictionary, participants tasked minor items which included: consulting a dictionary by three input methods, setting some individual information and operating multimedia functions. There were minor items for the PDA and the cell phone that included: calculating or dialing, setting some individual information and operating multimedia functions. The participants had to describe their initial opinions when operating the digital products during the experiment.

2.4 Experiment Environments

The participants were asked to operate digital products in a realistic environment. The illumination of the experiment was between 600~800 lux and the brightness of the background in all experiment instruments were set at 100%.

3 Results

The experts classifying the opinions of the participant groups recorded nineteen difficulties with the digital dictionary, eighteen with the PDA and thirteen with the

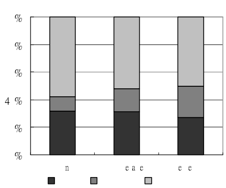

Fig. 1. Percentage of difficulties in three human abilities with the digital dictionary

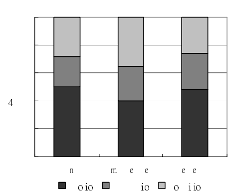

Fig. 2. Percentage of difficulties in three human abilities with the PDA

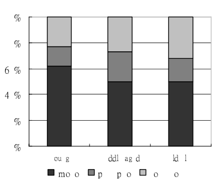

Fig. 3. Percentage of difficulties in three human abilities with the cell phone

Table 3. Difficulties with the digital dictionary

	Description of the difficulties
Motion	• Participants made more mistakes when the buttons were minute. • The position of handwriting was under the screen which entailed hand instability. • Speed or strength of handwriting influenced the accuracy of recognition. • There was no hold button for the touch-screen of the digital dictionary. It was not stable for participants.
Perception	• Some of the fonts or icons were too small to be read clearly. • The contrast between font and background was not intense enough.
Cognition	• The icon buttons were confusingly similar. • Multiple modes of input made keyboards complex and confusing. • Increasingly frequent errors were due to inappropriate icons. • Participants could not understand the complex information.

Table 4. Difficulties with the PDA

	Description of the difficulties
Motion	• The area was too narrow when Chinese fonts were input, so that strokes were complex. • The position of handwriting was under on the screen which caused hands' instability. • Speed or strength of handwriting influenced the accuracy of recognition. • Some buttons were too small and increased the difficulty for participants. • The volume PD s too large for female participants.
Perception	• Some of the screen fonts were too small to read clearly. • Participants found it tiring reading complex information on the smaller screen. • The screen brightness was not sufficient for the recognition of smaller icons or fonts. • The light reflecting off the screen influenced participants.
Cognition	• The meaning of icons was not readily apparent and participants had more difficulty recognizing them. • The operation process was not easily remembered. • Two similar icons placed together confused participants. • Participants could not understand the complex information if they had had no past experience with digital devices.

Table 5. Difficulties with the cell phone

	Description of the difficulties
Motion	• The area for handwriting was too narrow to write Chinese fonts with the stylus. • The position of handwriting was under the screen which caused hands' instability. • Speed or strength of handwriting influenced the accuracy of recognition. • The cell phone was too heavy for some people to hold. • Participants found it hard to point accurately at the smaller buttons. • The interface space was too narrow to operate the cell phone. • Pointing at other buttons when the area of handwriting was full on the screen was liable to cause an error.
Perception	• The size and font of the touch-screen were too small to read clearly. • Participants found it tiring reading complex information on the smaller screen. • The screen brightness was insufficient for the recognition of smaller icons or fonts.
Cognition	• Participants easily forgot the operation process. • Participants could not understand incomplete icons and fonts. • It took more time to find the function of complex information. • The feedback of vision was insufficient for participants' perception.

cell phone for the young subjects. The middle-aged participants reported twenty-three difficulties with the digital dictionary, twenty with the PDA and twenty-two with the cell phone. The elderly participants had the most difficulties with each item: twenty-six problems with the digital dictionary, twenty-seven with the PDA and twenty-two with the cell phone. According to these results, the elderly adults were the group that was most challenged in the operation of small-touch-screen digital devices.

3.1 Percentage of Difficulties in Three Human Abilities

Each group experienced different problems in operating the three experiment instruments. Fig. 1 to Fig. 3 show the analysis of the digital dictionary, PDA and cell phone for the three groups. With the digital dictionary, the greatest number of difficulties for the three groups centered on cognitive ability. The majority of problems were related to motion in the PDA, and Fig.2 shows that the middle-aged participants also had more cognition-related difficulties. Overall, the most notable problems in all participants were related primarily to motion, and secondly to cognition.

3.2 Common Difficulties for the Three Groups

In order to investigate the common difficulties for each of the groups from a universal design perspective, the parallel problems were generalized for all of the participants. Tables 3~5 describe the main difficulties common to the three groups in their operation of small-touch-screens as related to the human abilities of motion, perception and cognition.

4 Discussions

Pointing and handwriting were the major ways for inputting information on small-touch-screens. All participants had similar motion-related difficulties which centered on button size and space for handwriting. Lee and Kuo (2004) indicated the button size was at least 5mm x 5mm by stylus. Multifarious information on the screen affected some buttons or narrow font. In the experiments, the smallest button size of 1mm x 2mm caused participants to make increasingly frequent errors especially when attempting multi-motion tasks such as pointing & holding, or pointing & dragging. On the other hand, for the participants tasked in handwriting, the right hand was not able to maintain stability because the position was on the right side under the screen of the digital products. Space was also an important factor for handwriting performance. Table 4 and Table 5 show that the handwriting area was not wide enough to write the more complex Chinese fonts on either the PDA or the cell phone. With the digital dictionary, the area of handwriting was 25mm x 25mm (per grid) so this result was applicable to all of the groups.

According to these results, various aged users were confronted with different difficulties. Declines in visual acuity appear at about forty years old (Fozard, 1990). Fig.1 to Fig.3 shows that the middle-aged and elderly participants had more difficulties with perception than did the younger participants. Furthermore, as shown in Table 3 to Table 5, the majority of problems were related to visual perception. Empirically-derived guidelines suggest that presenting important information in 12- to 14-point font size for elderly people with a normal decline in their vision (Kurniawan et al., 2006). The font on the small-touch-screens in this study was 6-8 point, and the middle-aged and elderly participants had more vision-related problems and labored harder to operate the digital products.

The most general cognition-related problem for the three groups involved the icon or exposition on buttons. Multifarious functions made the information more complex, and many buttons were displayed by compendious icon or font which users tended to misinterpret; thus they made mistakes if they had no experience with the icon in the past. In addition, the working memory for normal young adults is seven items and for elderly adults it is five point eight items Schieber, 2003, p 64 . Schieber also indicated that the decline in working memory was related to age and to the complexity of the task. Middle-aged and elderly participants forgot the operating sequences more easily than did the young adults, especially when the procedure was complicated.

The touch-screen size of the digital dictionary was the largest and the cell phone was the smallest in three experiments. Fig. 1 to Fig. 3 show that there were more motion-related difficulties with the cell phone and that the problems centered on the size of the area for handwriting or the size of the buttons These results show that the motion ability in older adults is an essential consideration for the development of smaller digital products in the future.

5 Conclusion

Each group experienced different operational problems with the three experiment instruments with small-touch-screens. In this study, the results have also generalized the common difficulties for the three age groups, including: the space or position of handwriting and the button size on motion ability, the size and color of fonts or icons, and the brightness of the screen for perception ability. Lastly, most participants faced difficulties with cognition when confronted with complex information inconsistent with the interfaces of the digital products. Results of this study were based on the opinions from various age groups and could be used for future designing of small-touch-screen interfaces.

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Strategy of Visual Search of Targets on Screen Through Eye Movement of Elderly Person

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Abstract. It is important that the operation characteristic of the elderly have to clear for designing information equipment that was deeply considered about influences of aging. Visual search tasks were imposed on the elderly in this study and found strategy for searching target by analyzing their eye movements that gazing time, gazing position and locus in the search task. Experimental parameters of stimulus were the number of character strings, the letter types, and the number of stimulus represented on screen. Results showed that mean gazing times become long in accordance with the number of characters. When alphabetic letters was reproduced on screen, the elderly hesitated to search a target stimulus. By analysis of gazing position and locus of eye movement, the strategy of visual search of the elderly was categorized three patterns.

Keywords: Elderly person, Information equipment, Eye movement, Visual search.

1 Introduction

Information instruments that has rapidly complicated the function in recent years cannot necessarily say an easy-to-use one for the elderly. It is enumerated that consideration-and-attention to them is insufficient in the design of information Instruments as one of the reasons. To design Information Instruments, a variety of design models are applied. However, there is little model by whom the design of an easy-to-use information devices to them can be examined. For example, a human information processing (HIP) model proposed by Card et al. which is useful for design of information-processing equipment is the simplified model which divides the information processing system of human being into three subsystems that are perception, cognition, and movement system [1]. However it is hard to use the model in consideration of effect of aging for process stage by each subsystem. Moreover, the proposal of the information processing model who considered eye movement of the elderly that is closely related to perception is not found. Therefore, it is difficult to

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make the best use of their information processing characteristic for the design of the equipments.

At first this study analyzes eye movement of the elderly in operation of information equipments to suggest the information processing model that can explain the influence of aging in the information processing. Their eye movement characteristics are examined by using visual search task in this research to know basic information processing characteristics of the elderly.

2 Experiment Method and Conditions

2.1 Visual Search Task

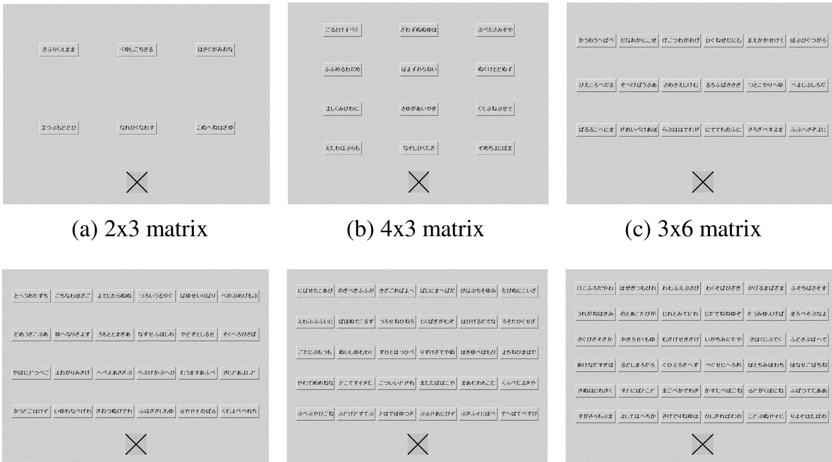
The character string represented on LCD screen was observed by both eyes, and it was assumed the task of looking for the target stimulation from among two or more stimulation [2], [3]. The character string, the start button, and the home position that was the target stimulation to an initial screen were displayed. The subjects memorize the character string that is the target stimulation. Afterwards, the target stimulation and the start button disappeared when pushing the button to start, and the target stimulation was presented with two or more obstruction stimulation one second later.

The target stimulation and the obstruction stimulation went out of the screen when stimulation was selected, and the following target stimulation and the start button were represented. The home position was always presented. The next target stimulation was presented without looking for the same stimulation again when stimulation other than the target were selected. Moreover, the subjects put the finger of his/her dominant arm on the home position except touching the selection button of the character string on the screen. If time from leaving of the finger from the home position to pushing stimulation was too long, the obtained data was invalid because it was considered that he/she had searched the target for the period. Level of horizontal illumination of screen was approximately 500 lx.

2.2 Stimulus

There were three kinds of numbers of characters of character strings of stimulation, that is, 3, 5, and seven characters. Four kinds of character of stimulation is hiragana, katakana, alphabet that was a meaningless spelling and the numeral. There were six kinds of numbers of obstruction stimulation of 5, 11, 17, 23, 29, and 35 pieces. The target stimulation was 1 piece. The color of the character was assumed that the color of the black and the background was grays, and presented on the screen button. A typical layout of buttons displayed is shown in figure 1.

Target stimulation that was searched by one session was changed for different ten types. The subject carried out 72 sessions in all because he or she searched for all of the combination of three characters, four types of character and six character numbers. So the task of looking for the target stimulation as many as 720 times was imposed on the subjects. The order of the session was assumed to be random in each test.



(a) 2x3 matrix (b) 4x3 matrix (c) 3x6 matrix

(d) 4x6 matrix (e) 5x6 matrix (f) 6x6 matrix

Fig. 1. Typical screen of visual search task on pointing the same character with the target character (seven characters, hiragana)

2.3 Experimental Devices

The eye movement was measured by using the experimental system composed by goggle and camera. Resolution on the touch panel display (Touch panel systems) used to experiment was 1280×1024 dots, and the size was 17 inches. Measuring device of both eyes' movement (Takei equipment) was used for the measurement of the eye movement. The subject whose head was fixed with the jaw stand had the glance when he/she sat on a chair, and it looked straight up ahead come to the center of the screen. The viewing distance from the subject and the presentation stimulation was about 35cm. It took a picture of eye movement with a camera attached on the goggle that the subject had wear, and it recorded with the VCR (EV-S2200, SONY company). The sample rate of the images was 16(msec).

2.4 Subjects

Ten senior people of 65 years or more (7 males and 3 females) participated in the experiment and undertook the reward as the subjects. They had normal eyesight or anormal corrected eyesight. In the one's dominant arm, nine people were right-handed, and one person was left-handed. We understood that feeling of the elderly is comparatively little in difficulty of the search for daily life since questionnaire survey was conducted for concerning the easiness to use an Information Instrument.

2.5 Searching Time

Search time was the period from the presentation of the target stimulation and the obstruction stimulation on the screen to parting of the finger put on the home position, and hand movement time was the time to pushing stimulation separating the finger from the home position. The frequency in which the obstruction stimulation was selected was measured, and the error rate was calculated.

2.6 Analysis of Eye Movement

Statistical analysis on eye movement data obtained by both eyes' movement measurement device was carried out by special software that is being offered by Takei company. We can indicate three factors influences in visual search that are gazing time, gazing position and locus of eye movement. The definition of the gaze point is needed to analyze the eye movement. The gazing location is defined by setting the reference value separating the gazing time and saccades of the glance.

When the character is presented, eye movement of 5(deg/sec) above might be defined as saccades. However, it was difficult for this task to separate eye movement in 5(deg/sec) because it was high-speed. Then we decided to separate it by 10(deg/sec).

3 Results and Discussions

3.1 Average Gazing Time

It is said that the gazing time will account for 90 percentages at all eye-movement time only though saccades account for 10 percentages because it is very high-speed [2]. Therefore, we thought that huge influence is exerted on the search of the gazing time. Then, the average gazing time in visual search of the elderly was analyzed. And, the differences were compared between the number of characters and each character types according to the presentation number of stimulation of the screen. Figure 2 shows the typical gazing time.

It is understood that the average gazing time was often becoming long when the number of characters becomes seven characters even if which graph is seen. However, the average gazing time was not proportional to the number of stimulus characters. It is guessed that it is because only the first three or four characters was remembered even if the stimulus is composed with five or seven characters. However, we can guess that the hesitation is caused in collation because the character string becomes complex when being seven characters, and the gazing time became long a little for three characters and five characters.

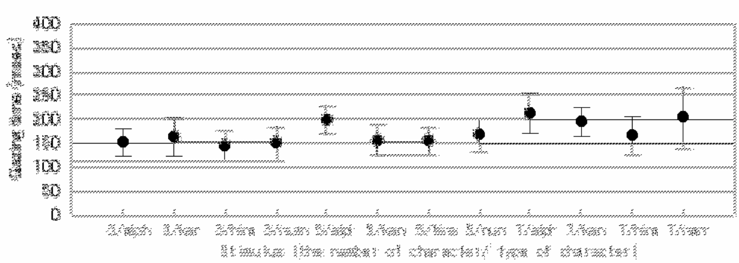


Fig. 2. Relationship between targets and average gazing time in 6x6 matrix

The average gazing time became long, too, according to the number of characters at the time of five characters for the alphabet. It is guessed that the tendency to this character type depends on the experience of the subjects. Moreover, the changes were not seen at the average gazing time though the number of stimulation increased.

3.2 Gazing Location and Locus of Eye Movement

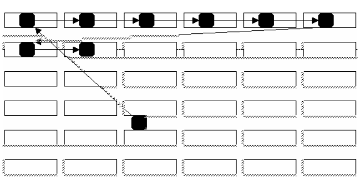
We used the video images and software of statistics program in eye movement for analyzing the gazing position and movement locus. We found there were three patterns in the gazing position and eye movement locus of the elderly.

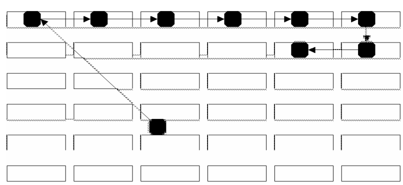
Pattern 1: The subjects horizontally collate the character from the edge of the row of the array as shown in Figure 3(a). And, when collation is finished, they sequentially collate it from the first edge side again.

Pattern 2: The subjects sequentially collate the target character from the edge of the row. They take a strategy that sequentially collate from the same edge side when the collation is finished. Figure 3(b) shows the strategy.

Pattern 3: The subjects collate a target from the stimulation that exists near the position in which the eye gazed when the screen is displayed. Then, they collate at random the stimulation that not collated still (Figure 3(c)).

We classified it into other patterns excluding these three patterns. For instance, the glance is in the target stimulation by chance when stimulation is presented on screen, and the target might be found at once. At this time, we judged that the strategy did not work either.


(a) pattern 1


(b) pattern 2

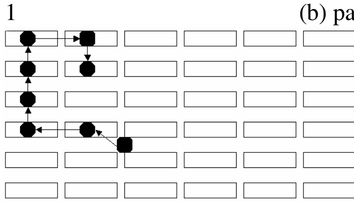

(c) pattern 3

Fig. 3. Three patterns of searching strategy

Table 1 shows the relations between the number of stimulation presented and these three patterns. The number of presentation stimulation indicated 12 pieces or more in Table 1 because it was able hardly to read a remarkable pattern at the time of 6 pieces in number of presentation stimulation.

Table 1. Relationships between the number of stimulation presented and these three patterns

stimulus	character	Rate of pattern (%)			
		Pattern1	**Pattern 2**	**Pattern 3**	others
12		1.4	15.0	73.6	10.0
		4.3	19.3	66.4	10.0
		3.8	8.1	77.5	10.6
18		8.6	48.6	30.7	12.1
		6.2	58.5	21.5	13.8
		4.0	44.7	46.0	5.3
24		6.0	45.3	32.7	16.0
		5.4	53.1	26.2	15.3
		4.3	36.9	46.9	11.9
30		6.0	46.7	34.0	13.3
		10.0	56.9	23.1	10.0
		1.9	43.1	51.2	3.8
36		3.3	41.4	49.3	6.0
		5.4	43.8	40.0	10.8
		6.0	25.3	60.7	8.0

We understood that there were a lot of patterns 3 at the time of 12 pieces in number of presentation stimulation. It is guessed that this is because the collation that reduces the leakage of the search by pattern 3 can be done for the number of stimulation and the stimulation position shown in Figure 1(b). It was clarified that pattern 2 increased as the presentation stimulation increased. This is guessed that pattern 2 increased because there is a possibility that the leakage occurs in collation by pattern 3 for the number of stimulation and the stimulation position shown in Figure 1(c) ~ (e).

When quite a lot of numbers of presentation stimulation become, it has been understood that pattern 3 increases as shown in Figure 1(f). The following is considered as this reason.

It is necessary to collate target characters politely to search for it sequentially by using pattern 2 one by one. However, we think that the elderly adopted the pattern 3 to keep the strategy at a distance because it is troublesome that the elderly accomplishes the strategy of pattern 2. Moreover, it has been understood that pattern 3 increases at seven characters. Because it is necessary to collate this politely by one character when the character increases, it is guessed that the elderly kept at a distance pattern 2. It seems that it is because the elderly wanted to avoid the saccades of a long distance as a reason why the strategy of pattern 2 and pattern 3 is often taken.

We can guess the reason why pattern 1 is not so used as follows. The elderly memorizes only the first three characters or four characters at five and seven characters in the number of the target characters. So, the character string of the presentation stimulation need not be collated from the left with the right. Therefore, it is guessed they can search enough in the strategy of pattern 2 though pattern 1 was not adopted.

4 Conclusion

We measured eye movement of the elderly in visual search task to obtain initial data to construct the information machine design model for them, and analyzed the characteristic of the gazing time, the gazing position, and the locus of eye movement. The results showed that there was the tendency that average gazing time becomes long when the number of alphabets stimulation increased. Moreover, other tendency that the average gazing time becomes long when the character increased was seen in any character types.

In addition, the tendency was revealed that the gazing position and the locus of eye movement were changed by differences of the number of stimulation. Therefore the visual search becomes difficult for the elderly when the character increases, the character type is not accustomed or the number of stimulus increases. Finally, it was clarified that the elderly properly used the strategy of three patterns when searching the target on screen. Finally, we can propose that the presentation character strings of one screen were 12 pieces or less, and when seven characters or less were suitable for the elderly through the search time and the characteristic of eye movement.

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Methodologies for Involving Older Adults in the Design Process

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Abstract. Older people provide much greater challenges to user-centred design than more traditional user groups. It is also very important to encourage (often young) designers to develop a relationship with, and an empathy for, older users. It is recommended that older users be fully integrated into the design process. Researchers, however, need to take care to be sensitive to the characteristics, sensory and cognitive capabilities, and the attitudes of older people to computers and to being included in research studies. The paper suggests strategies for doing this, together with the more radical approach of using professional actors as surrogates for real older users.

Keywords: Older users, accessibility, user centred design, theatre in usability studies.

1 Older Users and the User Centred Design Community

The design community has been aware of the importance of involving users in the design process for many years [1]. This approach is also an integral part of "Participatory Design" [19]. These and other mainstream techniques, which recommend involving users, however, rarely consider the particular challenges of older users. The needs of older and disabled people are more often addressed by the "inclusive design", "design for all", and/or "universal design" communities. These tend to focus on designers ensuring that products can be used by as wide a range of people as possible, and have produced a range of guidelines and standards to assist designers in achieving this objective [e.g. 10, 31]. There is, however, increasing evidence that guidelines alone are not sufficient.

Milne et al. [17], for example, found that designers need more than just W3C guidelines if the web sites they develop are to be usable by, as well as "accessible to", older people. This view was confirmed in a recent survey of the accessibility of websites by Petrie et al. [28], who found that the observance of W3C guidelines did not necessarily lead to a site which was usable by disabled people. Newell et al. [23] describe a specific example of the ineffectiveness of only reading guidelines and attending lectures for educating software designers. He and his co-workers acted as advisers to a consultancy company developing a proof of concept web portal for older people. The engineers in the company were high quality engineers well aware of user centred design principles, and had been given data and presentations on the characteristics of older people. It was not

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until they actually met with older users, and saw them trying to use paper prototypes, however, that they really understood the very low level of awareness of all aspects of computers of many older people. This also confirmed Wixon's comment that "it is no accident that most usability testing involves encouraging entire design teams to watch the test, and it is well known that much of the effectiveness of the test comes from this active participation" [32].

The level of engagement between many HCI professionals and older people was illustrated in a recent HCI conference where, unusually, a keynote speech [25] focussed on the challenges computer interfaces provided to older people with little or no experience of computers. This keynote was also unusual in that the presentation included professional actors who presented common scenarios which occur with these users, examples of which can be found at [33]. The presentation provoked a very lively discussion, but, amongst the points made by the audience was "that the older couple would not have had any problems if they had a new computer. This comment focused on the couple's computer not having a spare USB port, and ignored the major challenges which installing a web cam had provided for them. An even more disturbing trend which appeared during the discussion with the audience was that many saw the problem simply being one of the need for training. When the presenter asked whether there were any lessons to be learnt for HCI design, a member of the audience commented that "the interface design (of the software being used in the scenario) was not our responsibility".

There is a real need for designers to interact with older people and the most effective way to do this is for older people to be part of the design process. Unfortunately, traditional User Centred Design methods provide little or no guidance about how to involve that user group [20]. Hypponen [10] commented that "there were many different methods of choosing how to collect user needs and integrate them into product development, and that the suitability of this approach to accommodating a range of disabilities into the design process (in an effective and efficient manner) is unclear" and Keates and Clarkson [13] "that there are relatively few examples or guidelines for successful involvement (of older and disabled people), and often traditional formats have to be adapted".

2 Involving Older and Disabled People in the Development Process

Obtaining requirements and evaluation data from marginalized groups, such as older people is not straightforward. Newell and Gregor [24] have suggested that a new design paradigm should be developed for these groups of people which they call User Sensitive Inclusive Design where "sensitive" replaces "centred" to underline the extra levels of difficulty involved in user groups which contain older and disabled people.

The inclusion of such groups can involve significant communication problems between users and designers due to hearing deficits, and to their lack of understanding of computer jargon and metaphors [6]. Many older people have a fundamental distrust and a very limited understanding of the underlying computer concepts, leading to a reluctance to experiment – a *sine qua non* for successful interaction with most software [9]. Visual language conventions can also cause confusion - scroll bars being an example of a whole repertoire of "widgets" of which older people have limited or no experience. Various researchers also report on the problems encountered when running focus groups with older people [2, 14]. There are some case studies about design processes involving older people which give valuable pointers as to how information can be elicited from this age group [8].

Older people tend to be very positive about the prototypes which are presented to them, wishing to praise the developers rather than give an objective view. If they cannot cope with technology, they tend to blame themselves rather than poor design [6]. They often experience anxiety, and can be negative about the amount of effort required to learn to use computers, often increased by their assumption that they are no use to them [15]. Age related factors can also make self reporting inaccurate (for example, in questionnaires), with recent research showing that there are age differences in the ways in which people respond in self-reports [27]. In addition, challenges may arise because older people tend to tire more quickly [12], and this can severely limit the duration of sessions.

Because of their unfamiliarity and potential fear of computers, older people's confidence in their ability to use technology can be very fragile. A usability flaw could thus have a catastrophic effect on an older person's confidence. User centered designers thus need to be particularly sensitive not only to the sensory and cognitive abilities of older people, but also to their psychological state and their perceptions of technology. Some of the information which designers are trying to elicit can be particularly sensitive, and care needs to be taken to carefully choose topics and appropriately introduce sensitive topics. For example, Russell [30] found that many older people may not want to talk about topics such as social isolation, "because such an acknowledgement challenged their identity as independent people".

In addition, motivations behind user participation should be considered and an awareness of, and sensitivity to, users' motivations for participating are important considerations in working successfully with older people. For example, the author and his colleagues, and Lines and Hone [14], have found that it is not easy to keep a focus group of older people focused on the subject being discussed. They suggest that a contributory factor to this is the motivation of the participants: many informants see these groups as vehicles for socializing as well as providing information to the researchers. It is thus important to provide a social gathering as part of the experience of working with IT researchers rather than treat them simply as participants. Researchers in Dundee, for example, devote at least the same time to allow older users to socialising with each other as for the formal experiments.

3 Laboratories

This need for close interaction between researchers and users also means that traditional Usability Laboratories with two-way mirrors are less appropriate for older users. As has been stated, many have very low confidence in their abilities and thus it is important that experiments be conducted in a supportive environment, where the users are shielded from making major mistakes which could destroy their confidence altogether. The authors of this paper thus deliberately decided to have a studio theatre rather than traditional usability laboratories in our new building [26] (also see the discussion on the use of theatre below). It is also now normal practice to have a researcher in the same room as the user who will give help when necessary. With this methodology, it is necessary to use measures such as the number of tasks completed “with no assistance”, “with minimal assistance”, and “with significant researcher intervention” rather than the more traditional measures of number of tasks completed [5].

4 Choosing a Users Group and Interacting with it

The methodology of choosing a user group is also important. Because of the very wide diversity of the sensory, motor, and cognitive characteristics of older people, as well as in their education and technical background, one is never likely to obtain a “representative sample” of the user group as can happen when the user group is much more constrained. Thus the users to be tested must be picked with care to illustrate those characteristics which the researchers believe important. It is thus important that an adequate cohort of older people is available to the experimenter, and it is valuable to form a long-lasting partnership with them [7].

Eisma et al. [7] propose that both the users and the designers should be involved in concept development, initial requirement gathering and prototype stages of the project, so that both sides are aware of the various criteria that shape the project, and both can influence early design choices, but they stress that both parties need to be willing and able to talk about their expertise in language comprehensible to the other party, and always to respect the other’s contribution and expertise. This can be facilitated by making focus groups, or other activities, into pleasurable social events, by providing refreshments and, crucially, time for social interaction, both among the participants and between participants and researchers [18]. Hands-on sessions, where older people experience new technology, have also proved more successful than verbal explanations or demonstrations, and these can often lead to spontaneous suggestions for improvements or for new products [11], and hands-on sessions allow researchers to observe the difference between what people report and what actually happens [18]. Gheerawo and Lebbon [8] describe a similar process which they called ‘empathic bonding’ to stimulate creative thinking and user-facilitated innovation.

5 Self Reporting

Questionnaires and other methods of self reporting are widely used in HCI, but research shows that there are age differences in the way older and younger people respond in self reports. For example, they use the “don’t know” response more than younger respondents, and are also likely to use the “don’t know” option to questions that have complex syntax or are semantically complex. Eisma et al. [6] specifically excluded a “don’t know” response, but even this was thwarted by some respondents, a number of whom penciled in their own “don’t know” column. Older respondents are also generally also more “cautious” in their behavior, and need to “have higher threshold levels of certainty” before responding to questions [27]. Their responses also tend to avoid the extreme ends of ranges.

Eisma et al. [6] found that the best way of addressing this reluctance was for a researcher to administer the questionnaire directly. This had the advantage of leading to spontaneous excursions into users' own experiences, and demonstrations of various personal devices were relatively common, and provided many useful insights. Dickinson et al [4] found that that in-home interviews were very effective in producing many stories about how the equipment in the home was obtained, how people learned to use it, who supported them, and the reporting of a variety of both good and bad experiences. They believe it to be unlikely that such a wealth of information could have been obtained in a laboratory situation.

6 The Use of Theatre

Interacting with older people thus has to be done with care and needs time and effort to do it well. This is not always possible due to constraints of time and resources.

Newell and his colleagues therefore have investigated the use of theatre professionals - actors, script writers and directors - who were experienced in Interactive Forum Theatre techniques [21,22]. This particular type of theatre encourages substantial interaction between the audience and the actors about the particular issues addressed by the theatrical presentation. They have used this format both for requirements gathering with older people and for encouraging dialogue between older users and designers.

A script writer conducts detailed research on the subject area and produces a series of short plays which address the important issues to be discussed. They contain 'human interest', humour, and dramatic tension as well as illustrating how the system may work, the errors which could occur in its use, and the effects of these errors on the participants. Each scenario lasts approximately five minutes, which typically leads to about twenty minutes of discussion. The format can be a video presentation followed by discussions, or live theatre, or a combination of the two.

These techniques have been used within the requirements gathering phase of a project developing a video camera based 'fall' monitor and detector for older people in their homes [16]. It was reported that the dramatized scenarios provided an excellent way of setting a shared context for discussions between potential users and designers, focused discussion on specific scenarios of likely system usage, and were very effective in provoking discussion of relevant details because elderly users could imagine themselves within the scenarios shown in the video.

Similar techniques were used as part of the UTOPIA (Usable Technology for Older People: Inclusive and Appropriate) project, whose primary aim was to develop techniques for changing the mind sets of designers concerning the usability needs of older people [4]. This project culminated in the production of the UTOPIA Trilogy [33], a series of videos addressing issues of older people's use of technology. Overall these videos were found to be a very useful method for provoking discussion and one which potential users find interesting and enjoyable. This ensured that user requirements were explored effectively early in the design cycle, and that designers became more aware of the issues addressed [3].

Newell and his colleagues have also used live performances [25] and have discussed the pros. of cons. of this type of presentation [22, 29]. Although the use of actors may not be wholly appropriate for very detailed evaluations of user interface, they describe the advantages both when a more holistic approach is required, and for very novel design briefs where an entirely new technology is being developed. It is worth noting that script writers and actors are trained as professional observers of human behavior and their skill is presenting that behavior in a way which engages the viewer/audience.

In addition, actors could also be valuable in usability testing by encouraging dialogue between the participants and the researchers. The use of actors removes the ethical problems of "protecting the users", and it is possible to envisage a situation where the designers and the users can verbally attack each another as part of addressing the usability issues of a particular system – a situation which would be difficult in a traditional usability laboratory setting, and likely to be unethical. Actors can also present a more generic picture of a user and can change their personae in response to requests from the designers (e.g. what would happen if you were older, if your sight/hearing was impaired, if you were under pressure?).

Finally theatre encourages a creative approach to design, involving users as well as designers, rather than the traditional view of focus groups and usability testing being solely a method of eliciting users' views and opinions, and to determine their abilities to use specific interfaces and systems.

7 Conclusion

It is essential that the voices of users are heard in the design process, but this provides significant challenges when the user population contains older and/or disabled users. They are a much more diverse population than most traditional user groups, and there are communication challenges caused by sensory loss, culture, language and attitudes to technology. There can also be major ethical problems in dealing with such groups.

Thus special care needs to be taken when working with older people, and a range of techniques need to be adopted to ensure that the data obtained is accurate and not distorted by the 'surface' attitudes of the older people. It is most effective if the older people are seen as part of the development team rather than just subjects of experimentation, and that the interactions between them and the designers are set within an enjoyable social experience. This ensures that not only is appropriate data gathered but also that the designers develop a real empathy with this user group.

The use of professional actors and live theatre is a further way which has been shown to be effective in facilitating discussions with users, or in those cases where it is too difficult or inappropriate to involve real users in experiments and dialogues. Although not an inexpensive option, the value which can be brought to the interaction by theatre professionals can be very significant.

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RFID Cards: A New Deal for Elderly Accessibility

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Abstract. Elderly adults face two serious challenges bridging the digital divide. First, many suffer from physical or cognitive disabilities, which inhibit computer use. Second, the "traditional" personal computer interface constitutes a foreign and forbidding paradigm. Consequently, elderly adults are less likely to access the Internet, and this lack of accessibility denies them increased social contact and access to information. This paper presents the design of a tangible user interface (TUI) for an email client that is suited to the physical, neurological, and cognitive needs of elderly users. A review of the TUI literature identifies radio frequency identification (RFID) tagged cards, integrated with standard personal computers, as a viable alternative to the mouse. These cards can represent interaction objects and actions, forming the basis for an interaction language. The email client interaction design illustrates many simple and advanced RFID card interaction techniques.

1 Introduction

The juggernaut of computing technology has largely bypassed a large and growing pool of potential users, older computer users. Consequently, many elderly adults are alienated from a powerful tool that can improve the quality of their lives. The obstacles they encounter include cognitive and physical disabilities and difficulty in developing a mental model of the computer as a tool.

The elderly constitute a significant portion of the population in industrialized countries. A 2000 U.S. Census study put the number of those aged 65 years or older at over 33 million, 12% of the total U.S. population [19]. The online presence of the elderly, however, is shockingly small: a 2004 study reported that only 22% use the Internet, compared to 58% aged 50-64, 75% of those aged 30-49, and 77% aged 18-29 [5]. The negative correlation of Internet use with current age is linked to several factors. Many older people suffer from some sort of disability such as decreased vision or hearing acuity. The 2000 study (ibid.) reported that 42% of those over 65 have such a disability, compared to 19% of those aged 5 and older. Besides physical barriers, the elderly also experience age-related cognitive changes that inhibit learning and their use of computers. Older adults show a decline in both episodic and spatial memory

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[9, 12]. Psychomotor abilities decline with age [23], and older users have more difficulty positioning the cursor over small targets [21].

The small percentage of older Americans using computers and the Internet is particularly regrettable because these tools have great potential to improve the quality of their lives. Social interaction and support can have profound effects on emotional and physical health, but transportation expenses and lack of physical mobility make social interaction difficult for many older adults. The Internet offers the promise of an effective and low-cost medium for social interaction [22]. For example, older Internet users are just as enthusiastic as younger users to send email: 94% of older users as compared to 91% for all users [5]. On SeniorNet, a nonprofit organization of computer users aged 50 and older, popular activities include emailing family and friends, making and managing photos, conversing with friends, and creating greeting cards [18]. Another potential benefit of computing technology is the ease of access to information. For example, the Internet has become a rich source of knowledge about health issues [2, 11, 16].

There is evidence that user interfaces (UIs) present a significant barrier to the elderly. Physical and cognitive barriers suggest that the windows, icons, menus, and pointing (WIMP) UIs so prevalent in today's computing technology are not the most appropriate for this population. Particularly problematic is the ubiquitous use of menus and pointing tasks [13], both of which tax the decreased memory and motor skills common to the elderly.

There are potential alternative computer controls and input devices. Radio frequency identification (RFID) technology makes new interaction techniques feasible. RFID technology is now an affordable alternative to the mouse as a computer input device and suggests techniques for making computers more accessible by mimicking everyday tasks and providing a more tangible, less abstract interface. We also believe that tangible user interfaces (TUIs) can facilitate computer literacy by enabling new paradigms more appropriate for casual computer users. The standard desktop metaphor is appropriate for sophisticated computer users with many tasks to perform simultaneously, but not for those who typically perform tasks sequentially at an unhurried pace. Multiple windows break up the visual space, confusing casual users and decreasing visual real estate that could be used, for example, to display larger text. Currently we are exploring the implementation of TUI using RFID technology and the potential of RFID technology to replace mouse and keyboard actions with ones that are more feasible for persons with mild cognitive and physical disabilities.

In this paper we propose alternative interaction techniques using RFID tagged cards and describe the design of an email client using RFID technology.

2 Review of Tangible User Interfaces

Ishii and Ulmer [7] expressed the goals of TUI as "augment[ing] the real physical world by coupling digital information to everyday physical objects and environments." They defined five generic TUI tools with close analogy to WIMP interface objects and demonstrated their use in three applications. Although categorizing TUI objects as transformations of WIMP interface objects restricts the TUI vision, their demonstrations made clear that TUI is more than a transformation. The WIMP to TUI transformations does provide a categorization, albeit incomplete, and a means to measure the progress of the HCI community and industry to achieving TUI. However, in the intervening ten years only one of the five generic tools, the physical icon (phicon), has been developed sufficiently to render it affordable for commodity PCs. RFID tagged cards constitute a viable implementation of physical icons and are mass produced, and RFID readers are becoming more affordable.

Physical icons are powerful interaction tools. Clicking an icon can specify either a task or an object. Selection of multiple icons can represent the subject, task, and object of the task, i.e., a set of icons can represent a complete sentence in verbal communication. Because the computer is aware of the icon-sets' context, icons have multiple or modal meaning, so the number of required icons can be limited. For example selecting the "save" icon with an unnamed icon while viewing a web page can save the web page's URL to the unnamed icon. Later the saved URL icon can be loaded into a browser simply by selecting the icon. In addition, the usability benefits of replacing screen icons with physical icons should not be overlooked. Fitzmaurice and Buxton [4] demonstrated that selecting and placing physical icons is much easier than selecting icons with a mouse on a monitor. Physical icons have inherent meaning that even non-computer users understand. For example, almost everyone understands the meaning of placing a card in a card game or exchanging business cards. Manipulation of physical icons is more understandable and consequently provides more user confidence. The permanence of physical icons "potentially leaves users with more confidence and a stronger sense of control over the status of the interaction" [17]. Users tend to find auxiliary uses for physical items in a workplace setting, which they can tailor to their own needs [6]. Physical icons can also be personally adorned with pictures, text or Braille, making them more accessible.

We were inspired by the UIs described by Jacob *et al.* [8] and Davidoff *et al.* [1]. Both interfaces use RFID cards as physical icons representing objects of the task. Jacob *et al.* use a grid of RFID readers embedded in a Senseboard, a large board for scheduling conference presentations. Presentations are represented by RFID blocks and magnetically mounted on the Senseboard. The interface demonstrates how TUI can add computer support to a task that is traditionally performed by sorting cards on a table.

ElderMail, a TUI email system for the elderly developed by Davidoff *et al.* [op. cit.], uses RFID cards to represent email addresses. This TUI reduces initial learning costs by modeling the UI as an instruction manual on top of a fax machine. Users select the task by opening the "book" to the proper "chapter" and complete the task by reading instructions and inserting RFID cards into slots built into the "book." The final page reveals a scanner bed to place handwritten letters and send the scanned document as an email attachment.

Although this approach demonstrates how a novel TUI can reduce initial learning costs, we suspect that users will quickly tire of turning pages after just a short learning time. This illustrates an interesting tension in TUI design: while physical icons are familiar and therefore good for learning, a slavish adherence to physicality can limit users who have made it over the learning curve. Older computer users do not want to be treated as novice users forever. As they gain confidence and ability they should be allowed to take advantage of the flexibility and efficiency of the new technology.

RFID cards representing personal information like email addresses demonstrate a general benefit of physical icons: because the cards are portable, they can remain in the possession of the user. In addition, the cards can be used like traditional cards, meaning users can exchange email addresses by exchanging cards offline. As the well-known ethnographic study of air-traffic control centers demonstrated, users can develop their own uses for physical icons, beyond those originally intended by the designers [6]. Playing card games is a popular recreational activity among this user group, so they have already mastered the skill of laying down and manipulating card sized objects. By replacing the "book" with a short training session, we believe that ElderMail can be simplified while retaining its critical benefits: reducing user memory overhead and pointing tasks.

Both Sensorboard and ElderMail are bulky interfaces developed for a single task. Although they perform their intended tasks well, they do not address the use of TUI in a general PC computing environment. We believe that TUI devices can be integrated into general purpose computer environments and improve their accessibility and usability for older computer users.

3 RFID Card Interaction Techniques

Several interaction techniques are possible using RFID cards with a single reader, and more are possible with multiple readers. Below is a short list of RFID card interaction techniques. All of these techniques can be used in combination, resulting in a large variety of interactions.

- Card selecting – a selection is made by placing a card on the reader.
- Card context – the meaning of a card depends on the other cards on the reader.
- Time sequencing – the meaning of a card depends on when a card is placed on the reader and the cards preceding and following the placement of that card.
- Position sequencing – the meaning of a card depends on which reader in an array of readers the card is placed on.
- List manipulation – Cards on an array of readers can represent a list and the user can manipulate the list (*e.g.,* rearrange the card order or select alternatives).
- Labeled sequencing – the user can label the readers in an array by the cards initially placed on them. Subsequently placed cards designate set membership represented by the reader.

Time and position sequencing can represent commands issued to the computer using a simple sentence structure:

action [options] [direct object] [indirect object]

RFID card interactions can imitate this simple sentence structure using either time or position sequence. Using time sequencing, the temporal order of placing the cards would determine which cards are the direct or indirect objects. Using position sequencing, the placement of the cards on a reader in an array of readers would determine which cards are direct or indirect objects.

List manipulation interaction techniques make possible the selection of websites resulting from a web search and the labeling of RFID cards. The result of a web search is a list of possible web sites to visit. After making a key word search, the user can populate the array of readers with new RFID cards. The computer system would automatically associate the new cards with the URL address. Replacing a card on the array of readers with a new card could designate that the associated web site is not of interest and to add a new web site to the list. Removing a card from the array of readers and placing the card on a reader designated as the *command reader* could issue a command to the web browser to visit the corresponding web site. If the selected web site is not interesting, the user can immediately visit another web site by placing another card from the array of readers on the command reader.

Labeled sequencing is an interaction technique for the user to define categories and sort a batch of cards into the categories. Consider the process of managing digital photos. After taking pictures with a digital camera, the user downloads the images to her computer. The user sequentially reviews the photos. When the user decides to save a photo, a label printer makes a thumbnail image to adhere to the RFID card. If the user had anticipated the categories for sorting the photos, the user could place a RFID card representing the category on the reader and the photo would automatically be sorted into that category. But defining the categories without first previewing all the photos is difficult. More natural is for the user to preview all the photos, making RFID cards of the saved photos, and then to decide on the sorting categories. RFID cards representing sorting categories can be placed on each reader in an array, then the user can sort the photos by stacking the RFID cards representing the photos on the readers.

The readers in the array can be implicitly labeled. Consider an implementation of the game of single-handed bridge using RFID cards and readers. Three readers are arranged to represent the virtual players around the table, and a fourth reader in the center of the table for placing the card in play. Playing bridge begins by dealing playing cards with RIFD labels on the three readers and to the user. Dealing the cards is effectively sorting the cards into four categories, one for each player. Play continues by the user making bids and plays by placing RFID cards on the play reader, with the computer responding by displaying bids and played cards on the screen.

The fundamental principle underlying all the RFID card interactions above is that the RFID card contains a key to a database resident on the PC, server or Internet. Laying an RFID card on the reader triggers a lookup into the database for the entry with the key on the card. An analogy to natural language is that cards are words and the database is the dictionary containing the meaning of the words. But because the system is aware of the context of the card, it can choose between multiple meanings for a word. The analogy of natural language can be extended. Sentences are ordered sequences of words; as in natural language the card sequence can be constructed in either time or space. Listed manipulation and labeled sequencing interaction techniques are particularly interesting because they transcend the natural language analogy for card interactions and demonstrate card interactions that exemplify tangible interaction techniques and the full advantage of tangible interactions.

4 RFID Card Email Client Design

The HCI literature has clearly identified that UIs for the elderly should employ slower on-screen motion [15], larger font sizes [20], and increased contrast [14]. We observed the need for these design principles while teaching basic computer skills to older computer users. We also observed that using the mouse and knowledge of basic computer use are major barriers to effective and enjoyable computer use. A good match between the user's cognitive model and an application's metaphor results in a natural and fluid user experience, while a poor match leads to errors and frustrations [3, 10]. We also observed that older computer users typically perform computer tasks sequentially at an unhurried pace, unlike younger users, who perform multiple tasks simultaneously. The process of sending and receiving emails can be simplified for users who do not require the flexibility demanded by expert users. And the application's metaphor and interaction style should conform to principles of a simple single-function interface performed sequentially. Our RFID card email client will conform to the following general design principles.

- minimal or no mouse pointing
- low functionality with sufficient flexibility
- uncluttered, high contrast, visually clear displays

These design principles support each other. Simple low functional interfaces will encourage visibly uncluttered graphical interface and allow more monitor space for larger fonts. Higher contrast and larger fonts will make more apparent the possible selections and the current selected item. Limited functionality will reduce many of the selections required in higher functional interfaces. Correspondingly, a design goal to reduce mouse pointing will encourage the low functionality interface goal.

There are a few design goals that are specific to an email client for older computer users. Modern email clients mimic standard postage mail by dividing the process of communication into sending and receiving text documents. Our RFID card email client should adhere to this established division of tasks. While instructing older users, we learned that older users were very specific about who they wanted to send an email and from whose email they wanted to receive, typically relative and friends. This unambiguous and precise delineation of correspondents should be realized by an email client for older computer users, especially in light of the current proliferation of spam in email. An email client for older computer users should severely filter email. Not only will email filtering fulfill the older users' desires, but will enable simpler interfaces.

4.1 Writing and Sending Email

Since sending email is initiated by the user and involves a small number of objects (message body and recipient email address), the interaction design can and should be simple and straightforward. A TUI can reduce the process to laying down four RFID cards on a single RFID reader and entering the message. The four cards identify the user, the task, the object of the task, and task completion. For example, the user would first place a "login" card on the reader and then lay down a "send email" card retrieved from a "Rolodex." The system would open the email client ready to accept the user's message.

The graphical interface can be very simple and uncluttered. It can display the task, "Send Email" and the recipient in a large title bar. The rest of the screen is a blank text field, labeled "Message."

The text of the email can be entered by typing the message or by scanning a handwritten document. While the "send email" card is on the RFID reader, the system can display the scanned image in the message text field. The user can continue to add to the message by typing or scanning additional images. Note that this naturally allows users to intersperse text with images.

At any time the user could lay down a card identifying the email recipient, "recipient" card, and the recipient's name appears in the title bar. Finally, laying down a "deliver" card from the Rolodex would send the email. Picking up the cards before laying down the "deliver send" card would cancel the email. Users could add more recipients by simply laying down more "recipient" cards.

4.2 Receiving and Reading Email

Receiving and reading email is more complex than sending email, since the number, source, and content of the messages do not originate from the user. However, a restrictive email filter can insure that the number of incoming emails is small enough to be managed by list manipulation interaction techniques. The configuration of RFID readers consists of a command reader and short array (perhaps 4 readers) of list readers. Again the user is identified by laying down the "logon" card on the command reader, and laying down the "inbox" card, which opens the email client to the inbox window.

The graphical interface of the inbox covers the monitor's screen and consists of a title bar, labeled "Email Inbox," and a short list of incoming email. Initially the list is empty. As the user adds new RFID cards, cards with keys that are not in the RFID database, to the list readers, the list of incoming email is populated with the correspondents' names and subject lines. Replacing a new card will display a new incoming email on the inbox list.

The user can read an email by moving a card from the list reader to the command reader. The inbox window changes to display the message, both simplified header and correspondence text. The user can view a different email by exchanging the new email card with any other card from the list readers. The user can choose to delete, save or reply to the email but laying the appropriate command card from the "Rolodex." The command is completed by picking up the command card with the new RFID card. In the case of deletion the new RFID card can be reused on list readers a display another new email in the inbox. In this way the user can move through a list of incoming emails. When saving an email, a label printer makes a label with the correspondent's name and subject line, which can be adhered to the RFID card. The email can later be reread by laying it on the command reader, which will open the email client and display the message.

4.3 Managing Email Filtering

In addition to insuring a manageable number of incoming emails, the email filter is crucial to protecting the users from spam and email hoaxes — this is particularly important for the elderly, since they are targets of scams. The filter should be restrictive, but the syntax of the filter rules should be to permit a correspondent email address.

We expect that initially the filter will be managed by a system administrator, but eventually the older computer users will want to add permitted correspondents themselves. An "email filter" command card can display a short list of permitted correspondents, and list manipulation interaction techniques similar to receiving email can be used to move through the list, view details of the correspondents, and delete correspondents from the permitted list. Adding a new correspondent to the permitted list is a bit problematic without typing and understanding the syntax of email addresses. But in some cases typing the email address can be avoided by the exchange of email address cards. Users of the RFID email client can make "email address" cards and exchange them. The new address can be added to the permit list by laying both the "permit" command card and email address card on the reader.

We do not presume that the above description is a complete interaction design specification. Our intent is to give a detail example of RFID cards interaction techniques in context, and to illustrate that the laying of cards can replace many selections using a mouse. Earlier, we proposed that older computer users should not be enslaved by the new technology; the interface should permit more skilled users to make selections with the mouse. All the text in the graphical interface can double as text entry fields and/or buttons; consequently all the standard commands should appear as buttons in the interface. This way the older computer user can choose to interact using RFID cards or the keyboard and mouse.

5 Summary

Elderly adults in assisted living communities and especially those who are wheelchair-bound are deprived of much human contact. Increased social contact can improve both the moral and physical health of elderly adults. The computer offers several media for communication, notably email, chat and web browsing, with the greater society. Older computer users' favorite task on computers is communicating with family and friends using email. But older computer users face many barriers to computer use. Old age brings failing eyesight and decreased motor and cognitive skills, making it difficult to read small text on the monitor and select items with the mouse.

Our review of the TUI literature and categorization of RFID card interaction techniques illustrate that RFID tagged cards are a viable tangible interface device with a rich interaction technique. They can enable selection by laying RFID cards or more tangible interaction techniques such as manipulating lists. We believe that the description of an RFID card email client demonstrates an older computer user accessible UI, which eliminates many if not all mouse-clicks. It also illustrates advanced RFID interaction techniques in the context of a computer application with multiple and dependent interactions. The RFID card email client also illustrates an interface metaphor that makes use of limited functionality and a graphical interface that has sufficient monitor space for large fonts.

The results of our designs can be generalized to other user contexts. For example, the TUI card system does not have to replace mouse pointing. Rather, the RFID cards can be used in conjunction with the mouse. We expect that TUI techniques can be tailored to a wide range of computer users. For example, business cards might be equipped with RFID labels so that an exchanged business card can open a web browser to the new acquaintance's website.

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An Investigation of Older Persons' Browser Usage

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Abstract. This paper reports on a study comparing Microsoft Internet Explorer 7 and Mozilla Firefox 2 with 18 participants aged 60 years old and over. The participants performed six groups of tasks related to browsing, navigation, navigation enhancement, bookmark, information transfer, personalization and technical manipulation. The study covers their performance, problems, and comments. This study found that menu bar is an important feature for supporting browsing activity. The participants performed the navigation tasks well but less so for personalization and technical manipulation tasks.

Keywords: web browser, ageing, performance, user interface.

1 Introduction and Background

In 2003 there were 20 million people aged 50 and over in the UK. It is projected that the number will increase by a further 36% in 2031, when there will be 27.2 million people aged 50 and over [1]. The number of older people using the Internet had also increased dramatically in the past decade. A survey performed in February 2006 revealed that 54% of 55-64 year olds living in the UK and 15% of 65 years olds and older went online [2].

Studies on Internet and ageing had shown that the Internet can potentially help older persons maintain their independence and improve their quality of life [3]. When it comes to web browsing, most older persons use either Microsoft Internet Explorer (IE) or Mozilla FireFox as their web browsers [4]. In October 2006, Microsoft released a new version of IE: IE7. The user interface of IE7 is quite different from the earlier version (IE6), as shown in Figure 1. As Microsoft is currently distributing IE7 as a high-priority update via Automatic Updates [5], users might unintentionally install it. Furthermore, Microsoft will integrate IE7 as a part of Windows Vista. This forms the motivation of this study. We are interested in investigating how older persons would react to this new browser.

A few days after Microsoft released IE7, Mozilla Foundation also released its new version of browser, Mozilla Firefox (FF) 2. The user interface of FF2 does not differ much from the earlier version, Firefox 1.5 (see Figure 2). The detailed features and improvements of both browsers are available on their developer websites. This study will use this new version to compare users' opinions, performance and problems with those experienced when using IE7.

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Fig. 1. Internet Explorer 6 (above) and 7 (below) user interface

Fig. 2. Mozilla Firefox 1.5 (above) and 2.0 (below) user interface

It should be noted that one major difference between IE7 and FF2 is that in IE7 the menu bar is hidden by default while in FF2 the menu is displayed and can not be hidden. The design chosen by IE7 results in a less cluttered screen, but also results in an added effort for users to guess where particular functions are located. The design chosen by FF2 is more cluttered, necessitating users to read through a series of texts, but might result in less effort in guessing where certain functions are located. This leads into an interesting research question of the effect of hidden vs. displayed menu bar on older persons' performance and opinions.

2 Method

2.1 Demographic Questionnaire

The participants were asked to fill a short questionnaire that gathers background information. The questionnaire includes questions on demographics such as age group and gender, Internet and computer usage, duration of computer and Internet use, and the browser they normally use. The inclusion criteria for participating are that they are familiar with computer, windows system and web browsers and that they were 60 years old or older at the time of study, and that they had never used IE7 or FF2 before.

2.2 Performance Test

The performance test consists of six groups of task: Navigation, Navigation Enhancement, Bookmark, Transfer, Personalization, and Technical Manipulation. The task groups were adapted from our previous work [4]. The participants were asked to perform the same browsing tasks using IE7 and FF2. The websites used were cached for offline browsing to reduce the difference in Internet connection speed. To counter balance, participants were divided into two groups: half of them performed the tasks using FF2 first and IE7 second; the rest performed the tasks using IE7 first and FF2 second.

During the performance test, the steps and time the participants took were recorded for each unique activity on the task list. Task time is defined as the elapsed time between the time the tester (one of the authors) finished reading the task and either the time the participant finished the task successfully or the time s/he gave up. There was no time limit for each task.

2.3 Participant Debriefing

After testing each browser, participants were asked to complete a post-test satisfaction questionnaire that consists of 10 product satisfaction questions derived from a usability testing of Netscape Navigator and IE [6]. The questions were listed in Table 3. In this questionnaire, they ranked each product on 5-point Likert scales, from strongly agree to strongly disagree with the statements. After finishing this questionnaire, the participants were interviewed on the problems they experienced or any comments they made in the task session to understand the underlying cause of the problems or to clarify the researcher's observation.

3 Results

3.1 Participants Demography

In total, 18 older adults participated in this study. Most of participants were familiar with computer and Internet, only one participant had used computer for less than a year (but more than six months) and two participants had used the Internet for less than six months. Table 1 shows the participants' profile.

3.2 Performance Test

The participants were asked to perform six groups of browsing tasks individually, with the researcher observing from a nearby location (within the same room). The detailed performance comparison is shown in Table 2.

3.2.1 Navigation Tasks

Expectedly, all participants were able to go to a website by entering the website name and go back to the previous page within a very short time. The numbers of participants that were able to go to a website in favourite/bookmarks list and reload a web page using FF2 are higher than those using IE7 (15 vs. 9 participants). They also

Table 1. Participants' profile

	No.	%
Age		
60-64	1	5.6
65-69	6	33.3
70-74	7	38.9
75-79	1	5.6
80 or above	3	16.7
Gender		
Male	6	33.3
Female	12	66.7
Education		
Less than high school	4	22.2
High school	11	61.1
Post graduate	3	16.7
Length of Computer use		
6-11 months	1	5.6
12-23 months	3	16.7
2-5 years	4	22.2
More than 5 years	10	55.6
Length of Internet use		
Less than 6 months	2	11.1
6-11 months	3	16.7
12-23 months	5	27.8
2-5 years	4	22.2
More than 5 years	4	22.2
Web browser used		
Internet Explorer	16	88.9
Mozilla Firefox	1	5.6
Other (AOL)	1	5.6

Table 2. Participants' performance using IE7 and FF2. # = number of participants successfully performed the tasks. The averages of trials and times in seconds are only for successful tasks. In cases where only one participant completed the tasks, standard deviations were omitted.

	Internet Explorer			Mozilla Firefox		
	#	Trials(S.D.)	Time(S.D.)	#	Trials(S.D.)	Time(S.D.)
Navigation						
Go to a website by	18	1(0)	31.4(22.7)	18	1(0)	25.4(12.9)
entering the website						
name	9	1.6(1.1)	65.2(34.9)	15	1.1(0.4)	17.7(10)
Go to a website in						
Favourite/Bookmarks list	18	1(0)	3.6(1)	18	1(0)	4.1(2)
Go back to previous page	8	1.4(1)	42.9(62.9)	11	1(0)	23(18)
Refresh/Reload a web	10	1(0)	8.9(6.7)	8	1.1(0.4)	11.2(11.6)
page						
Go to browser home page						

Table 2. (*Continued*)

	Internet Explorer			Mozilla Firefox		
	#	Trials(S.D.)	Time(S.D.)	#	Trials(S.D.)	Time(S.D.)
Navigation						
Enhancement	1	1	61.7(0)	5	1(0)	50.2(27.3)
Search within a web page	5	1(0)	33.1(19.1)	5	1(0)	7.3(5)
Change displayed language encoding	8	1(0)	30(30)	17	1(0)	7.3(5)
View history	8	1(0)	97.7(27.8)	18	1(0)	38.2(18.1)
Using browser help						
Bookmark						
Set browser's home page	4	2(2)	132.8(74.3)	2	1(0)	48.1(42.4)
Add a website to Favorite/Bookmarks list	10	1.1(0.3)	27(8.8)	16	1(0)	19.7(11)
Rename a website in Favorite/Bookmarks list	5	1.8(1.1)	47.8(37.6)	4	1.75(1)	124.5(50)
Delete a website in Favorite/Bookmarks list	6	1.2(0.4)	12.35(4.9)	11	1.4(0.7)	21.2(13.5)
Transfer						
Copy a part of web page to other program	14	1.1(0.4)	62.5(34.1)	17	1.1(0.2)	46.2(22.6)
Save a web page	9	1.2(0.4)	47.3(28.7)	18	1.1(0.5)	27.9(14.2)
Print a web page	17	1(0)	17.7(14)	18	1(0)	19.6(11)
Setup a web page printing	16	1.7(1.3)	41.3(38.1)	16	1(0)	16(6.2)
Preview a web page printing	15	1.1(0.4)	10.8(5.2)	18	1.11(0.5)	12(12.5)
Personalization						
Adjust the text size	11	1.18(0.4)	45.4(38.4)	13	1.23(0.6)	40.8(36.6)
Change text and background colour	1	5	420(0)	1	2	222(0)
Hide images	1	1	48.5(0)	3	2(1.7)	130.5(40.4)
Technical						
Show or hide toolbars	8	1.13(0.4)	97.7(27.8)	1	1	17.7(0)
View HTML source	1	1	48.1(0)	2	1(0)	21.1(10.5)
Set the proxy server	0			0		
Set a security option	0			0		

took longer performing this task when using IE7 than when using FF2 because they needed to search for Favourite icon. Around half of the respondents were able to go to home page using home icon (10 participants using IE7, 8 participants using FF2). The problem when using IE7 is that many participants cannot understand the yellow star icon that IE7 uses to represent the Favourite Center. Some participants also cannot associate the Refresh/Reload and Home icons of both browsers with their intended meaning.

Most of tasks in this group were done using browser icons except to go to a website in bookmarks list, which most used the menu bar for FF2.

3.2.2 Navigation Enhancement Tasks

Most participants were able to view history and search for help in FF2 but less than half could do so in IE7. The reason is that both the help and history functions are easily accessed from FF2's menu but were hidden in IE7. Five participants were able to search a word within a web page using FF2 but only one participant was able to do so using IE7. The rest of participant were not aware of this function or have never used this function before and were therefore unable to complete the task. Five participants were able to change display language encoding using both IE7 and FF2. More time was taken when using IE7 because many participants could not associate this function with its super ordinate function, which was the 'Page' function (some did not even understand the meaning of the icon used to represent the 'Page' function).

Most of tasks in this group were done using menu bar or mouse's right-click except using help and searching for history in IE7.

3.2.3 Bookmark Tasks

Adding a website to favourite/bookmarks list is the most successful task in this group. Respectively, 16 (FF2) and 10 (IE7) out of the 18 participants were able to complete this task. They completed this task using FF2's menu and IE7's Add to Favorites icon. It should be noted that Add to Favorites icon is a yellow star with a green '+' sign on the top of the star – we could argue that even if the participant did not understand that the star represents 'favourite list', the '+' sign might help association, and therefore more participants successfully added a website to favourite/bookmarks list than those who successfully went to a website in favourite/bookmarks list. More participants were able to delete a website in the favourite/bookmarks list in FF2 than in IE7 again because of problem associated with finding the favourite/bookmarks list. Interestingly, more participants were able to rename a website in favourite/bookmarks list using IE7 than using FF2. One possible cause is that, once the participants were able to open the favourite list in IE7, they just needed to right-click the mouse button to find the 'rename' function. In FF2, the 'rename' function was located under the 'properties' menu, which arguably was less intuitive. Very few of participants were able to set the browser's homepage, arguably because it is an activity that only needs to be performed once or considered unnecessary (many users would probably pay very little attention to the default homepage of the browsers).

3.2.4 Transfer Tasks

All transfer tasks related to printing were highly successful using both browsers, possibly because all printing-related menus are easily accessible from FF2's menu and IE7's Print icon toolbar. Copying a part of a web page to other program is also highly successful, with most users using FF2's menu and IE7's Page icon. Please note that the times used in this task include the times to open Microsoft Word 2003. Saving a web page was successfully done by all participants using FF2 but only by half of the participants using IE7, indicating the difficulty in understanding where this function is located.

3.2.5 Personalization Tasks

Two thirds of the participants were able to change text sizes using FF2's menu bar and IE7's Page icon. The rest of participants reported that they were either not aware of this function or never used this function before. Only one participant was able to change text and colour background using each browser (and not the same person). Very few participants were able to hide images using both browsers. In general, the findings show that personalizing web browser is difficult for older persons, in line with the finding reported in [7].

3.2.6 Technical Manipulation Tasks

Eight participants were able to show and hide menu bars using IE7, while only one participant was able to do so using FF2. None were able to set proxy server and security options and very few participants were able to view HTML source. Arguably, these highly technical tasks are highly complex and were not normally done by regular users (young or old).

3.3 Participants Debriefing

After testing each browser, the participants were asked to complete a post-test satisfaction questionnaire. Table 3 shows results from the questionnaire.

In general FF2 received more positive ratings than IE7 did (an interesting finding as only 1 participant used FF as their browser before the study). The results of t-test suggest that there are no significance difference in terms of functions, users efficiency and effectiveness (in task completion), errors recovery and browser preference.

Observing participants' interaction with IE and recording their comments, the problems that they experienced seem to be centred on the new interface that was quite different from the one they use currently. The most common complaint was related to the fact that the menus were hidden. Some literally stated that they needed the menus to be visible at all time even if they clutter the screen. They also suggested that the help icon be more visible and centrally located. The new design of icons caused many problems, even for experienced IE users. The Page icon was considered unintuitive at first sight. Moreover for the Stop and Refresh icons, only highly experienced users were able to associate the icons with the functions they represent. Nearly half of participants thought the Stop icon meant 'close' (due to its similarity with a standard Windows OS 'Close' icon) and the Refresh icon meant 'scroll the page up and down'. Figure 2 shows IE7's Refresh and Stop icons.

Only few participants commented on FF2. Most of them stated that they were new to it and therefore were hesitant to comment. However, those who commented stated that the icons in FF2 were quite similar to earlier versions of IE and therefore helped them associate the icons with the functions they represented. In contrast with IE7's Stop icon, FF2's Stop icon was considered very intuitive as it resembles the Stop traffic sign. The only icon that the participants complained about was the Reload icon. Some of them thought that this icon represents 'forward navigation'. One participant suggested reversing the direction of the Reload icon to reduce confusion (the rightmost figure in Figure 3). Figure 3 shows FF2's Reload and Stop icons. One participant stated that for her there was little difference in these two browsers as she only used very basic functions, and therefore could easily remember where those functions were located.

Table 3. User rating for each browser. Number show Mean (S.D.) Options: 1 = Strongly agree, 2 = Agree, 3 = Average, 4 = Disagree, and 5 = Strongly Disagree. *p <0.05; **p <0.01.

	Internet Explorer	Mozilla Firefox	t
The functions I expected to complete the tasks were available	2.4 (1.4)	2.2 (0.9)	0.77
The browser was intuitive	3.2 (1)	2.4 (0.9)	2.96**
I was satisfied with how the browser works	2.9 (1.1)	2.1 (0.9)	2.25*
The browser was simple to use	3.4 (1)	2.7 (1)	2.40*
I could effectively complete the tasks	3.1 (1)	3.1 (0.8)	0.00
I could complete the tasks quickly	4.1 (1)	3.1 (0.8)	3.57**
I could complete the tasks efficiently	3.5 (1.2)	3.2 (1)	1.46
I thought the "look" of browser was pleasant	2.9 (1.4)	1.9 (0.7)	2.67*
I could easily recover from errors	3.3 (1.1)	2.9 (0.8)	1.64
I really liked using this browser	3.1 (1.6)	2.9 (1.3)	0.35

Fig. 2. Internet Explorer's Refresh and Stop icons

Fig. 3. FF2's Reload and Stop icons and the Reload icon suggested by a user

Four participants who used FF2 for the first time in this study stated that they were very happy with this program and expressed the wish to change their browser. They stated that they liked the plain and simple design of FF2 but suggested adding some other basic icons, e.g. print, save, copy and paste.

4 Discussion and Conclusions

Almost all participants were able to use all necessary basic functions (e.g., going to website by entering the website name, going to previous page, printing a web page, etc) using both browsers, which was good news. Arguably, this means that, if the participants recruited in this study are representative of the older web browser population in general, that older web browsers were able to perform basic operations that are needed to access information on the Web regardless of whether IE or FF was installed in their computers.

In addition to providing statistical evidence of the performance and opinion differences between the two tested browsers, this study has shed light into older persons' strategies in going around tasks they were not able to do. For example, many of the respondents were not able to recognize the Home icon as the easiest way to go to the browser's home page. The researcher's observation and the interview show that in general the participants solve this problem by performing two strategies to go to browser's home page: 1) closed and re-opened the browser and 2) click the back button multiple times until they reached the home page. However, this study also revealed that older persons were fast in learning new techniques. After the researcher informed them about the Home icon, they adopted the technique immediately. This result is not new; many studies on older adults and computers had shown that with appropriate training, tutorial or assistance, older persons were able to pick up new skills [8].

The study shows very low success rate in searching within a web page, which is unfortunate. Searching within a web page allows user to get the information required efficiently. The problem is due to the complexity of operation. IE7 search function is accessed by clicking at search engine selection and choosing to find in this page or by accessing a hidden menu bar which is not easily visible. FF2 search is easily accessed through its menu bar but the search box appears at the bottom of the screen, which makes it difficult to notice. This low success rate indicates that older users require a more noticeable and simpler way of accessing this function.

The participants performed very well the transfer tasks except saving a web page. As explained earlier, in IE7, this function is placed under the 'Page' icon which is apparently unintuitive for some users.

Changing text and background colours will greatly help older adults when browsing low contrast web pages. However, this task requires many steps to complete. Even when users were able to select preferred text and background colours, they are also required to set the browser to ignore web the original colour schemes of the displayed web pages. This extra step was the main cause of failure of this task. Hiding images also required advanced technical skill especially in IE7. The setting is located in the multimedia part of the advanced setting menu. FF2 puts this option in a better position but the phrase 'Load images automatically' does not best represent what most users would understand as hiding images.

The technical manipulation tasks were rarely performed successfully by the participants (except show menu bar in IE7). It is difficult to remedy, except that it points to a need to ensure that web browsers that are used by older persons should come in the default settings that are ageing-friendly, thereby minimizing the requirement for older users to personalize the browsers.

This study sets out to understand the difference between two new versions of the most common web browsers: IE7 and FF2. While the study reveals findings that are expected, such as that basic browsing activities are reasonably performed by older web browsers and highly technical activities are more difficult, one important outcome of this study is the fact that readily available and visible list of functions, even at the cost of cluttering the screen, seems to help older persons perform more difficult browsing tasks. This study also shows that there is a need to maintain a consistent representation of functions in icon design (in relation to previous versions), rather than presenting 'pretty' and 'artistic' new icons, as this means that older persons have to relearn the association between icons and functions they represent again. Finally, this study also indicates that even though some studies suggest that older persons are hesitant to change the computer applications they use, they are actually willing to change when they like a certain application.

In summary, although this study has not arrived to the point of being able to crystallize the findings into design requirements of web browsers for older persons, it is a starting point in understanding how older persons perceive and perform with new web browsers.

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Investigation of Adaptation Dimensions for Age-Differentiated Human-Computer Interfaces

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Abstract. An important issue of the demographic change in the German population is the maintenance and promotion of the employability of aging workforces. However, there are hardly any suitable concepts or usable tools available to realize this goal. Possible approaches should push the individual strengths of the aging workers to the foreground and intercept the possible physical and cognitive losses in ability that occur with an increase in age. A model of age-differentiated adaptation of the human-computer interface, in which automatic adaptations are conducted based on individual user characteristics, is presented in this article. First connections between user characteristics and adaptation dimensions were analyzed in a study with 90 subjects ranging from 20 to 73 years of age. Results indicate a significant influence of graphical layout on memorization as well as interpretation performance.

Keywords: demographic change, adaptive human-computer interfaces, individualization of software.

1 Introduction

The demographic change of the population and the accompanying changes in gainful employment in Germany and other European countries will make it increasingly important to maintain and promote employability of the aging workforces. In terms of meeting these demands, however, there are hardly any suitable concepts and applicable tools currently available that support the individual strengths and weaknesses of the aging employed.

It is likely that a loss of physical abilities occurs with an increase in age. However, communicative, coordinative and creative activities that call upon the existing know-how possessed by older employees may play an ever more important role. The use of computers often poses a notable barrier for older workers since they lack experience and have a generally more reserved attitude towards information technology.

Work and work tools should be designed for individual abilities including the variability of abilities among older workers especially, thus securing employability.

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Current interfaces are not flexible though, and they are unable to compensate for the various operation methods or to specifically qualify the aging user. For example, older users do not receive adequate support, so individual adaptation to the characteristics, preferences and abilities of each individual user would be worthwhile.

In the adaptation of software to the individual user-initiated changes and independently computer-executed adjustments can be distinguished. Most of today's software systems possess a configurable user interface in which the appearance, menu structure, etc. can be customized according to individual preferences. However, the user usually does not have sufficient knowledge about the application and his/her own needs, meaning this type of individualization is rarely used [6].

A continuing approach is given by so-called adaptive user interfaces in which the system makes adjustments to itself based on user behavior. These "intelligent" interfaces attempt to anticipate the user's goals and needs through use of "artificial intelligence" and adjust accordingly [8].

Aging workers in particular benefit from the utilization of such computer workplaces because their specific abilities are consistently used and their weaknesses specifically supported. Such a targeted combination of different adaptation dimensions in relation to the physiological and cognitive abilities of aging people is not known, yet it is to be achieved with the approach of age-differentiated and individual adaptation described here.

2 The Approach of Age-Differentiated Adaptation

The approach of age-differentiated adaptation of the human-computer interface aims at the support of elderly people working with the computer. The individual age-based customization is exemplarily conducted in a project management software application. This software is particularly suitable, as it requires complex cognitive skills as well as coordinative-communicative abilities.

Based on the methodology of Jameson [5] three different phases are distinguished: the afference, inference and efference phases. The characteristic user attributes are registered in the first phase and analyzed in the second phase, followed by the drawing of conclusions regarding individualization. In the third phase, the individualized adaptation of the user interface is performed. The three phases are adapted accordingly for the approach of age-differentiated adaptation and then expanded through an evaluation phase. This evaluation phase involves the user in evaluating the adaptive software, which is then updated accordingly within an iterative design process.

Along with these adaptation dimensions, specific user data plays a particularly important role for the individualization of project management software. User-specific adaptation will be conducted based on the abilities of the individual user. The first step in doing so requires the identification of significant correlations between the user-specific data and those related to the adaptation dimensions.

A recently conducted experiment that examines different adaptation dimensions and their relation to age-specific user characteristics is presented in the following.

3 Empirical Investigation of Potential Adaptation Dimensions

In an empirical study, font size as well as memorization and interpretation performance were investigated with regard to the optimal age-differentiated and individualized adaptation of network plans for project management.

In the first experiment, Microsoft's standard font size and the recommended font size according to the standard (DIN EN ISO 9241-303) were examined to determine whether it is also suitable for older persons, or if there is an optimal font size according to age. It was hypothesized that an increase in font size has a positive effect of visual acuity on recognition ability as well as an improvement of performance, particularly for older users.

In the second experiment, the influence of layout design of a network plan on the memorization performance of the user was examined. A differentiation between vertical and horizontal orientation of task networks and different spatial spreads between activities of a network plan are highlighted. Based on investigations conducted by Winkelholz & Schlick [12], it was assumed that an improvement of memorization performance will occur for horizontal rather than vertical orientation, as well as for an increase in spread.

Analogous to experiment 2, experiment 3 tested the influence of layout design on contextual task processing. Based on the Proximity Compatibility Principle [10], it is assumed in experiment 3 that a small spatial spread between activities leads to better performance. Wickens postulates that the spatial proximity of data sources brings with it an advantage during integrative task processing, in which a compatibility of cognitive processes is ensured. A positive effect due to horizontal orientation is also expected in this case [11].

At the beginning of the experiments, user-specific abilities and characteristics of the test subjects were determined. Aside from experiments regarding visual acuity, the cognitive ability - in particular spatial sense, memory and fluid intelligence - were examined primarily by means of standardized questionnaires ([9], [7]). Moreover, the attitude and experience of the test subjects regarding technical devices and a project management software application was tested by a questionnaire [1].

The subsequent computer-based tests, which highlight two different adaptation dimensions, font size and layout design of a network plan in terms of age-specific aspects, was divided into three parts.

Each of the three experiments was conducted at a standard workplace PC. A 19” (48cm) LCD screen with a resolution of 1280 x 1024 pixels was used as a display.

In the experiments 90 subjects (45 male, 45 female) between 20 and 73 years of age were tested. For the evaluation of the experiment, subjects were divided into three age groups (20-39, 40-59, 60-75). The first age group consisted of 34 subjects, the second age group of 35 subjects, and the third age group of 21 subjects. The test subjects participated voluntarily in the experiment for a 20 Euro compensation. The majority of participants recruited were employees of the institute and the administration as well as senior citizen students at the university. Related to academic education level, 48.3 percent of participants claimed to have completed post-secondary studies. The second largest group of subjects (27.6 percent) had not completed vocational training.

Daily computer use is approximately 70 percent. Only four subjects indicated that they did not have a PC in their home. E-mail programs and the internet were also used by more than half of all test subjects on a daily basis. Even though 48.9 percent of test subjects dealt with project planning or project management in their jobs, either currently or in the past, only nine out of the 90 participants worked with the market leading MS Project software.

3.1 Experiment 1 – Investigation of Font Size

The goal of the experiment is to determine the connection between visual acuity of test subjects and the optimal font size for these subjects. The influence of various font sizes on recognition ability is highlighted in terms of age-specific factors.

In the first experiment the subjects had to perform a choice-reaction test. After the presentation of a control stimulus, the subjects had to differentiate between this stimulus and additional stimuli that were presented in various font sizes. The error rate and the reaction time are regarded as dependent variables and then evaluated according to the given font size.

Method

The symbol “4” served as a control stimulus that had to be differentiated from capital letters “A”, ”B”, “C”, etc. serving as alternative stimuli. A sequence of 165 symbols, which contained 15 control stimuli, was presented to the subjects. Each of the stimuli was presented for 1.5 seconds in duration. The sequence was randomly created under the condition that the number “4” appears once within a block of 10 symbols. The subjects were instructed to press the space bar when they believed they saw a “4”. All subjects were presented with an identical sequence of symbols. The resulting variance model consists of the factors font size (5 grades) and age-group (3 grades).

The display was placed in front of subjects at a viewing distance of 70 cm according to standards (BGI 650). The test subjects maintained this distance through the use of chin rests. In addition, the optimal height of the monitor was determined individually for each participant (BGI 650, DIN EN ISO 9241-303).

All symbols were presented in five different font sizes. If necessary, the subjects were allowed to wear glasses. Besides the stimuli in prescribed minimum font size as well as recommended font size (BGI 650, DIN EN ISO 9241-303), the test subjects were also presented with Microsoft's standard font size and a particularly large font size. The five fonts sizes used are 9, 12, 16, 22 and 27 minutes of arc (MOA).

3.2 Experiment 2 – Investigation of Effects on Memorization

The goal of the experiment was to determine the effect of age, as well as the cognitive abilities related to it, on memorization performance. Different layouts of network plans were thereby investigated as additional influencing variables.

The task of the second experiment was to memorize a randomly created sequence of highlighted activities from different layouts of network plans. The number of correct repeated sequences as well as the reaction time was used as a measure of performance.

Method

Figure 1 shows the six layouts that were used in the second experiment. Each layout consists of 25 activities. The six layouts differ depending on their orientation, horizontal (H) versus vertical (V), and their spatial spread, i.e., the distances between the activities (1 - no spread, 2 - clustered, 3 - uniformly spread). The motivation for the choice of these structures is based on experiments and analyses of Winkelholz & Schlick [12].

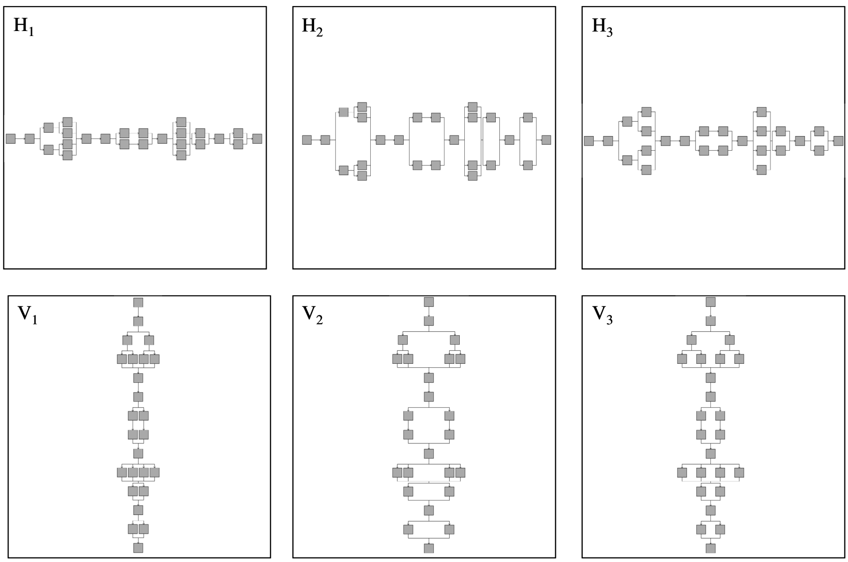

Fig. 1. Screenshots of the six layouts of task network plans

After an acoustical signal, the computer started to highlight activities of one randomly created sequence. Only singular activities of the sequence were highlighted for two seconds. The sequences were five items long. There was no break between the highlighting of two activities. The highlighted activities differed from the unhighlighted activities by color (blue instead of grey). The end of a sequence was indicated by a second acoustical signal. The test subjects were instructed to repeat the highlighted activities in correct order, by clicking them on screen with a mouse. After five activities had been clicked, another acoustical signal rang out. After a short break the next sequence was presented. There were six randomly created sequences for each layout. The same six sequences corresponding to one layout were presented to each subject. The order in which the various layouts were presented differed between groups of test subjects. The resulting variance model consists of the three factors age-group (three grades), orientation (two grades) and spread (two grades).

3.3 Experiment 3 – Investigation of Layout Effects on Interpretation Performance

The goal of the third experiment was to determine the influence of layout design on the interpretation performance (error rate and reaction time), as well as age-specific influencing variables and their relationship to layout design.

In this experiment, the subjects had to answer questions regarding the schedule as well as the duration of activities in differently laid out network plans. The amount of correct answers and the reaction time were measured as independent variables.

Method

For the third experiment the same six layouts as those used in experiment 2 (see Fig. 1) were used in simplified form. Additionally, the start and end times for each activity were added to each activity in the graphic. The subjects were asked four different questions per layout. Representatively, a layout with one of the four questions is depicted in Figure 2.

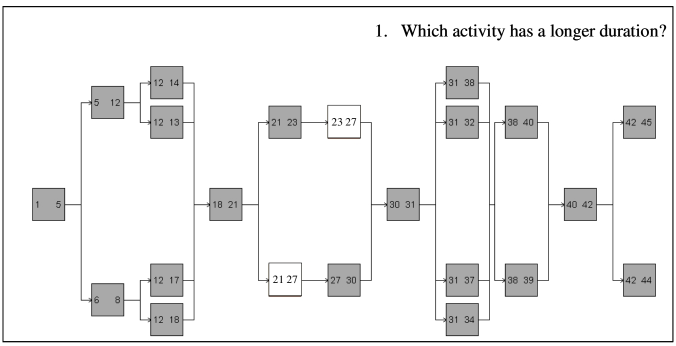

Fig. 2. Screenshot of one layout with one of the according task for this layout

After an acoustical signal, the computer started to highlight, depending on the question, one or two randomly created activities of the network plan. Here, a highlighted activity differs from an unhighlighted activity by color - orange instead of grey. Then, after two seconds, one question concerning the highlighted activities appeared. Afterward, the subject had to answer the question by marking the correct activity, respectively, the correct number, by mouse click. There was no time limit for this task. Following this, the next question was presented. There were four questions for each layout:

1. Which activity has a longer duration?
2. Which activity ends first?
3. How many direct predecessors does this activity have?
4. How many direct successors does this activity have?

These can be assigned to two question types according to their content: type 1, consisting of questions 1 and 2, demands a numerical analysis of the activities and type 2, consisting of questions 3 and 4, requires a visual-spatial analysis.

The sequence of questions within a layout was randomly selected. Each test subject was presented with identical questions in the same sequence per layout. The order in which the various layouts were presented differed between groups of test subjects. The resulting empirical design contains the four factors orientation (two grades), spread (two grades), type of question (two grades) and age-group (three grades).

4 Data Analysis

In order to compute the results, correlation analysis (Spearman coefficient) was used to determine connections between results of the preliminary interviews and psychometric tests and the computer-based tests. The data of the main investigation was evaluated using the general linear mode by analysis of variance with repeated measures according to the experimental designs mentioned above. Additionally, o^2 [4] was calculated for significant effects in order to be able to draw a conclusion about the strength of an effect by the extent of the involvement of the corresponding factors in the explanation of variance. The level of significance is $p<0.01$ if another level is not mentioned.

5 Results and Discussion

5.1 Experiment 1 - Investigation of Font Size

The results of the first experiment are outlined in the following according to accuracy, i.e., amount of correct and incorrect responses and reaction time.

Accuracy

At a font size of 9 MOA there are significant correlations with the quantity of correct answers. The older the subject, the lower the number of correct answers. However, there is no significant relationship between age and performance with a font size bigger than 9 MOA.

A main effect exists for age group, with $F=11.38$, $p<.01$ and $o^2=.032$, corresponding to an explained variance of 3.2 percent between subjects. An additional strong effect exists related to font size ($F=38.98$, $p<.01$, $o^2=.256$ within subjects). The interaction between font size and age group must also be pointed out: it indicates an explained variance of 13.7 percent ($F=11.14$, $p<.01$). However, a ceiling effect occurs above a font size of 12 MOA.

Reaction Time

A significant correlation of $r=.23$ ($p<.05$) for both 9 MOA and 12 MOA exists between age and the required time for problem solving at various font sizes. This means that, for smaller font sizes, older people require more time to give a correct answer. The font size factor is able to explain 42.8 percent of variance within the test subjects ($F=67.38$, $p<.01$). A ceiling effect occurs for font sizes greater than 16 MOA.

5.2 Experiment 2 - Investigation of Effects on Memorization

The following results are grouped according to accuracy and reaction time. The accuracy is measured through the number of correctly repeated sequences.

Accuracy

The age group of 20-39 year olds shows significantly better accuracy when memorizing the items in the network plans than the other two age groups. A significant main effect occurs for age group with $F=15.12$ at a level of significance of $p<.01$ and an explained variance of 12.7 percent between subjects.

A horizontal layout scores significantly higher than the vertical layout ($F=64.51$, $p<.01$, $o^2=.080$). No difference between cluster and uniformly distributed spread exists. A layout without spread, however, scores significantly lower ($F=64.63$, $p<.01$, $o^2=.19$). The interaction effect with a three percent explanation of variance between direction and spread is significantly more distinct for a horizontal layout direction than for a vertical layout. Significant correlations of $r=.28$ up to $r=.42$ exist between the memorization performance of this experiment and the results of the psychometric tests in the pretest for the determination of memory, spatial sense and fluid intelligence.

Reaction Time

A significant age effect between subjects can also be determined regarding reaction time ($F=7.93$, $p<.01$, $o^2=.054$). A significant orientation effect also exists ($F=6.2$), but at a level of significance of $p<.05$ and an explanation of variance of 1.2 percent it is not very distinct. The horizontal layout once again scores better than the vertical layout. The spatial spread effect is significant ($F=7.5$, $p<.01$) and lies at $o^2=.030$. Significant correlations exist between all layouts and age groups. Layouts H_2, H_3 and V_2 indicate highly significant negative correlations ($r=-.25$ to $r=-.44$) with the results of the dice test and the number-symbol test. Therefore, the better the test result, the lower the time needed for reaching the correct solution in these layouts.

5.3 Experiment 3 - Investigation of Layout Effects on Interpretation Performance

The results of experiment 3 are described only in terms of the required reaction time. No statements can be made regarding accuracy since nearly no mistakes have been made by subjects performing this task.

Reaction Time

In particular, the question type and the age group have effects on the time required to correctly answer questions in this experiment. The age effect explains 18 percent of the variance ($F=21.08$, $p<.01$), while the question type explains 17 percent within the test subjects ($F=77.58$, $p<.01$). Question type 1 leads to significantly better performance than question type 2. The spread effect is equally significant with

F=10.85 at p<.01 and an explanation of variance of 2.2 percent. Equally distributed spread thus leads to significantly better performance in terms of less time required than for cluster spread and layout without spread. A significant interaction effect exists related to question type and age group, and explains 7.5 percent of variance within test subjects (F=17.32, p<.01). Question type 2 scores significantly lower in age group 60-75 years than in the other two age groups. A significant negative correlation between both question types and all layouts is shown by test results regarding required time and spatial sense (r=-.449, p<.01), fluid intelligence (r=-.425, p<.01) and memory (r=-.465; p<.01).

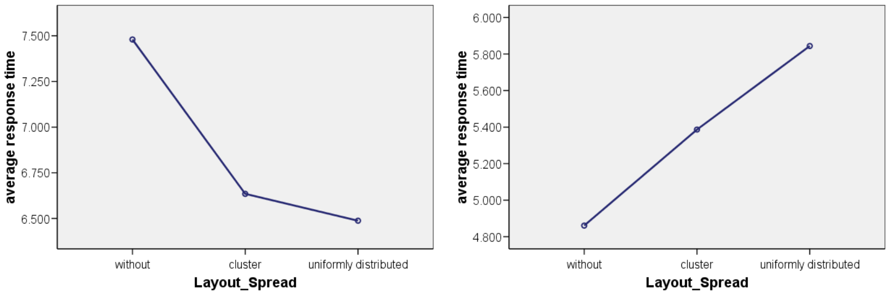

Fig. 3. Average response time concerning different layouts for memorization in exp.2 (left) and interpretation performance in exp.3 (right)

The results of the first experiments on age-differentiated font sizes in the design of software indicate that the often predefined standard font size of 12 MOA is sufficient for all age groups. This seems to be the case if, as in these experiments, only recognition and short-term strain are dealt with. The missing correlation between visual acuity and font size must still be explained. Even older subjects with significant limitations in visual acuity (age and visual acuity are significantly correlated) are still able to perform well. A possible explanation is the trade-off between limited visual acuity and short-term strain, or perhaps an increase in attentiveness. It is possible to perform well when dealing with a pure recognition task, such as the one in this case, yet it should be investigated if this performance level remains with long-term tasks, such as the execution of project management tasks. As a result, it can be asked which font size is most suitable for older users during long-term tasks that also pose more complex demands than just stimuli discrimination.

It can be noted that in terms of layout design, a large spread between the activities in a network plan is necessary for good memorization performance (high amount of correct answers, low amount of required time; see Fig. 3 left). This conclusion is supported by the theory of Winkelholz & Schlick [12], which assumes an improvement in memorization performance due to horizontal rather than vertical orientation and an increase in spread.

For the extraction of information on a semantic level, however, a small spread between activities has positive effects (see Fig. 3 right, corresponding to the Proximity Compatibility Principle according to Wickens & Carswell [10]). The expected positive effect of a horizontal orientation stated by Winkelholz [11] can also be confirmed by this experiment.

6 Future Work

The discrepancy related to layout design for different task types, memorization and interpretation discovered here should be further analyzed in future work. Additionally, the influence of scrolling on user performance must be taken into consideration in the determination of the optimal layout design for larger network plans. Therefore, it should be investigated whether an optimal layout structure, e.g., with greater spatial spread, leads to poorer performance due to the scrolling necessary because of its larger presentation manner.

Acknowledgement

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User Specific Design of Interfaces and Interaction Techniques: What Do Older Computer Users Need?

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Abstract. The increase of a "graying" society is apparent in recent decades and as such, the attention of marketing and product design is more and more focused on older users of technical devices. The study addresses the relevance of hardware and software design in human-computer interaction of older users. It was found that performance significantly increased (up to 3 times) with easier sensumotor transformation and easier task type. However, this was more prominent in middle-aged users than in younger users. Task difficulty revealed a rather unspecific impact on performance (43%), and was equally apparent in both age groups. Recommendations derived from this review show that older users will profit most from touch based or mouse operated interfaces. Additionally, easy icon and menu designs are often missed and will become more and more important for older users.

Keywords: Age, User Characteristics, Task Type, Task Difficulty, Input Device.

1 Introduction

Several input devices accomplish for an effective human-computer interaction (e.g. mouse, pen, touchpad, trackpoint). Yet, the user is still confronted with the question, which device serves the best for ones' purpose. The usage of input devices is also affected by the undergoing changes with aging, for example in motor and cognitive performance. The age-related decline in motor performance is well documented [e.g. 1,2,3,4]: Reaction and movement time slow down up to 200% [1]. When handling an input device, findings also showed an age-related decrease in motor performance of middle-aged and older adults compared with young users [e.g. 5-12]. The slowing-down was found to be quite independent from the type of input device (e.g. touchpad and trackpoint [5,6,7], pen [8]), though mostly reported for the mouse [8,9,10,11,12]. Smith et al. [9] reported that motor performance of middle-aged and older mouse users was 2.5 times and 3 times, respectively, inferior to that observed in young users. Also Chaparro et al. [10] numeralized the age-related decline of older mouse and trackball users by the factor 1.6.

In the present paper we will address several critical aspects in the design of human-computer interaction and its relation to age, i.e. the effect of input-device type on performance of older users, of task type and of task difficulty. The aim is to retrieve

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the specific impact of these factors in the human-computer interaction in order to establish recommendations for a user-guided design of interfaces and interaction techniques for users of older age.

Several experiments of our lab will be reviewed against the background of a framework of user-computer interaction (Figure 1 [5]). The framework assumes that technical features of the hardware and the transformation of hand movement into cursor movement (= sensumotor transformation [13,14]) determine the basis of interaction efficiency. Either user characteristics (e.g. age [11], expertise [15]) and / or task type and task difficulty [e.g. 16] further influence the outcome as well as both aspects may also interact with each other. The performance outcome will come under an evaluation process and feedback is provided to optimize soft- and hardware design.

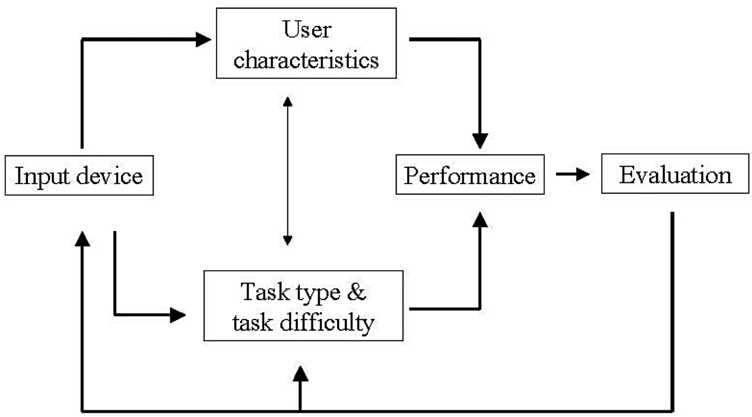

Fig. 1. A framework of user-computer interaction [5]

If input devices are categorized by their ease of sensumotor transformation, then they will be ranked according to their mapping between hand movement and cursor movement. Direct input devices, like finger or pen, represent the easiest way of transformation since the pointing gesture with either finger or pen directly activates the action on the display. The sensumotor transformation within the mouse is still easy. Hand and cursor movement are analogous, but appear in different locations and the output location is rotated by 90°. The hand movement is executed on a horizontal surface and is proximal to the user, and the cursor movement appears on a vertical display and is distal to the user. Similar to the mouse is the movement transformation of the touchpad: with the touchpad also finger movements on the pad are mirrored as a cursor movement on the display. However, it is assumed that the sensumotor transformation of the touchpad is less easy compared to the mouse since the touchpad is more sensitive towards velocity and acceleration changes due to less friction of the system [12,14]. The sensumotor transformation of the trackpoint is most difficult compared to the other input devices [14, 15]. The trackpoint senses finger force, which results in cursor velocity. Thus, the compatibility between finger action and cursor action is low. In a recent study we could show that the better performance of input devices with rather easy sensumotor transformations comes from an optimized movement execution in terms of fewer submovements and a good balance between movements' velocity and covered distance [14].

With this background results of the reviewed studies are analyzed according to two age-related hypotheses: (1) In literature age-related declines by the factor 1.6 and higher were reported for input device usage of older compared to younger adults [9, 10]. It is hypothesized that the usage of pen, mouse, touchpad and trackpoint is by the factor 1.6 less efficient for middle-aged users compared to young users. Furthermore, the sensumotor transformation will interact with age insofar that age differences are more prominent in input devices with a difficult sensumotor transformation. (2) The impact of software design on the efficient input of younger and middle-aged users is surveyed. It is assumed that motor performance becomes less efficient with an increase of complexity of task type and with an increase of task difficulty [16]. Furthermore, the age relevance of these software design factors will be analyzed.

2 Method

Table 1 shows methodological aspects of the studies [5,6,7,11,17,18], which were included to the data review.

Table 1. Input device and sample size per study

	Input device	Young age group	Middle-aged group
Sutter, Ziefle [17]; Oehl, Sutter, Ziefle [18]	Pen	N = 18	N = 18
Sutter, Ziefle [11]	Mouse	N = 14	N = 14
Armbrüster, Sutter, Ziefle [6,7]; Sutter [5]	Touchpad	N = 20	N = 14
Armbrüster, Sutter, Ziefle [6,7]; Sutter [5]	Trackpoint	N = 20	N = 14

2.1 Participants

In all experiments participants of the young-age group were aged between 20 and 30 years (M = 24 years). The middle-aged group consisted of participants aged above 30 years and age ranged from 30 to 66 years (M = 51 years). Sample size was between 14 and 20 participants (Table 1).

2.2 Sensumotor Transformation (Input Device)

The sensumotor transformation of input devices was varied from very easy (pen) to easy (mouse, touchpad) and to difficult (trackpoint). In the experiments a professional stylus for industrial touch applications (WES®) and the "Premium optical wheel mouse" (Logitech) were used. Data of pen and mouse were collected with a standard desktop computer, 266 MHz Intel Pentium II CPU. The touchpad was integrated into a Dell Inspiron 7500-notebook. The touch-sensitive panel (2" by 1.5") was located in the wrist rest beneath the keyboard with two mouse buttons underneath. For the trackpoint a Toshiba Satellite 1700-300-notebook with an integrated trackpoint was used. The small force-sensitive joystick was placed between the "G", "H" and "B" keys on the qwerty-keyboard, the mouse buttons are located in the wrist rest. In all experiments data output was provided to an external TFT flat screen (Philips 150x; 1024x768 pixel) to control the visual quality of display presentation. Cursor velocity of mouse, touchpad and trackpoint was set at "medium" speed (1500 - 4500 pixel per second), the cursor acceleration was deactivated.

2.3 Task Design (Type and Difficulty)

Task type was varied between simple (point-click task) and complex (point-drag-drop task). Task difficulty varied from 2.6 to 4.4 bits (see below). For the point-click task (Figure 2, subtask 1 only) a square target and a cross-hair cursor appeared on the screen. Users were instructed to move the cursor from the start position to the target and adjust the cursor inside the target. The correct cursor positioning was indicated by a change of the square target's color from black into green to provide visual feedback. A trial was completed by pressing the left-mouse button. Thereafter, a new trial was started with a self-paced press of the space bar.

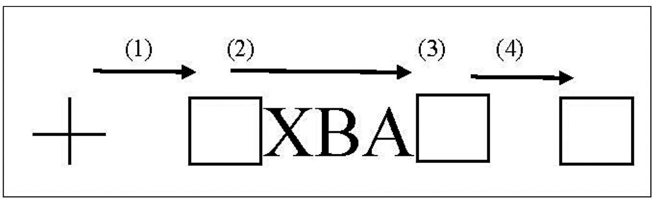

Fig. 2. Task types: Point-click task (subtask 1) and point-drag-drop task (subtasks 1-4)

The point-drag-drop task consisted of several single actions that were executed one after another. The task, as visualized in Figure 2, appeared on the screen. In a point-drag action the centrally placed strings are highlighted (subtask 1&2). Then the object is picked up and moved inside the square target (drag-drop action: subtask 3 & 4). For the drag actions participants are instructed to drag the cursor by pressing the left mouse button. For every successful subtask a visual feedback is given. Releasing the left mouse button at the end of subtask 4 completed the trial. Task difficulty varied in movement distance (2.5, 5 cm) and target size (0.25, 0.5 cm). This resulted in three IDs (ID = index of difficulty, [16]): 2.6, 3.5 and 4.4 bits.

To balance movement direction, targets were presented 45º, 90º, 135º, 180º, 225º, 270º, 315º and 360º to the centrally arranged cursor. This required horizontal, diagonal and vertical cursor movements to hit the target.

3 Results

Data were summarized according to the hypotheses with the independent variables age, sensumotor transformation, task type and task difficulty. For analysis t-tests and ANOVAS were carried out. The level of significance was set at 5 %.

3.1 Effects of Age and Sensumotor Transformation

The mean movement time (ms) for young and middle-aged adults is displayed in Figure 3 for mouse (square), touchpad (triangle) and trackpoint (circle). Effects of sensumotor transformation are obvious. In both age groups performance was best for the mouse, followed by the touchpad and was worse for the trackpoint. For touchpad and trackpoint significant main effects for sensumotor transformation and age were observed (sensumotor transformation: $p < 0.05$ and age: $p < 0.05$ [7]). The interaction of both factors was also significant ($p < 0.05$ [7]). Also for mouse performance significant age effects were found for the point-click task ($F(1,12) = 5.02$, $p < 0.05$). Younger mouse users were by 316 ms faster compared to middle-aged users (970 vs. 1287 ms [11]). The comparison of sensumotor transformation showed that mouse performance of younger users was 1.5 times better compared to the touchpad (970 vs. 1426 ms, $t(6) = -7.55$, $p < 0.01$) and 1.8 times better compared to the trackpoint (970 vs. 1719 ms, $t(6) = -12.41$, $p < 0.01$). This was found to be more prominent for middle-aged users. Mouse performance was 1.5 times better compared to the touchpad (1287 vs. 1993 ms, $t(6) = -5.53$, $p < 0.01$) and 2.5 times better compared to the trackpoint (1287 vs. 3195 ms, $t(6) = -14.94$, $p < 0.01$). This means that in both age groups performance significantly decreased when sensumotor transformation became more difficult. However, the interaction between age and sensumotor transformation seems to be exponentially. Whereas in the difficult sensumotor transformation the age effect is biggest (age factor for trackpoint 1.9), it drops when sensumotor transformation gets easier (age factor for mouse and touchpad 1.3-1.4) and is reported to distinguish completely for very easy sensumotor transformations (age factor for pen 0 [17,18]).

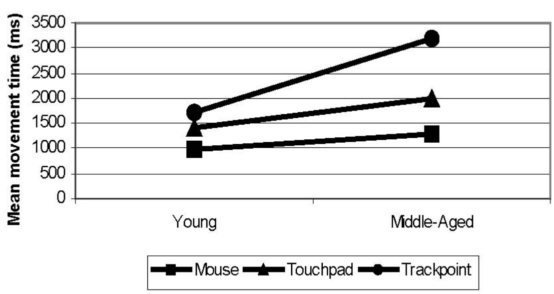

Fig. 3. Mean movement time (ms) in the point-click task as a function of age and input device

3.2 Effects of Age and Task Type

The mean movement time (ms) of middle-aged adults is displayed in Figure 4 for the point-click and point-drag-drop task (mouse = square, touchpad = triangle, trackpoint = circle).

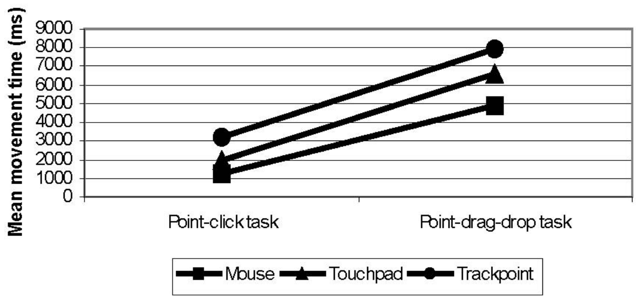

Fig. 4. Mean movement time (ms) of middle-aged users as a function task type and input device

The effect of task type is obviously apparent in all input devices (touchpad and trackpoint: $p < 0.05$ [6,7]; mouse: $F(1,12) = 30.24$, $p < 0.01$). As can be seen in Figure 4 middle-aged users solved point-click tasks 3.0 times faster compared to point-drag-drop tasks. This task-relevant increase of movement time was not affected by sensumotor transformation (interaction n.s.). As displayed in Figure 5, however, the increase was rather stronger for middle-aged users compared to young users as indicated by the significant interaction of age by task ($F\ (1,92) = 4.32$, $p < 0.05$). From point-click to point-drag-drop tasks movement time increased by 4284 ms and 3331 ms, respectively, for middle-aged (solid line, Figure 5) and young users (dashed line).

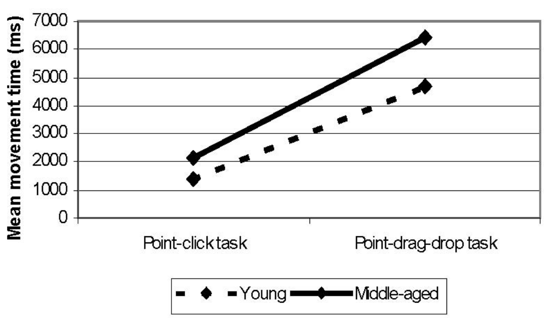

Fig. 5. Mean movement time (ms) as a function of age and task type

Findings show that middle-aged users are very sensitive towards task type and execute complex tasks far less efficient as younger users.

3.3 Effects of Age and Task Difficulty

In all studies significant effects of task difficulty were found. The effect of task difficulty is apparent in all input devices and was found for middle-aged users of touchpad, trackpoint ($p < 0.01$ [6]) and mouse ($F(1,18) = 3.31$, $p < 0.1$) as well as for young users (touchpad and trackpoint: $p < 0.05$ [5]; mouse: $F(1,18) = 11.02$, $p < 0.01$). The regression analyses accounted for up to 97% of variance in movement time by task difficulty. From the easiest (2.6 bits) to the most difficult task (4.4 bits), movement time increased between 31% for the mouse and 43% for the trackpoint. Movement time of young and middle-aged trackpoint users increased by 40% and 43%, respectively. For the touchpad a raise of 37% for young users and 40% for middle-aged users was observed. And for the mouse, movement time rose by 35% and 31% for young and middle-aged users. A similar increase was reported for young and middle-aged pen users [17,18]. Apart from the age effect, no interaction between age and task difficulty was found in these studies (interaction n.s.). It can be concluded that the decrease of performance due to the task difficulty is equal in both age groups, young and middle-aged users.

4 Discussion and Recommendations

The design of human-computer interaction is more and more considered towards its usability for older computer users [8,9,10,11,12]. Beyond efficiency operating an input device itself also specific factors of the software design were addressed in this paper and analysed in its relation to performance decrements often observed in older computer users. In literature age-related performance declines by the factor 1.6 and higher were reported for older compared to younger users of mouse and trackball [9,10]. The studies reviewed in this paper [5,6,7,11,17,18] focused on middle-aged adults and therefore maybe underestimate age effects that will become more and more apparent in the older adulthood [1].

The findings of the present study demonstrate that efficiency of input-device usage distinctly drops from early to middle adulthood by now. Performance differences between young and middle-aged users were not constant, but were affected by sensumotor transformation. As hypothesized age differences were biggest for the trackpoint (factor 1.9), which had the most difficult sensumotor transformation. It dropped for mouse and touchpad, where sensumotor transformation is easier (factor 1.3-1.4). And, in contrast to Charness et al. [8], there were no performance differences at all between older and younger users for the pen (factor 0). In further studies this rather exponential impact of sensumotor transformation on age should be addressed more systematically. The question arises if older users react less flexible towards changes in sensumotor transformation. Assumed that older users possess more specific stimulus-response associations, consolidated by lifelong experience, then they react very efficient to already known sensumotor transformations (e.g. pen: pointing gesture). However, their performance will drop distinctly and more prominent compared to younger users when sensumotor transformation gets difficult and unfamiliar (e.g. trackpoint: force-velocity transformation). This assumption could also be true for task complexity where a similar pattern of age-related performance was found. Middle-aged users reacted very sensitive towards changes in task type and executed the more complex task far less efficient than younger users. The performance decrement from the point-click- to the point-drag-drop task was by 1s higher for middle-aged users compared to young users. For task difficulty no relation with age has been surveyed. From the easiest (2.6 bits) to the most difficult task (4.4 bits) movement time increased by 31 to 43%, independently from age and input device. So far, the results for task difficulty clearly underestimate the situation given in software applications. The range of IDs will be much wider and therefore (up to 6 bits [19], the performance will be much more affected than surveyed here (65% [5]). As can be derived from these studies, sensumotor transformation and task type have a specific age-related impact on performance. That means, transferred to the framework of user-computer interaction [5], hard- and software features should be harmonized with the age of its user in order to achieve an optimized interaction.

So there is still the question about what older computer users need? What recommendations can be derived from this review for an optimized design of interfaces and interaction techniques for users of older age. The choice of interaction technique is often restricted by space, pollution and other environmental factors (e.g. vibration, heat), and mobility. Whenever possible easy input techniques should be chosen, i.e. a touch based interface that is operated with either finger or pen. This is realized in a huge amount of publicly used interfaces (e.g. ATM machine, information terminal). However, it lacks in many consumer products (e.g. desktop computer, television) that are still operated by mouse or remote control although touch screens are very widespread. Besides the pen, with all other input devices interaction becomes more or less inefficient (dependent on their sensumotor transformation) and even worse for older users. This can be faced twofold: either to level the effect of sensumotor transformation with a simple pointing task instead of complex drag actions and / or with easy designed object in term of task difficulty (e.g. big and nearly located icons). The simple task type in combination with an input device with easy sensumotor transformation will be operated by 6.2 times faster than the contrary. This was shown in the present review for middle-aged users executing with a mouse point-click tasks in contrast to executing point-drag-drop tasks with a trackpoint (Δt = 6.6 s). At least, all interfaces and interaction techniques have in common that, if task difficulty is reduced (e.g. enlargement of icon and menu size, reduction of distance) then users will profit up to 43%. However, task difficulty in common software applications was found to be higher (up to 6 bits [19]) than surveyed in our studies (max. 4.4 bits). Thus, the advantage of easy tasks will be even more distinct than 43%. That means also, that the design of easy tasks is a crucial and neglected factor in interface design up to now. It is still an important way to optimize the interaction not even for older users.

All in all, recommendations derived from this review show that older users will profit most from touch based or mouse operated interfaces. Additionally, easy icon and menu designs are often missed and will become more and more important for older users.

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Older Adults and the Web: Lessons Learned from Eye-Tracking

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Abstract. An eye-tracking study of a prototype website was conducted with 10 younger adults (ages 20-39) and 10 older adults (ages 50-69) to determine if there are differences in how they scan webpages. They performed the same tasks on the website. On the average, the older adults spent 42% more time looking at the content of the pages than did the younger adults. They also spent 51% more time looking at the navigation areas. The pattern of fixations on almost all pages showed that the older adults looked at more parts of the page than did the younger adults. Implications for designing webpages that work well for older adults are provided.

Keywords: eye-tracking, web design, usability, age differences, seniors, older adults.

1 Introduction

Several studies have found that older adults tend to encounter more problems in using websites than younger adults (e.g., [1], [2]). For example, Coyne and Nielsen [1] found that the older adults they studied were only 68% as successful, took 66% more time, made 7 times as many errors, and were 22% less satisfied with their interaction in comparison to younger adults. Chadwick-Dias [2] tested a variety of techniques for improving the performance of older adults in using a website, including clearer wording of links, more consistent visual treatment of links, and the use of simplified terminology. They found that these enhancements yielded a 27% improvement in performance for both older and younger users. But the performance of the older adults was still significantly lower than that for the younger adults.

The primary purpose of the current study was to determine if some of the differences in behavior between younger and older adults could be accounted for by how the two groups look at web pages. One earlier study [3] which used eye-tracking to investigate possible age differences in visual search of web pages was inconclusive, but a more extensive eye-tracking study might be more informative.

2 Method

The study was conducted in our Usability Labs at Fidelity Investments in Boston, Massachusetts, USA. We used a Tobii 1750 eye-tracking system, as shown in Figure 1.

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This system has the eye-tracking apparatus built-in to the monitor and is not at all intrusive. The user does not have to wear any apparatus for the eye-tracking, and it works even if the user wears corrective lenses. The calibration process for each user takes less than one minute.

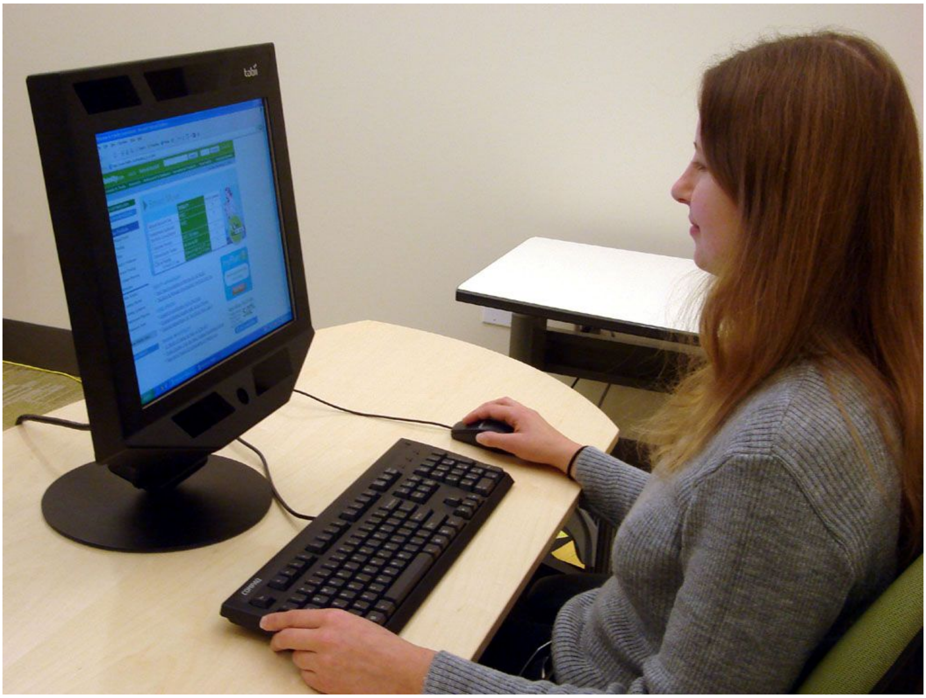

Fig. 1. The Tobii 1750 eye-tracking system in use in our Usability Lab at Fidelity Investments

The study used a prototype version of a web-based employee benefits system. Some of the functions of this system include the ability to define percentages the user wishes to allocate to monthly savings contributions toward their retirement, checking the balances in their accounts, and viewing various characteristics of their employer-sponsored health insurance and life insurance. A sample page from the prototype is illustrated in Figure 2.

Twenty employees of Fidelity Investments participated in the study: 10 aged 20-39 years and 10 aged 50-69 years. These two groups will be referred to as the "Younger" and "Older" participants, respectively. All reported that they use the web daily. All also reported that their experience with the employee benefits website that the prototype was patterned after was minimal.

The session with each user started with an explanation of the study. This was followed by the calibration of the eye-tracker, which involved having the user look at five defined points on the screen. Each user was then asked to perform four tasks using the prototype, as follows:

1. Determine the overall balance in their savings plan.
2. Determine how much they have invested in a specific mutual fund.
3. Increase their monthly contribution to their retirement savings such that they get the maximum match from their employer.
4. Find out how much life insurance they have through their employer.

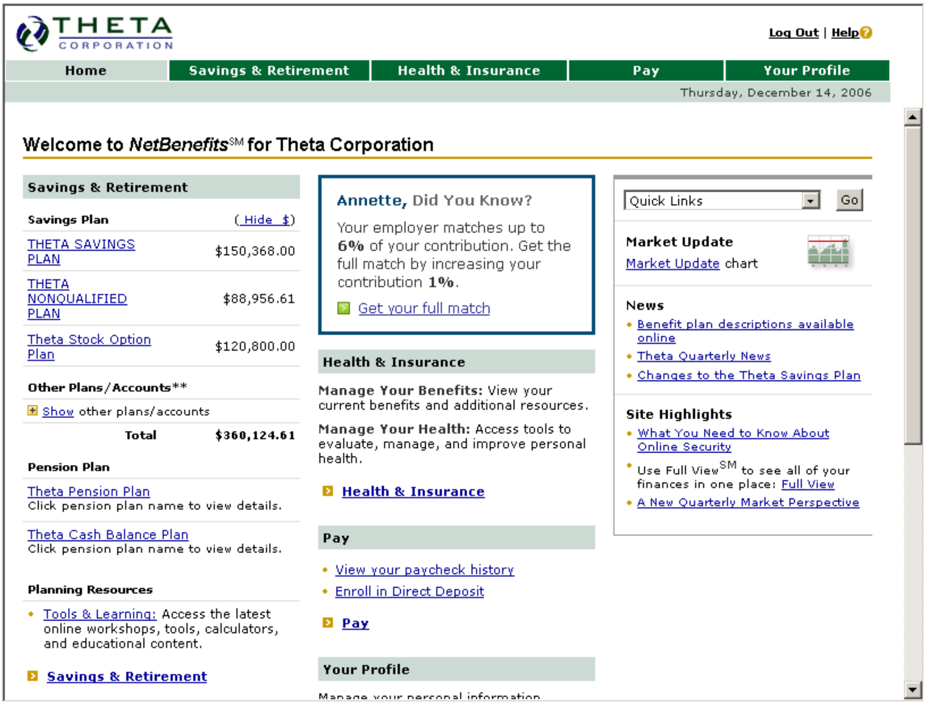

Fig. 2. A sample page from the prototype of an employee benefits website that was used for the eye-tracking study

The order of presentation of these tasks was counter-balanced across the participants. The tasks were chosen to be representative of common or important tasks that someone would do on a real site like this. Eye-tracking data was continuously recorded by the system throughout the session, across all tasks and all pages that they visited.

Although not a primary focus of this paper, there were slightly different versions of the prototype's homepage shown at different points in the user's interaction. The page shown previously in Figure 2 is one of those homepages. The message box at the top-center ("Annette, Did You Know?") was presented in four different ways at different times in each session. Sometimes the box was shown with a contrasting background color and sometimes with an associated image. There were four different versions of the message box, based on the combination of same or different background color and the presence or absence of an image. All other aspects of the homepage stayed the same.

3 Results

The primary findings from the eye-tracking data, focusing on how the older users differed from the younger users, are summarized in the following sections.

3.1 Time Viewing Pages

Twelve key pages in the prototype were analyzed to determine how long each participant actually spent looking at the page. The results are shown in Figure 3. Across the pages, the younger users spent an average of 40 seconds viewing each page. The older users spent an average of 57 seconds viewing each page—42% longer. The difference was statistically significant (p<.05 via t-test).

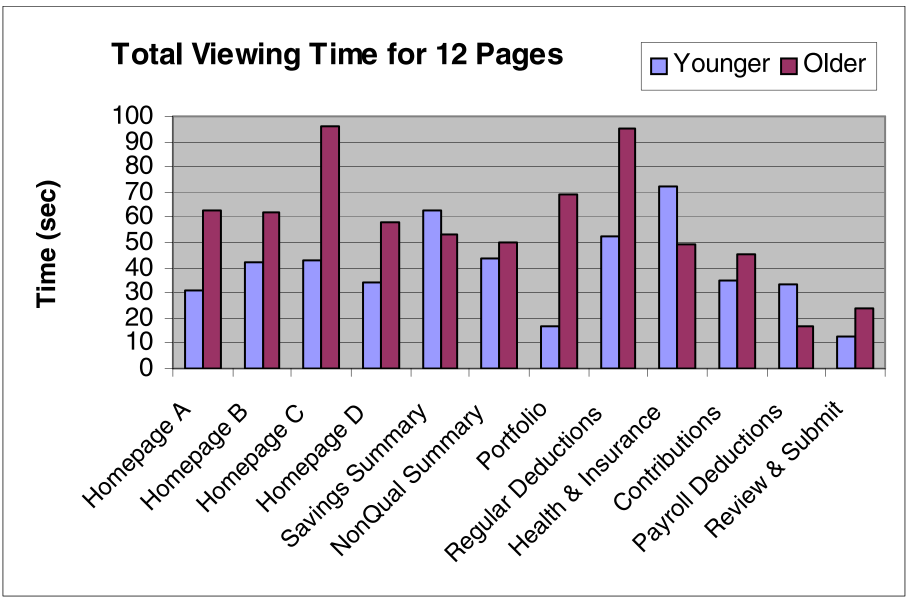

Fig. 3. Total time spent viewing each of 12 pages of the prototype, split by age group

3.2 Time Viewing Navigation Areas

The prototype contained two main navigation areas: a top navigation area and a left navigation area. The top navigation area appeared with all pages. The left navigation area appeared with many of the pages. These are illustrated with the sample page shown in Figure 4.

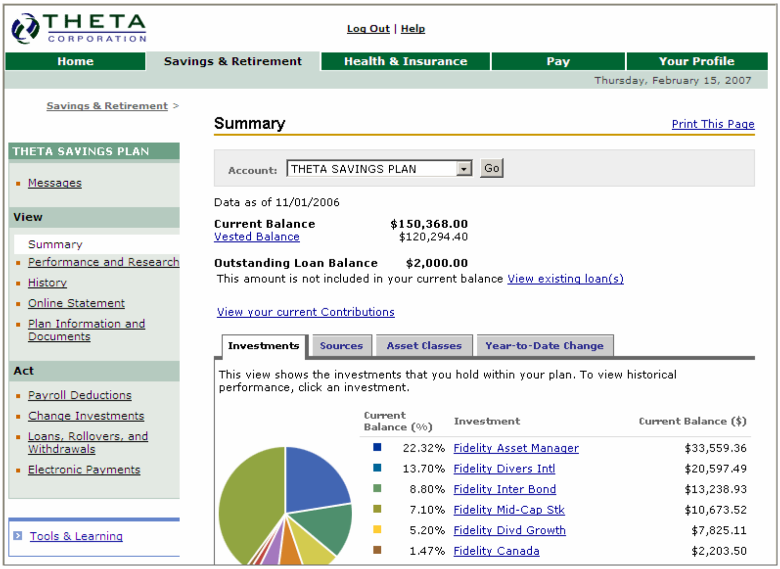

Fig. 4. The Savings Summary page, showing the top navigation area ("Home", "Savings & Retirement", etc) and the left navigation area ("Messages", "Summary", etc)

The total time spent viewing each of the navigation areas was analyzed for the younger and older users and is shown in Figure 5. The older users spent an average of 51% more time viewing the navigation areas than did the younger users.

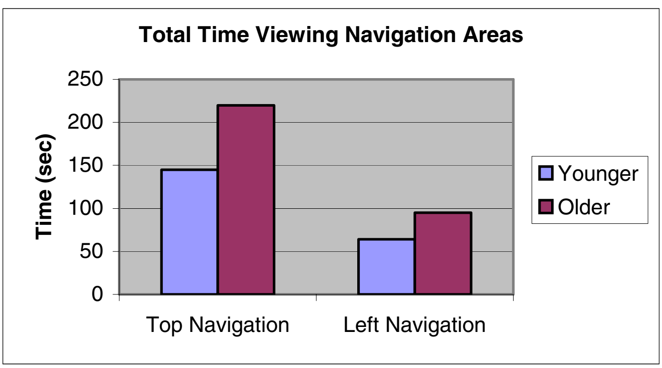

Fig. 5. Total time spent viewing the main navigation areas of the prototype, split by age group

3.3 Fixation Patterns

Perhaps the most useful way of visualizing the pattern of fixations from the eye-tracking data is using so-called "heat maps" to overlay a representation of the page with color coding to indicate the number of fixations in each area of the page. (White indicates six or more fixations.) These heat maps are shown in Figures 6-9 for each of the four versions of the homepage and for the younger and older users.

Fig. 6. Heat maps showing the number of fixations on Version A of the homepage, for the younger (left) and older (right) users

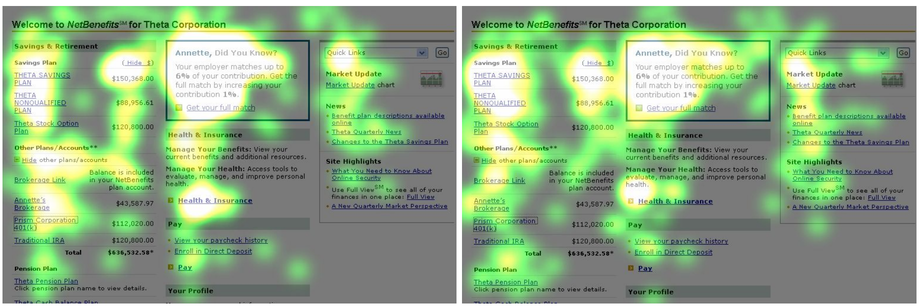

Fig. 7. Heat maps showing the number of fixations on Version B of the homepage, for the younger (left) and older (right) users

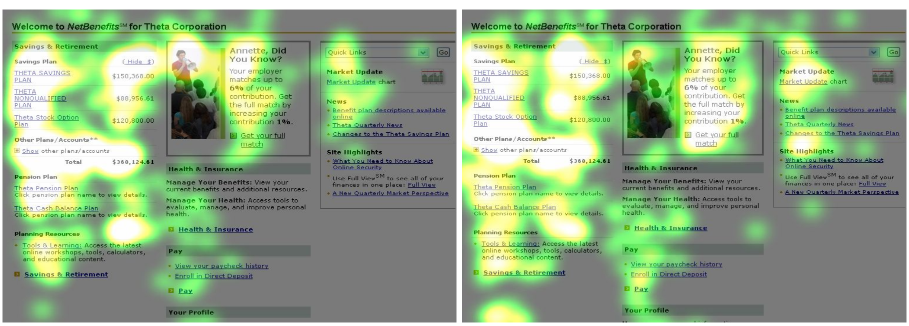

Fig. 8. Heat maps showing the number of fixations on Version C of the homepage, for the younger (left) and older (right) users

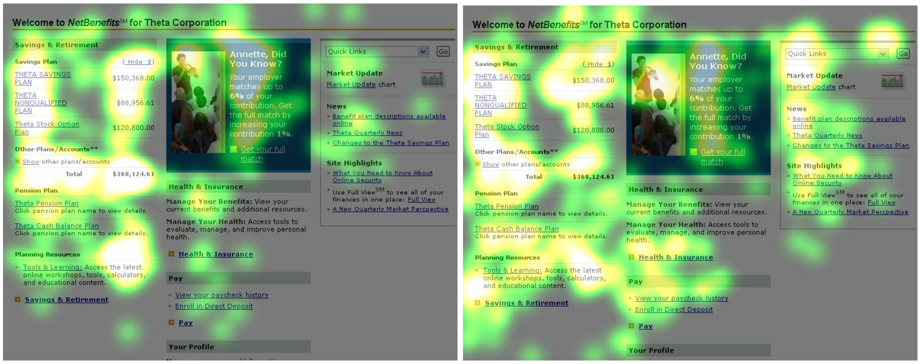

Fig. 9. Heat maps showing the number of fixations on Version D of the homepage, for the younger (left) and older (right) users

Inspection of Figures 6 through 9 indicates a pretty consistent pattern of greater dispersion of the fixations for the older users. In other words, not only were they looking at the pages longer than the younger users, they were generally looking at more areas of the page. Looking beyond the homepages shows a similar pattern for the lower-level pages, as illustrated in Figures 10-13.

Fig. 10. Heat maps showing the number of fixations on the Account Balances page, for the younger (left) and older (right) users

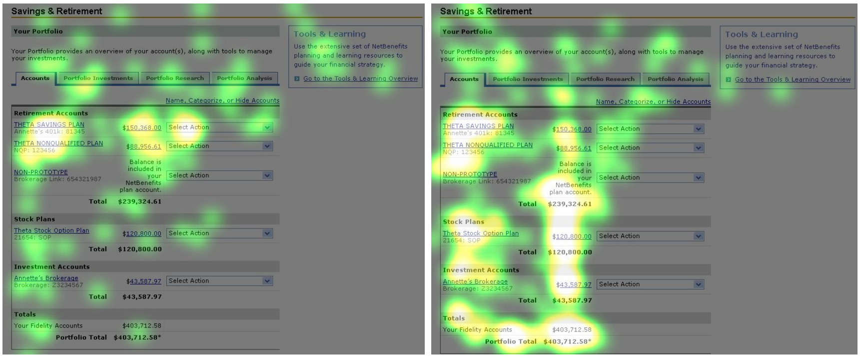

Fig. 11. Heat maps showing the number of fixations on the Savings & Retirement Portfolio page, for the younger (left) and older (right) users

Fig. 12. Heat maps showing the number of fixations on the Regular Deductions page, for the younger (left) and older (right) users

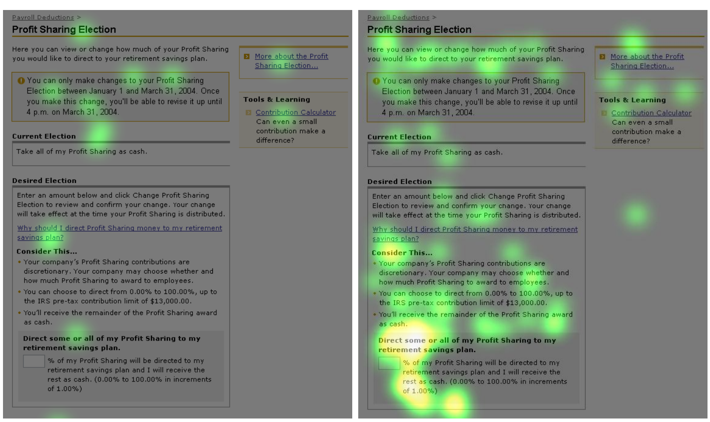

Fig. 13. Heat maps showing the number of fixations on the Profit Sharing Election page, for the younger (left) and older (right) users

4 Discussion

Some interesting patterns emerge from the eye-tracking data:

- Older users spent significantly more time viewing almost every page than the younger users did. This could be due to many factors, such as a greater degree of caution in interacting with the website, a greater interest in certain aspects of the pages, a greater likelihood of being distracted by elements of the pages not critical to their task, or greater confusion in interpreting the information on the pages. Which of these factors is the underlying cause, or perhaps others, cannot be determined from eye-tracking data alone.
- Older users spent significantly more time viewing both of the navigation areas (top and left) than the younger users did. This is consistent with the earlier finding that Chadwick-Dias and colleagues [2] termed the "cautious clicking" behavior they observed with many older adults. Older users spent more time comparing links in a menu to each other before clicking on one of them.
- Older users not only spent more time looking at the pages, they often looked at areas of the pages that the younger users did not even come close to. This is especially obvious from Figures 10, 11, and 13, where the older users looked at entire areas of the pages that the younger users skipped.
- On pages that were mostly text, the older users tended to read more than the younger users. This is apparent from Figure 13, where the pattern of fixations for the older users indicates significantly more reading.
- Some of the fixation patterns seem to indicate that the older users were often doing more comparing and contrasting of information from different parts of a page than were the younger users.
- One thing we did not see was any difference in the likelihood of older or younger users to view page content "below the fold" (i.e., that they had to scroll to view). Of course, there were fewer fixations overall below the fold than above, but the older users were just as likely as the younger users to look below the fold.

5 Implications for Design

Based on the results of this study, some implications for the design of web pages that work well for older adults are as follows:

- Since older adults tend to look at more of the content on a page, consider reducing the total amount of information per page.
- Older adults may be more easily distracted by extraneous information on a page, so minimize or eliminate it.
- Conversely, there may be certain types of content that older adults are more likely to be interested in, and view, than younger adults, and it may be important to provide that information. Identifying this kind of information requires a detailed analysis of the needs of the various types of users.

- It is clear that older adults spend significantly more time in navigation areas, comparing and contrasting menu items or links. Be sure that the options in navigation areas are as clearly worded as possible and that the differences between the options are apparent. We previously found [2] that adding "action words" to links made them clearer (e.g., "Go to accounts" instead of just "Accounts").
- Since older adults are more likely to read the text on a page, be sure that the text is truly relevant and as concise as possible.
- Since older adults seem to do more comparing and contrasting of information on a page, try to put elements that users may want to compare close together to facilitate scanning. Tabular formats work well for comparisons when appropriate.

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Usability Design of a Scanning Interface for a Robot Used by Disabled Users

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Abstract. The results of examining a scanning user interface implementation with command inputs in the form of head gestures for a rehabilitation robot using Fitts' law variations and comparing these with a servo eye tracking model are made. Calculations show that the movement time prediction is more accurate in this case using the servo eye model. The response from the linearised eye model predicts that there is a minimum scanning distance that can be used and minimum spacing between commands display.

Keywords: scanning user interface, Servo-eye-model, Fitts' law, rehabilitation, robotics, gestures.

1 Introduction

This work results from the charity Aspire supported research programme [1] to develop a cheap robot arm to attach to a wheelchair for assistive technology for paraplegic users. Other workers have examined the use of computer interfaces for disabled users [2], [3]. Keates et al. [2] found quite significant differences in response times for impaired users as well as noisy responses while Lesher et al. [3] found it was possible to allow for anticipation.

Two methods for presenting robot language commands to the disabled user were employed by us. The first presented commands in the form of a flat scanning menu system, and was used during initial development and evaluation of the Middlesex Manipulator. The second presentation form employed a Microsoft Windows dialog based graphical user interface. This allowed all control options to be presented simultaneously, allowing for faster task completion. However, the interface required the user to be fairly competent when using a mouse or trackball. This requirement led to the development of a 'Head Mouse' and voice control. These proved to be better suited to use with the flat menu system. A moving bar scanned the menu from left to right and the user responded when the bar was in line with the chosen command. These commands were translated to motor commands using a special robot language JUVO.

Fig. 1. Simple scanning system

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A typical pick and place task was modelled with the values of the primitive operators dependent upon the user, the input device and the style of interaction [4].

To increase the diversity of performance levels the subjects were not allowed to select their own gestures, but were required to use a pre- determined vocabulary of gestures. Three such vocabularies were created, containing gestures with varying levels of complexity. The approach taken was to estimate these characteristics empirically, while subjects were trained to use a particular form of input device. User interaction was then modelled for typical user tasks, by decomposing task goals into sub-goals and lower-level actions, described in a format similar to Natural GOMS Language.

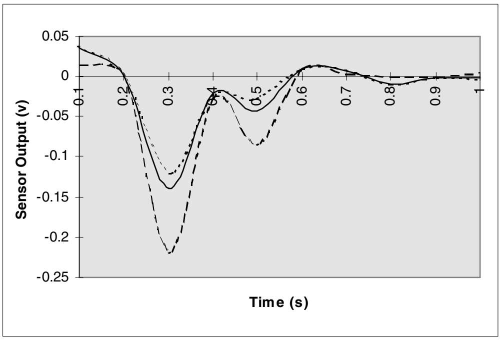

Fig. 2. Sample of gestures with the head mouse

For initial system evaluation a number of input device modules were developed to allow comparison of various input and output devices including a Trackerball, a standard mouse, Voice recognition and a built 'Head mouse'. The Neural Networks were used to recognise these Gestures, shown in Figure 2. Gestures were able to activate the computer to implement a command in a time interval of 0.8±0.05s.

The gestures were used to control the scanning interface by stopping the scan at the correct command.

Move	Goto	Speed	HereIs	**Power**
On	Off	End		
Move	Goto	Speed	HereIs	Power

Fig. 3. Interface menu sequence - selecting 'power on'

Move	Goto	**Speed**	HereIs	Power
Slow	**Med**	Fast		
Move	Goto	Speed	HereIs	Power

Fig. 4. interface menu sequence - selecting 'speed medium'

Move	Goto	Speed	HereIs	Power	
Base	Arm	**Shoulder**	Elbow	Hand	Wrist
End					
In	**Out**	Wrong	End		
Stop					

Fig. 5. interface menu sequence - selecting joint movement

Each evaluator was provided with a description of a typical user task, employing each of the control modes presented by the interface.

Pick and Place task description
Switch on the power to the system, and set the speed to medium. Move to a pre-taught position near the target object. Set the speed to slow, and adjust the elbow and hand joints to approach the target. Close the gripper, and at medium speed move to a pre-taught position near the destination. Adjust the base and shoulder joints, then release the object.

Evaluators independently simulated undertaking the user task by walking through appropriate command sequences with the interface. Aspects of user interaction were recorded that could be deemed as conflicting with the usability heuristics. A meeting was then convened to allow the separate findings to be pooled and discussed. Where appropriate, a possible solution was suggested, and an attempt was made to estimate both the severity of the problem, and how difficult the problem would be to address. This allowed for decisions as to whether design modifications should be made, and if so, at which stage of the project's design cycle.

1.1 Objective

The objective of this paper is to illustrate how the design of a universal interface using a scanning and selecting approach can be achieved using a control engineering eye tracking approach and compare this to that using Fitts' law.

This procedure allows design considerations to include the speed of response to be dealt with in a systematic manner. It gives a richer picture of the features that can be controlled in a dynamic interface. It will cater with variability in user dynamics in a measurable sense.

1.2 Fitts'Law Approach

The conventional approach to design such an interface uses Fitts' Law [5]. Langolf et al. [6], Hwang et al. [7] and Phillips [8] have shown that Fitts' law agrees with the McRuer cross-over model [9] of manual tracking However the McRuer model assumes that the major effects include muscle and motor movement. Work by Jagacinski et al. [10] shows that with moving targets the basic Fitts' law has to be modified. The way these experiments were conducted may mean that they are not an exact comparison but they correspond reasonable closely to the way our operators worked. These results, when applied to computer interfaces, vary with the device used.

The results of the Fitts' law calculation of Movement Time (MT) using the relations derived by [14] can be obtained from equation 1

$$MT = a + b * ID \quad (1)$$

Where a=173 and b=197 ms for the mouse derived values and a=548 and b=420 ms for device B.

The calculations shown in Table 1 give a total movement time of 1.627 s, which is much less than the measured value of 2.4 s. The corresponding value for the device B is 4.007 s. The computations using the two versions of Jagacinski's paper, show

$$MTjag = 0.696 + 0.193(v+1)\left(\frac{1}{w} - 1\right) \quad (2)$$

for the position tests and
for the velocity tests.

$$MTJag = 0.544 + 0.077\left[A + 1.594(v+1)\left(\frac{1}{w} - 1\right)\right] \quad (3)$$

1.3 Eye Tracking

The eye is designed to trade visual acuity with field of view [11] The eye has high resolution in the central fovial region and less elsewhere. To make full use of this the eye is able to move quickly from one direction to another. This is achieved with two types of movements; one is a rapid *saccadic movement* at up to 600°/s. The intention of these rapid eye movements is to align the image with the fovial region.; the second is a *smooth-pursuit* where the eyes follow a moving object, not a stationary one.

The servo model of the eye developed by Young [12] assumes that the model (figure 7) consists of a sampler operating at a time of between 0.12 and 0.25 seconds. There are two branches of the response working together; the saccadic response and a pursuit branch. The saccadic loop has a dead zone corresponding to the fovea of 1°. The pursuit branch becomes open when the rate of movement exceeds 25-30 deg/s and saturates at 25-30 deg/s. The muscle and eyeball dynamics smoothe the response. Young gives a response of the eye servo model to ramp inputs for a linear system supported by experimental evidence. The limitations of the model are given as; the eye does not move until the image has scanned across the fovial region of 1°, the model applies to velocities in excess of 2.5 deg/s and less than 30 deg/s, the eyeball position saturation of 60° was not reached in the experiments, and the model slightly overestimates the position error resulting from a delay in velocity correction. There are observations to indicate that the pursuit branch does not perform the same in all individuals, especially some autistic children.

Later models of eye movement and observations of monkeys (Churchland & Lisberger [13]) agree quite well with the responses given by Young. However the experimental results, for a monkey subject, exhibit oscillations for some responses. The model of Young does not exhibit these as the oscillatory roots are well damped. The non-linearities are not well established and are not considered here.

The models treated in Churchland included acceleration of the image. This effect has not been considered here.

2 Methodology

For the scanning interface considered here we can assume that the tracking only affects the eyes and the time to activate can be represented by the time taken for the gesture used to interact with the machine. This is shown schematically in figure 6. Calculations using this approach are shown below. Since this is a post design and use analysis, we compare with two devices used by MacKenzie and Jusoh [14] and the data from Jagacinski. For the case we are considering the bar underneath the command listing starts moving at a constant rate, pausing at each command. The design procedure proposed here uses a control model of the eye devised by Young and Stark [12] (figure 7) and examines the problem as a tracking problem. We assume that the saccadic movements are just disturbances to the following of the cursor. The analysis uses the results of the sampled data control transfer function model to produce simulated responses to the tracking input to the user. The maximum and minimum time the icon bar is covering the command aperture can be determined from simulation and optimised to give sufficient time for the switch to be operated by the user, allowing for reaction delays inherent in the response. Parametric analysis could then be produced to find an optimal solution for users using average human data. This can be modified in practice to allow for the measured time delays for each user. This is compared to the Fitt's law approach used in the initial design.

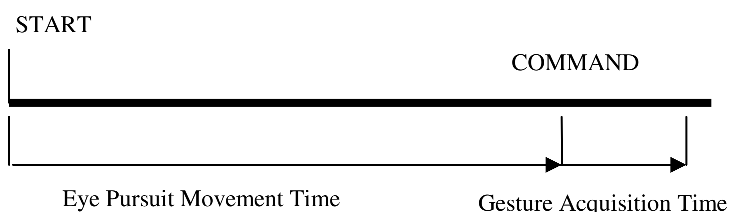

Fig. 6. Schematic for Movement time

3 Results

3.1 Measured GOMS Results

Figure 8 shows the predicted and measured task completion times for each subject using the scanning system during the initial testing with head gestures and other simple switches. The maximum difference between the predicted and measured values is 9%, with the average difference being 6% using a task based measurement. Error bars are used to show the predicted values as a range, computed as the limits of a 95% confidence interval (based on a sample of measured user characteristics n = 40). The measured values fall within the predicted range for each of the six subjects. The average measured value is 214s, with a standard deviation of 5.8s. This shows that conventional analysis gives quite reasonable results. However it relies on measurements of an individuals training responses to each task. So the results of

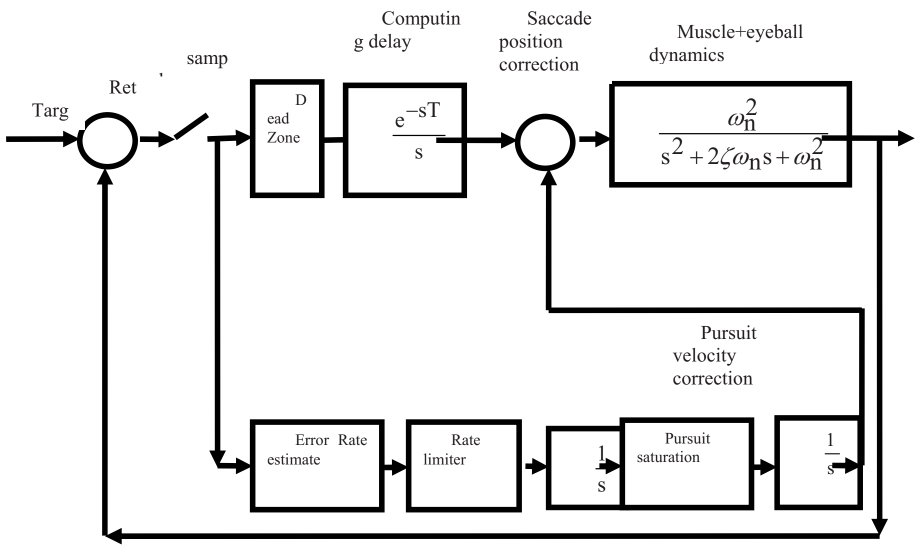

Fig. 7. Young & Stark's Eye Servo Model

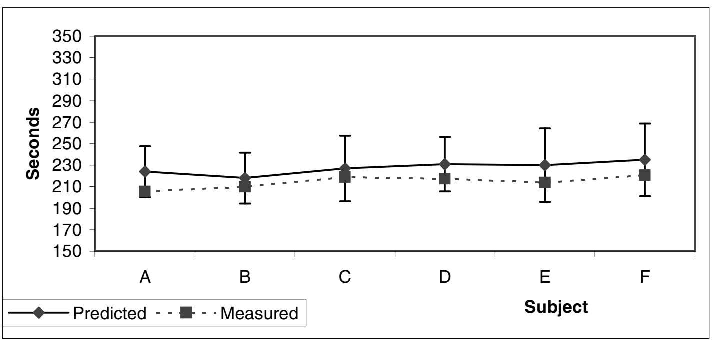

Fig. 8. test results of the scanning system

using conventional HCI design were quite good but when the errors were considered, however, the greatest part came from the estimation of the capture via the screen. Estimates of the driving time of the arm were within 1%. The calculations using equation 3 show in figure 8 that the predictions are greater than the measured times. The subsequent analysis based on one set of operations only shown in figure 10 are calculated using all three equations yield movement time values of 1.627, 3.605 and 3.137 s respectively. The actual movement time measured for these commands is 2.4±0.05 s. Examining this data in Table 1 shows now that these equations 2&3 indicate a much greater impact on the movement time due to the narrow target for the OK move.

Customisation of individual responses would be possible. The viewing angles will differ from individual as distance L varies due to focusing accommodation problems. The minimum velocity of the scan in this model is sufficient for the scan to move across the fovial area on the retina in less than one sample period.

The particular example used shown in figure 10 is of the selection of joint speed although similar results were obtained for the other parts of this pick and place command set.

3.2 Servo Model Design

The data obtained for the eye servo model has a number of interesting aspects. In figure 11 top, the eye does not follow the ramp input until two sample periods have elapsed. This limits the position the closest action point to the start of the scan to 0.4*v. The lower of the two graphs shows that when a dwell time is inserted into the scanning process to enable the user to capture the position the eye does not follow the ramp again until nearly three sample periods after the scan has started again. This dictates how close together the positions of the choices can be placed. Since the sample time may vary between individuals in the example D=160 mm and L=550 mm. It is clear from Table 2 that the total movement time indicated by the servo model, of 2.476 s is closer to the measured value 2.4 s than the values from the Fitts' calculations. The values for the mouse are less than those measured, whereas the values calculated using movement parameters are greater.

The salient points from this analysis, limited by a small amount of data, is that the different variations of Fitts' law give values that differ from the experimental data by 30% of the movement time for this type of interface whereas the eye servo model is within 3% here, and generally within 10% for all the commands.

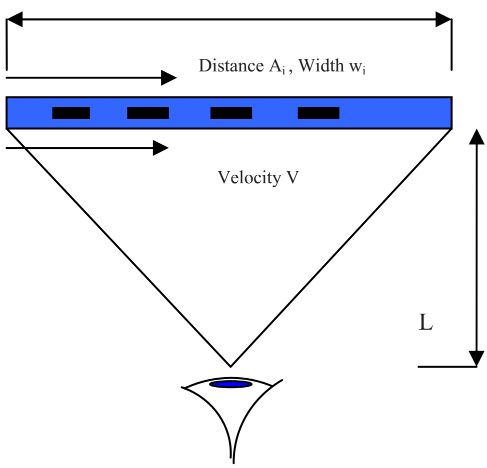

Fig. 9. Geometry of scanning interface

Method to accomplish goal <general goal description>
step 1. accomplish goal <set speed slow>
step 2. accomplish goal <move arm left>
:
:
Method to accomplish goal <set speed slow>
step 1. select <speed>
step 2. select <slow>
step 3. select <ok>

Fig. 10. Task selection

Table 1. Movement time calculation using Fitts' approaches

Select Mode	A_i/deg	w_i/deg	A/w	ID	MT Mouse/s	MTdevB/s	MTJag Posn/s	***MTJag Vel/s***
Speed	4.687	1.25	3.75	2.248	0.615	1.492	0.5443	0.8085
Slow	1.333	0.833	1.6	1.379	0.445	1.127	0.8478	0.7432
OK	0.999	0.333	3	2	0.567	1.388	2.213	1.5858
Sum					1.627	4.007	3.605	3.137

Table 2. Servo predicted movement values

Select mode	Servo time predicted/s	Delta T/s	***T/del T***
Speed	1.606	0.427	3.761124
Slow	0.461	0.197	2.340102
Ok	0.409	0.007	58.42857
sum	2.476		

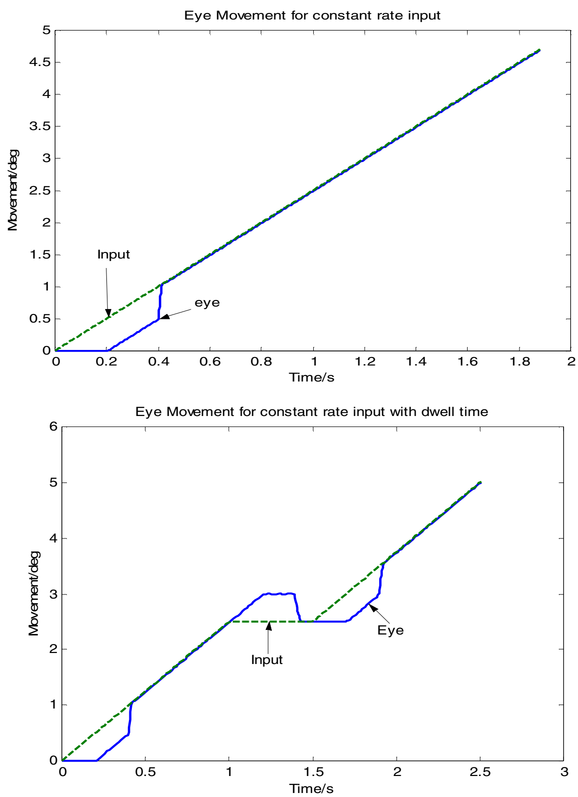

Fig. 11. Tracking results for eye servo

If the scanning were just to continue across the screen without a dwell time, unlike our case then Table 2 shows that the minimum time across a target command for the OK would be just 7 ms! This problem has been identified by Sears et al. [15] who used speech recognition in a similar situation. The time for which the bar is adjacent to the command is far too short and a dwell time must be included even for the fastest time of capture using a mouse click. The principle of the Fitts' law index of difficulty is confirmed by the values of (T/del T) in Table 2, which ranks the 'OK' command as much the most difficult.

4 Conclusion

This paper describes a design approach using an eye transfer function model to evaluate the way a scanning interface analysis is performed to enable it be user optimised to give the best individual response for a disabled user. The comparison with the use of several versions of Fitts' law show the approach used here is more accurate.

A number of design issues can be drawn from the work.

1. The scan angular velocity should be greater than 2.5°/s and less than 25°/s. This is to ensure that the image is moving out of the fovial region and is using smooth pursuit
2. The closest command on the screen should be at a greater distance than 2 sample periods*angular velocity from the start of the scan.
3. If a dwell period is incorporated for easier capture then the commands must be a greater distance than 2.5 sample periods*angular velocity apart.

Measurements of individual user sampling period and maximum and minimum angular velocity limits will enable a more individual response to be tailored together with information about their own decision time increment.

Further research needs to be undertaken to see whether there are any collective differences in users that can be identified, due to age ,infirmity or fatigue.

Symbols

a	constant
A_i	distance of command on screen from start of scan
b	constant
D	width of scanning display on screen
L	distance of users eye from screen
MT	movement time
w_i	width of target command

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