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Ergonomics and Health Aspects of Work with Computers

International Conference, EHAWC 2007
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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 Marvin J. Dainoff, contains papers in the thematic area of Ergonomics and Health Aspects of Work with Computers, addressing the following major topics:

- Health and Well Being in the Working Environment
- Ergonomics and Design

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 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. Schmorow 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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In addition to the members of the Program Boards above, I also wish to thank the following volunteer external reviewers: Kelly Hale, David Kobus, Amy Kruse, Cali Fidopiastis and Karl Van Orden from the USA, Mark Neerinx and Marc Grootjen from the Netherlands, Wilhelm Kincses from Germany, Ganesh Bhutkar and Mathura Prasad from India, Frederick Li from the UK, and Dimitris Grammenos, Angeliki Kastrinaki, Iosif Klironomos, Alexandros Mourouzis, and Stavroula Ntoa from Greece.

This conference could not have been possible without the continuous support and advise of the Conference Scientific Advisor, Prof. Gavriel Salvendy, as well as the dedicated work and outstanding efforts of the Communications Chair and Editor of HCI International News, Abbas Moallem, and of the members of the Organizational Board from P.R. China, Patrick Rau (Chair), Bo Chen, Xiaolan Fu, Zhibin Jiang, Congdong Li, Zhenjie Liu, Mowei Shen, Yuanchun Shi, Hui Su, Linyang Sun, Ming Po Tham, Ben Tsiang, Jian Wang, Guangyou Xu, Winnie Wanli Yang, Shuping Yi, Kan Zhang, and Wei Zho.

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Constantine Stephanidis
General Chair, HCI International 2007

Preface

This collection of papers represents the breadth and diversity of current research on the topic of ergonomic and health aspects of work with computers.

Part 1 reflects new research on concerns that have been present since the emergence of computers into the workplace over thirty years ago. Musculoskeletal, visual, and psychosocial/organizational stressors continue to have impacts on health, performance, and comfort of computer users; understanding the interactions of these factors and how to mediate them remains a subject of active investigation

Part 2, Ergonomics and Design, includes a varied collection of research indicating the central role ergonomics should play in design of computer-related equipment and systems. Topics include workstation layout, display and input devices, implications for education, medicine and industrial processes.

Marvin Dainoff, Editor

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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Can Visual Discomfort Influence on Muscle Pain and Muscle Load for Visual Display Unit (VDU) Workers?

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Abstract. In three different prospective epidemiological studies, correlation between visual discomfort and average pain intensity in the neck and shoulder, were $0.30 < r < 0.72$ for VDU workers. In the first study, correlation between visual discomfort and pain in the neck and shoulder was $0.30 < r < 0.40$. In the second study, visual discomfort was related to neck pain, ($r=0.40$, $p=0.003$). In the third study, visual discomfort correlated to neck pain ($r=0.69$, $p=0.000$) and shoulder pain ($r=0.72$, $p=0.000$). In order to study more in detail the correlation between visual stress and muscle load, a laboratory study was carried out. Visual stress was induced by the size of characters on the screen (8 points and 12 points Times New Roman) and the luminance levels in the surroundings of the screen (between 1500 and 2300 cd/m^2) versus (between 70 and 100 cd/m^2). The results showed that the smallest characters 8 points and the highest luminance levels had no significant influence on the muscle load in neck and shoulder regions. However, the productivity was significant lower when using the 8 points characters compared with 12 points. There was also a tendency to an increase in the number of errors made.

Keywords: VDU workplaces. Lighting conditions, Visual conditions, Visual discomfort, Musculoskeletal illness, Eye blinking.

1 Introduction

Visual discomfort has a high prevalence for VDU workers [1]. Eye discomfort is related to VDU work according to Bergqvist and Knave. They found that symptoms of gritty feeling or redness of the eye as well as sensitivity to light were associated with VDU work [2]. Bergqvist et al. documented also a positive dose-response association between eye discomfort and VDU use [3]. Furthermore, Sjøgren and Elfstrøm found that the frequency of eye discomfort was related to working time at the VDU [4]. Both lighting conditions and optometric corrections are documented to be important to reduce visual discomfort [5]. Glare has significant correlations to eye focusing problems and tired eyes [6]. In a laboratory study by Sheedy and Bailey, glare from a luminarie in the upper visual field was examined. Subjective rating of light discomfort was strongly related to the luminance level of the glare source. Further, the glare magnitude was significantly related to asthenopic symptoms

($p=0.004$) and musculoskeletal symptoms ($p=0.017$) [7]. Horgen et al. has shown that optometric corrections reduced visual discomfort and musculoskeletal pain in VDU workers [8]. More details regarding VDU work and health consequences for such work are given by Aarås et al. [8]. Punnet and Bergqvist reported very frequently pain in the musculoskeletal system for VDU workers [9]. Static muscle load, high frequency of repetitive movements and high force requirements of these movements seem to be predictors for onset of musculoskeletal discomfort [10]. Duration of repetitive movements of the upper arm was found to be associated with neck and shoulder symptoms [10]. Up till now, few studies have examined relationship between visual discomfort and musculoskeletal pain.

2 Epidemiological Studies

The aims of these studies were to investigate the correlation between visual discomfort and pain in the upper part of the body. Longitudinal epidemiological studies were performed to evaluate the aims [5, 11].

2.1 The First Study

This was a prospective epidemiological study where VDU workers were followed for a period of six years. Visual discomfort showed a relationship with pain intensity in the neck and shoulder ($0.30 < r < 0.40$) [12]. The level of discomfort/pain was assessed on a Visual Analogue Scale (VAS). Visual discomfort was 29.9 (21.7– 38.09) and shoulder pain 23 (15.3–30.7) as group mean with 95 % Confidence Interval (CI). Zero was no pain 100 indicated extreme or unbearable pain. However, such studies have a lot of confounding factors such as organizational and psychosocial factors. For all psychosocial factors, there was no statistical intervention effect or time effect and no interactions between time and intervention were found.

2.2 The Second Prospective Field Study

This study was a multidisciplinary multinational ergonomic study MEPS (musculoskeletal-eyestrain – psychosocial – stress). The objective of the study was to examine the effects of various kinds of ergonomic interventions including corrective lenses on a combination of musculoskeletal, postural, and psychosocial outcomes among VDU workers. In this study, visual discomfort was related to neck pain, $r=0.40$, $p=0.003$; regression coefficient 0.37 with CI of 0.18-0.57. Neck pain was also related to burning and itching of the eye ($p=0.004$). Headache was related to visual discomfort, ($r=0.34$, $p=0.01$) [13].

2.3 The Third Epidemiological Study

This is the same study as described in 2.1, where the follow up period covers from 6 to 13 years. The results showed a significant correlation between visual discomfort and neck pain ($r=0.64$, $p=0.000$) as well as shoulder pain ($r=0.56$, $p=0.001$). For the forearm this correlation was weaker, but still significant ($r=0.35$, $p=0.04$). In a

multivariable regression model when lighting and glare were excluded, visual discomfort explained 53 % of the variance of the neck and shoulder pain [14].

3 Laboratory Study

The aims of the study was to evaluate how the luminance levels of the surroundings of VDU and the size of the characters on the screen effect the muscle load, the accommodation and the fixation pattern during VDU work [15].

3.1 The Design and Methods of the Study

The design and the methods of the study are described by Horgen et al. [15]. The experiment was conducted at an optimised VDU workplace. The table was adjustable and constructed to give support for the forearms on the tabletop [16]. The illumination



Fig. 1. The Workplace, with glare source

level was approximately 500 lx on the work table. The line of sight to the midpoint of the screen was approximately 15° below horizontal. A constant visual distance from the eye to the midpoint of the screen was set to approximately 60 cm [17, 18]. The “glare” luminaries had each two 40 W fluorescent tubes, with a diffusing screen of opal acrylic sheet 1.25 m x 0.57 m, giving a luminance between 1500-2300 cd/m² (measured across the screen) [15]. These two “glare” luminaries were mounted vertically on the right side of the VDU, at approximately 45° horizontal angle from the sightline to the centre of the screen, simulating windows as they very often

appear in a normal work station set up. The work task was interactive work on a 15 inch LCD screen. The test set up is shown in Fig. 1.

To neutralize the influence of the test sequence, a 3 x 3 orthogonal Latin square design trial was used [19]. The lowest luminance level of the surroundings of the screen, (between 70 and 100 cd/m²), and the normal size of the characters on the screen, (12 points New Roman), were defined as baseline. This baseline was recorded for each participant at the start and the end of the trial. The mean of these two measurements was used as a baseline in the statistical analysis [1]. The smallest text size was 8 points Times New Roman. The combination of high luminance/normal character size, high luminance/small character size and low luminance/small character size was tested according to the orthogonal Latin square design.

The postural load on the neck and shoulder muscles was quantified by electromyography (EMG) using the Physiometer. Surface electrodes were used [20]. The load in m. trapezius (descending part) and m. Infraspinatus was used as indicators

of load on the neck and shoulder areas. To perform continuous measurement of postural angles, three dual axis inclinometers were used. Angles were measured relative to the vertical by these inclinometers attached to the upper arm, head and back. The angle measurements were mainly used to control the work posture during the VDU work. The EMG and the postural angle methods are described and the methodological limitations discussed [20, 21, 22, 23, 24, 25].

There were five test sessions. Each session lasted 10 minutes of active recording, with a period of rest in between. The reason for 10 minutes active recording for each session is the recommendations by Mathiassen [26], who observed marginal information beyond approximately 10 minutes sampling of EMG of stereotyped work. The rest period was about 5 minutes. 16 subjects were needed in order to detect a difference in muscle load between 0.5 to 1 % Maximum Voluntary Contraction (MVC) at a power level of 80 %.

The measurements of eye-tracking and accommodation are described by Horgen et al [15].

3.2 Results

The size of the characters and the glare condition had small influence on the muscle load.

M. trapezius activities did not show significant differences when comparing the mean of the two baseline measurements with muscle activities when working with small characters and glare. This was true both for static ($p=0.21$) and median values ($p=0.07$) [14]. This was opposite what to be expected. For the median muscle load, there was significant higher activity at baseline than when working with small characters with glare ($p=0.008$) and small characters without glare ($p=0.015$). The maximal difference in static m. trapezius activity within subjects between the baseline and the measurements when the subjects were glared and bolded small characters was 1.8 % MVC.

M. infraspinatus was in most cases relatively heavy loaded. There were no significant differences when comparing the static value of the baseline measurement, working with small characters with glare ($p=0.11$) and small characters without glare ($p=0.14$). However, when similar comparison for median muscle load were done, there were significant higher activity at baseline then when working with small characters with glare ($p=0.008$) and small characters without glare ($p=0.015$). The maximal difference for static m. infraspinatus activity within subjects between the baseline measurements and the test of the glare and smaller characters was maximal 3.5 % MVC.

Erector spina lumbar part, at L3 level did not show significant differences between the baseline and the three test situations. This was true for both static and median values ($0.13 < p < 0.96$). The maximal induced stress situation within subjects was 2.75% MVC. Gaze tracking showed that the fixation time within the whole computer screen area was almost 100% of the total testing time [15].

A small transient myopic shift was observed in spite of the rather mature test subjects.

4 Conclusion and Recommendations

Three different prospective epidemiological studies have shown that there is a clear indication of a relationship between visual discomfort and pain in the neck and shoulder. In a laboratory study visual stress had small influence on the muscle load.

Working with small characters and glare did not impose or increased static muscle load for Trapezius, Infraspinatus and Erector spina. M. infraspinatus was relatively heavily loaded during this type of computer work due to high precision-dependence during tracking work. Productivity, in terms of less amount of text processed was significantly reduced when working with 8 points characters. In addition there was a tendency an increased number of errors when working with glare. A reasonable explanation of the differences in the results between the epidemiological and the laboratory studies may be that in the laboratory study the visual stress in terms of small character and glare reduced the productivity. Reduced productivity may reduce the static muscle load and pain. For presbyoptic VDU workers, the character size should be more than 8 points letters. According to a study by Helland et al. [27], glare had a significant correlation to visual discomfort, $r_s=0.35$, $p=0.040$. They showed also that visual discomfort explained 53% of the variance of the neck and shoulder pain in VDU workers.

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Neuromuscular Principles in the Visual System and Their Potential Role in Visual Discomfort

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Abstract. The aim of this study was to analyse the neuromuscular arrangement in the human extraocular muscles in order to obtain a better understanding of the mechanisms behind visual discomfort associated with reading and VDU (visual display unit) work. Histological evaluation of muscle samples from 10 subjects revealed fibrous extensions from the distal insertions of rectus muscles to the orbital wall. The number of neural elements found embedded in these collagenous extensions suggests that nociceptors are present in large numbers, capable of creating pain during movements of the eye. It is reasonable to assume that these structures and other parameters described in this study can contribute to visual discomfort associated with demanding visual tasks.

Keywords: VDU-work; extraocular muscles; muscle pulleys; muscle sleeves; visual discomfort.

1 Introduction

A modern designed workplace imposes great demands on the visual system. The smooth muscle of the iris and ciliary muscle (figure1) must constantly co-contract with the striated extraocular muscles (EOMs) in order to maintain good visual perception. The co-occurrence of miosis, accommodation and convergence, which are the functions of the respective muscles, relies on a constant interaction between autonomic and somatic motor neurones in the mesencephalon of the brainstem. These neurones form the nuclear complex of the oculomotor nerve which in turn constitutes a vital component of the oculomotor system. Tuning of the neural activity in the oculomotor system is provided by sensory input through the optic nerve and ophthalmic division of the trigeminal nerve. Together these cranial nerves form a unique sensory-motor loop which enables the visual system to adapt to a wide range of light levels and viewing distances. The fact that there is no external load on the EOMs and that they do not initiate any stretch reflex [1], imply that they are not influenced by proprioception in the same manner as their somatic counterparts [2]. Based on the factors described above it is legitimate to argue that the structural organisation of the oculomotor system departs from the conventional somatic motor system.

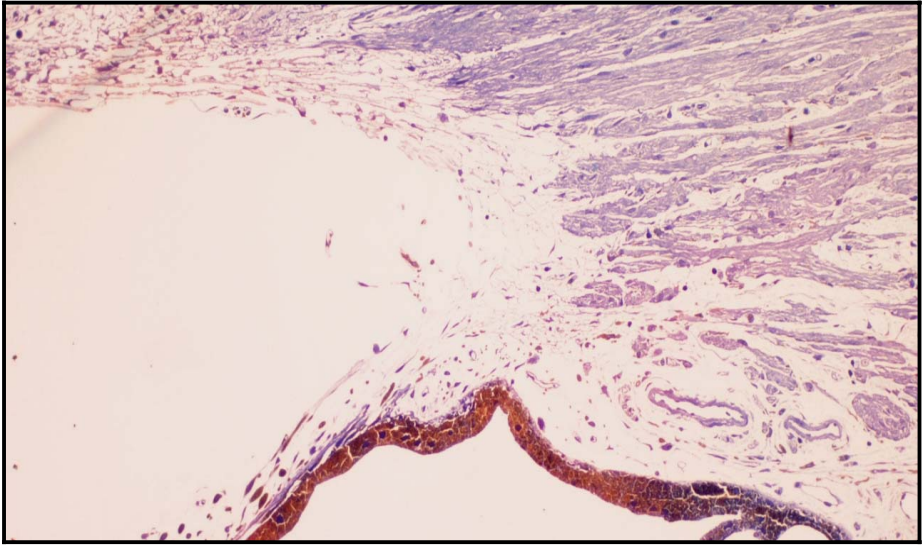


Fig. 1. The micrograph shows the pigmented surface of the iris and ciliary body and associated smooth muscle. (100x).

Hence, although detailed knowledge of somatic muscle control is essential for understanding the principals behind somatic muscular fatigue and discomfort, it may not serve as an adequate model for understanding the mechanisms behind visual discomfort.

Recent studies promote the concept that the connective tissue and neuromuscular architecture of the eye is more complex than previously assumed. Muscle fibres in the distal region of EOMs departure from the main bulk of the muscle and terminate on complex collagen structures capable of altering the angle of the muscle insertion during eye rotation. These structures have been referred to as muscle pulleys [3] and muscle sleeves [4]. The structural organisation of pulleys/muscle sleeves is not fully understood but their proposed role in oculomotor control suggests that these structures might also play a role in muscular fatigue and associated discomfort.

The purpose of this study was therefore to examine the neuromuscular structures of the orbit, histologically, and thereby obtain a better understanding of the neuromuscular mechanisms behind visual discomfort.

2 Material and Methods

EOMs were dissected from 10 human subjects of both sexes (1 day-90 years). Samples were obtained either following enucleation or post-mortem. All specimens were obtained in conformity with legal requirements. None of the patients had any history of binocular vision abnormality or neuromuscular disease. After the muscles were dissected from the eyes they were immersed in 2% glutaraldehyde buffered to pH 7.4 with sodium cacodylate, most of them with a post-operative/post-mortem

delay of less than 5 hours. Muscles with the complete distal musculotendinous junctions were selected for study of the collagenous architecture and search of tendon receptors.

The tissues were transferred from fixative to dissecting fluid (buffered sucrose) for 24 hours, washed, then immersed in a solution of osmium tetroxide for 1 hour. After washing they were dehydrated in graded mixtures of ethanol with water, initially in 50%, followed by 70%, 90% and finally absolute alcohol (with a duration of 20 min in each). Before embedding, the muscle samples were cleared with xylene for one hour. They were then transferred to a solution of equal amounts of xylene and Araldite for 30 minutes. At each stage the samples were left in a specimen rotator. They were finally left rotating overnight in pure Araldite resin. The specimens were embedded in Araldite-filled trays which were incubated at 52°, for 24 hours. Transverse sections of 0,75 μm and 75 nm thickness, were cut on a RMC ultramicrotome for light and electron microscopy respectively. Semi thin sections were stained with toluidine blue after removal of Araldite with sodium methoxide followed by a methoxide diluent, acetone and distilled water. Sections for electron microscopy were stained in a solution of uranyl acetate and ethanol for 20 minutes, followed by 20 minutes in a solution of lead citrate and sodium hydroxide.

The semi thin sections were collected with intervals of 50 μm . Measurements of structures were taken through the light microscope by the aid of a calibrated microscope eyepiece graticule. The obtained data was later confirmed by using data analysis. Sections were also cut through tendon with 50 μm intervals until nerves were identified. Serial sections were obtained following identification of neural elements. Ultra thin sections for electron microscopy were collected with regular intervals.

3 Results

Observations made in the current study confirmed many of the unique features of extraocular muscles previously described by others. Slender tendons leave the orbital surface of rectus muscles at regular intervals and enter connective tissue structures located near the equator of the eye, as illustrated in figure 2. These collagen structures, referred to as pulleys [3] or sleeves [4] are continuous with the fascial canopy of the globe, the fascia bulbi. The thickest muscle sleeves were found to contain smooth muscle and were associated with the medial rectus muscles, the muscles responsible for convergence of the eyes. The compact mass of collagen which forms the orbital side of the sleeve in the medial rectus muscles were attached to the orbital wall by fine ligaments. Consistent with previous observations [4], these ligaments were found looping behind the orbicularis muscle to reach the periosteum. In the current study, using methods of high resolution, well defined circular structures identified as axoplasm were found embedded in these ligaments. Serial sections showed that these axons were initially small myelinated or unmyelinated axons, 1-3 μm in size, which with regular occurrence tapered off and ended as free nerve endings resembling the structural organisation of nociceptors (figure 3).

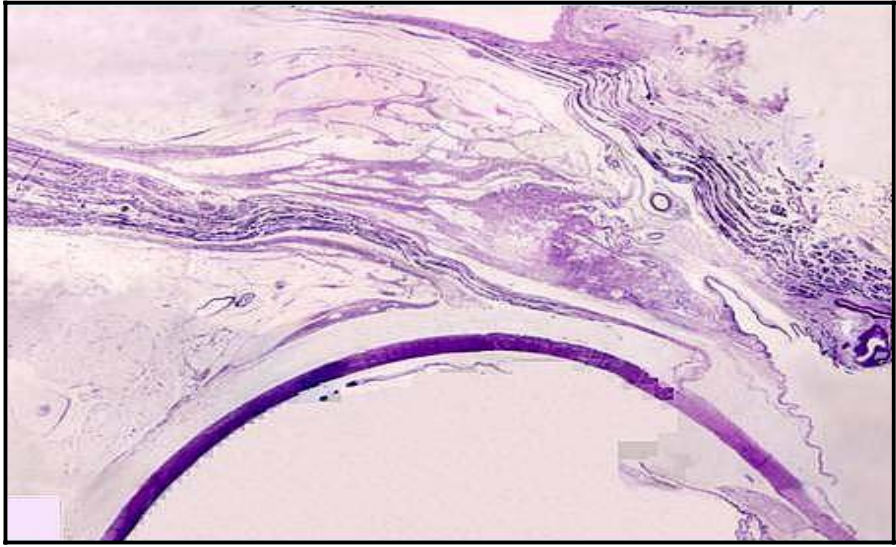


Fig. 2. The collage of micrographs shows the distal end of a human rectus muscle inserting on the globe. A number of muscle fibres departures from the main bulk of the muscle and terminate on a sleeve of connective tissue. Extensions from the sleeve attaches to the orbital wall.



Fig. 3. The micrograph shows small unmyelinated and myelinated nerve fibres embedded in the collagenous tissue of the fibrous extensions. A number of these axons tapered off progressively resembling the structural organisation of nociceptors. (1000x).

Nerve terminals were also found associated with distal tendons of slow contracting, multiply innervated Felderstruktur fibres (figure 4). They conformed to the structural organisation of sensory receptors previously described as myotendinous cylinders [5, 6]. Analyses of the muscle fibre population in this region of the muscle revealed large individual differences in the number of muscle fibres and associated receptors. Previous studies have promoted the view that there is a division of labour between the fibres in human EOMs [7] and there is a general agreement in the literature that the Felderstruktur fibre is responsible for the slow contractions needed during reading. The current study showed that the content of Felderstruktur fibres, previously assumed to constitute 20% of the fibre population [7], ranged from 15-30%. These results confirmed previous observations made by the authors [8, 9].

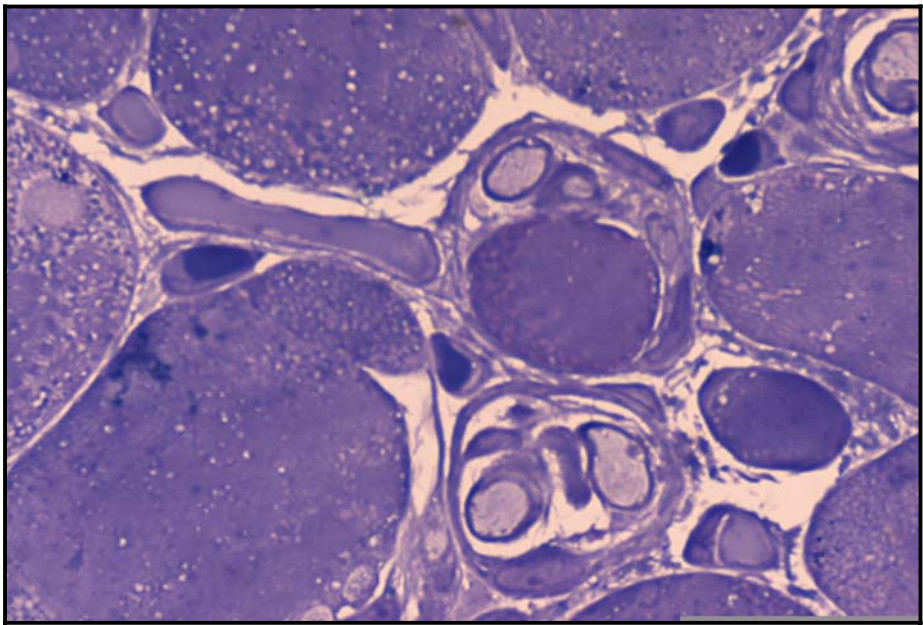


Fig. 4. The micrograph shows two Felderstruktur fibres surrounded by larger fast contracting Fibrillenstruktur fibres. The Felderstruktur fibre is slow contracting and responsible for prolonged contractions during reading and VDU work. The Fibrillenstruktur fibre is responsible for fast saccadic eye movements. (1000x).

In muscle samples from the mature subjects these muscle fibres displayed age related changes, such as accumulation of lipofuscin (figure 5), Ringbinden fibres (figure 6) and fragmentation of myofilaments (figure 7). Reduction in muscle fibre numbers were a generally occurring feature of in all the mature muscle samples. These findings confirm previous observations [10, 11, 12, 13, 14].

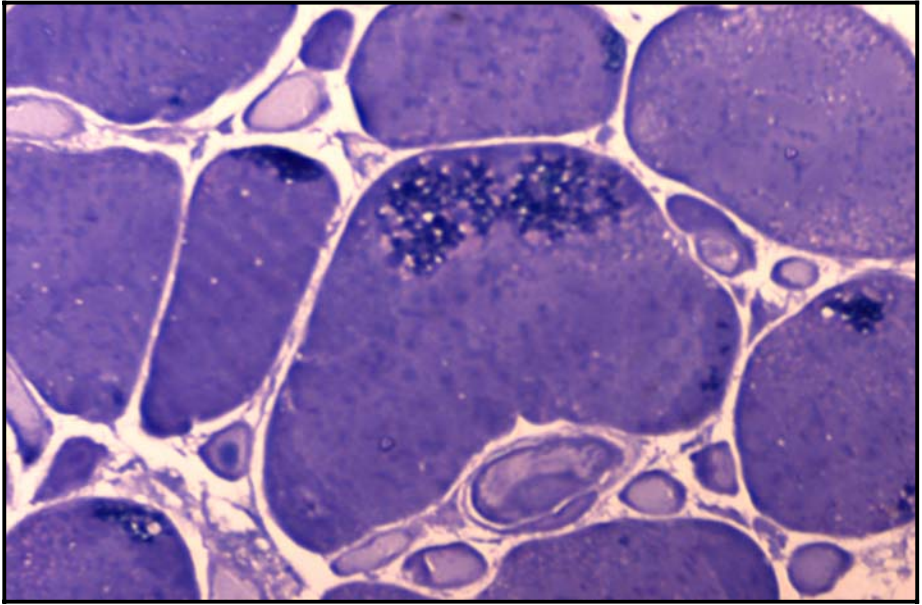


Fig. 5. The micrograph shows a muscle fibre with accumulation of lipofuscin. (1000x)

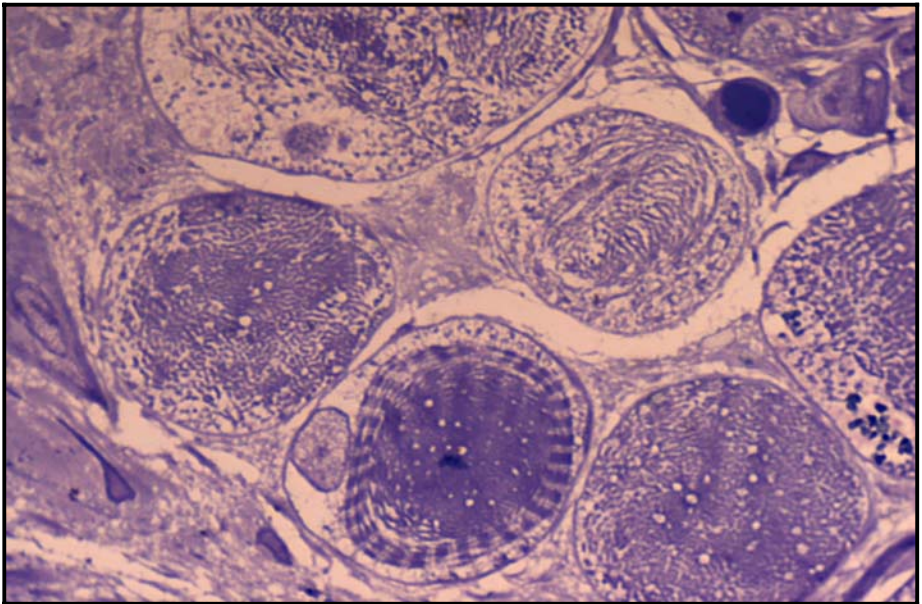


Fig. 6. The micrograph shows a transverse section of a Ringbinden fibre. (1000x)

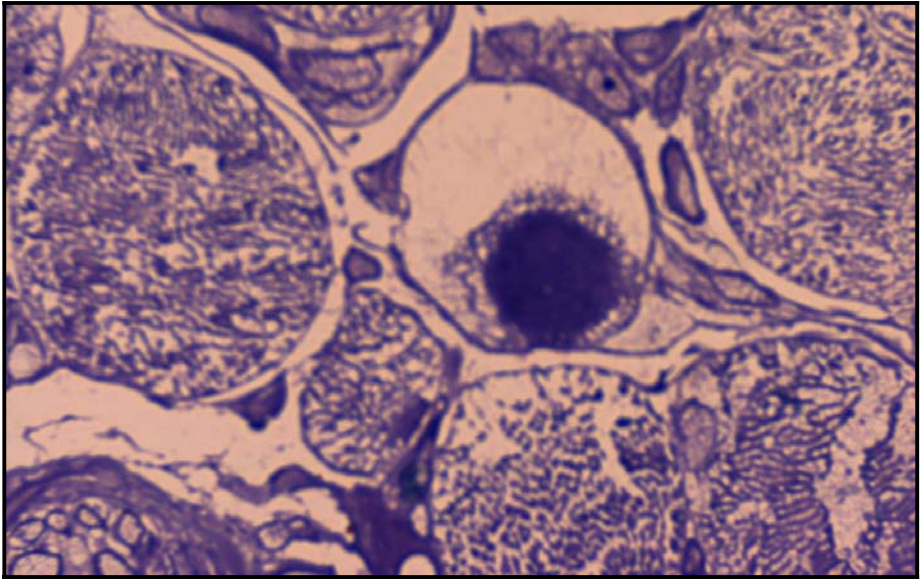


Fig. 7. The micrograph shows loss of contractile material in a mature muscle fibre. (1000x)

4 Conclusion

Sustained near-visual work, such as reading and VDU work, imposes demands on the visual system which can cause visual discomfort. Based on the observation in previous and current studies, it is legitimate to argue that the following neuromuscular parameters may contribute to such discomfort:

1. *Variations in fibre population.* Prolonged near-visual activity requires long standing contractions of a sufficient number of muscle fibres with appropriate physiological properties. The current study revealed large individual variations in the number of such fibres. A low concentration of these so-called Felderstruktur fibres will not only reduced the patient's capacity to maintain fixation, but also affect the interaction between accommodation and convergence. Furthermore, the Felderstruktur fibre is associated with receptors providing proprioceptive feedback. A reduction in afferent signals may induce instability in the oculomotor system, not only because of reduced afferent signals from the oculorotary fibres but also from the fibres terminating on the muscle sleeves. A low number of muscle fibres with the required physiological properties will demand an increased effort from the remaining fibre population. A compensatory contraction will increase the tonus in the muscle which in turn will narrow the endomysial space where many of the muscular nociceptors are located. From this follows that long lasting compensatory contractions represent a potential source of visual discomfort.
2. *Head movements and ocular rotation.* The Medial Longitudinal Fasciculus (MLF) is an extensive pathway linking the vestibular nucleus with the oculomotor system. Axons in the MLF influence directly or indirectly the neural activity in all of the

oculomotor cranial nerves. Habitual head posture during near-distance work may therefore have functional implications and be a potential cause of visual discomfort. The compensatory ocular rotation which is induced by the vestibular input can cause an increased tonus in the extraocular muscles and result in deformation of the free nerve ending in a similar manner as promoted in the section above (nr 1).

3. *Collagen connections to periorbita and dura mater.* It is generally accepted that free nerve endings, branching to form plexuses, are present in many tissues including tendons and the meninges of the central nervous system. The duramater enters the orbit through the optic canal and divides at the site of entry. One part of the duramater forms the periorbita, lining the orbital wall, while the other extends forward and envelopes the optic nerve all the way to the posterior pole of the eye. The origin of the extraocular muscles forms a ring of collagen around the optic canal and fuses with the collagen of the periorbita. Tension on the periorbita through rotation of the eye is a well documented source of orbital pain and is believed to be the main cause of discomfort in cases of inflammation of the orbital apex such as retrobulbar neuritis. The filaments connecting the muscle sleeves with the frontal part of the orbital wall, as described in current and previous studies can arguably apply a similar tension on the periorbital tissue. The presence of embedded neural elements within the filaments as well as in the periorbita suggests that the level of tension does not necessarily have to be excessive in order to produce a sensory signal. Constant changes in working distances will create a pull on the collagen fibres running between the globe and orbit. It is reasonable to assume that if this activity persists over longer periods of time it may trigger the embedded nociceptors, creating sensation of discomfort and/or pain. Free nerve endings cannot always be discriminated from passing autonomic nerve fibres with certainty and the notion that some of the observed fibres terminated on blood vessels or smooth muscle cells cannot be dismissed. However, since no such structures were observed in the vicinity of where the axons terminated, confusing the two seems unlikely.
4. *Age-related changes.* The current study suggests that the potential discomfort in relation to VDU work may increase with age due to degenerations in the neuromuscular architecture.

Although visual discomfort is a subjective experience of a multi-factorial origin, the current histological study has arguably revealed some of the potential underlying neuromuscular mechanisms.

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Forget About Aesthetics in Chair Design: Ergonomics Should Provide the Basis for Comfort

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Abstract. Helander and deLooze have proposed a model of seated comfort in which *comfort* and *discomfort* are conceptually separate. They argue that ergonomic chairs tend to be overdesigned with insufficient attention paid to aesthetics. This argument is critiqued on both methodological and conceptual grounds. The methodological critique is based on psychometric criteria. The conceptual critique is based on the need for an integrated (ecological) approach in which work context and user characteristics are explicitly considered. An alternative model for an ecological ergonomics is presented.

Keywords: seated comfort, ecological ergonomics.

1 The deLooze/Helander Model of Seated Comfort

Based on his own survey of the literature, and with particular reliance on the work of Helander et al. ^[11], deLooze ^[6] has proposed a model of seated comfort. The deLooze model identifies *discomfort* and *comfort* as conceptually separate entities. While *discomfort* and *comfort* are both psychological states, feelings of *discomfort* are assumed to be causally determined by “objective” biomechanical factors traditionally associated with risk factor models of musculoskeletal disorders (i.e., physical exposure, dose, response). On the other hand, feelings of *comfort* have a more complex set of determinants. The social and emotional context of the user, including factors such as job satisfaction and social support, are superimposed on the physical and task components associated with *discomfort*. In addition, deLooze differentiates between *physical* and *aesthetic design* attributes of the chair and argues that the latter uniquely impacts feelings of *comfort*. The core of Helander et al’s argument is that ergonomic chairs are over-designed in terms of the amount of adjustability since users in their study were unable to differentiate ergonomic chairs with different ergonomic features on the basis of reduction in discomfort. On the other hand, the same chairs could be differentiated on the basis of satisfaction and comfort. Thus, Helander^[11] concludes: “Discomfort is based on poor biomechanics and fatigue. Comfort is based on aesthetics and plushiness of chair design and a sense of relaxation and relief” [p. 1315].

1.1 Methodological Critique

DeLooze's argument for independence of comfort and discomfort rests on a psychometric approach in which the user is asked to assess multiple attributes (chair features) of multiple stimuli (chairs) on multiple dimensions (comfort and discomfort indices). The psychometric adequacy of this model remains to be demonstrated. However, even if an approach similar to multi-trait multi-method reliability and validity could be established, the context in which the chair is used is still missing. A chair is not an isolated object, but needs to be considered as an integrated component in a complex work environment. At the very least, the user's body scale (anthropometry), biodynamic capabilities, and understanding of how the chair functions needs to be included in the model.

We have a fundamental concern with the psychometric adequacy (i.e., reliability and validity) of the subjective measures utilized in these studies and most studies of seated comfort. See, for example, Kolich^[12] The users in these studies must compare several different chairs along several different dimensions. We have seen no published data on reliabilities of these scales, or on convergent or divergent validities^[3]. If a serious theoretical argument about the nature of comfort and discomfort is going to be based on the psychometric differences between clusters of comfort and discomfort ratings, these methodological issues will be need to be addressed.

However, even if we take the obtained results^{[6],[11]} at face value, there are legitimate concerns about the efficacy of the overall approach. The methodology utilized in these studies is essentially that of consumer research. Users were given a selection of chairs and a series of ratings scales on a questionnaire. There is no indication that they received the kind of training which is essential for successful ergonomic intervention. See Amick, et al^[1]. Users were expected to intuit, for themselves, the functional relationships between chair controls and resulting postures, as well as the rationale for alternative seated postures. Hence, it is not surprising that preference ratings would be more highly loaded on aspects of the seat cushion rather than the control mechanisms. The resulting outcome, while perhaps important for marketing, is hardly a basis for a scientific discussion of design of ergonomic seating.

1.2 Conceptual Critique

A major problem with the DeLooze model^[6] rests on the epistemological confusion inherent in the categorical linkages between biomechanics and discomfort on the one hand and aesthetics and comfort on the other. The problems with these linkages are readily apparent to any serious tennis players who have searched for the "sweet spot" on their racquets, or a carpenter who has appreciated the "feel" of his/her favorite hammer. This type of problem requires a systematic approach, such as offered by Wagman and Carello^[16], Dainoff and Wagman^[4] or Wagman^[15].

If our goal is the scientific study of seated comfort, it is unclear why the conceptual separation of "aesthetic" and "physical" design features is useful. Helander's concept of "plushiness" as a prime example of an aesthetic factor is hardly non-physical. Instead, the term "plushiness" can be a surrogate for a combination of physical attributes including foam density and seat cover geometry. It is then an empirical question as to how variations in such attributes will interact with other chair design

attributes to afford seated postures appropriate to accomplishing demands of the task for which the chair is intended to support. (A chair that is too plushy may actually impair performance.) The flaw in the deLooze/Helander approach is to associate biomechanical design features with what is essentially a *medical* goal, i.e. the avoidance of pain and discomfort.

However, traditional ergonomics is much broader. Van Wely^[13] defined the field in terms of the relationship among efficiency, comfort and health. Thus, as in the example of plushiness, what deLooze calls aesthetic factors, can, at one level of analysis, be considered higher-order biomechanical factors, which must be taken into account when assessing effective user performance. Such performance can be assessed with a combination of carefully designed objective and subjective measures. One such subjective measure might be the emotions associated with ease and lack of effort entailed in using the chair.

Some sense of how this might be approached can be found in a recent proposal for “hedonomic design” (designing for user pleasure) by Hancock et al.^[10]. They suggest a principle of *seamless interaction*” which: “.....enables the user to interact optimally with the tool at hand. This in turn facilitates the transparency of the tool, enabling the user to focus effort of task completion and not on the tool itself.” (p.12) However, Hancock et al caution that it is, at present, premature to include design criteria for pleasure. In particular, we lack a reliable and valid measure of pleasure. Therefore, design criteria of safety, functionality and usability must take precedence. (We must also point out that as of this date, we do not yet have a valid and reliable measure of seated comfort or discomfort.)

The deLooze/Helander concept of *comfort* is conceptually similar to Hancock et al’s approach to hedonomic design. For this approach to be taken seriously, a body of theory relating the psychology of emotion to aesthetic design principles needs to be developed. Such a body of theory does not now exist in a form sufficient to applied to design concepts. Consequently, it is premature to explicitly include higher-order aesthetic concepts as such in a model of seated comfort.

Instead of diverting our professional and scientific attention to a completely new arena of “aesthetics”, we need to engage in a program which maps out the functional capabilities required for seated posture under various work constraints. If we can accomplish this goal, while not neglecting issues of ease of use (seamlessness), the aesthetics should come “for free.”

2 Ecological Approach as a General Solution to Incorporating Ergonomics in Design

We argue that the ecological approach to ergonomics provides a broad conceptual and rigorous framework that will allow systematic scientific research to be translated into practical design concepts. Ergonomics has been described by Dainoff and Dainoff^[5] as the fit between people and the elements of the physical environment with which they interact. As such, ergonomics is inherently relationship-oriented in that absolute dimensions and physical characteristics of objects in the work environment must be

defined with respect to the relevant anthropometric, biomechanical and perceptual-cognitive characteristics of the user. The ecological perspective based on the work of James Gibson^[9] provides a principled approach for conceptualizing such relationships.

Core concepts in the ecological approach are *affordances*, *effectivities*, and *perception-action cycles*. *Affordances* refer to the *characteristics of the physical environment* measured with respect to the individual or "actor." Affordances thus represent, in physical terms, the possibilities for action for a particular individual supported by the environment. Accordingly, any seat design factor (e.g., seatpan height) can be an affordance for comfortable seating for some group of people.

Effectivities are complementary in that they refer to action capabilities of individuals measured with respect to the physical environment. Effectivities thus represent human variability (body scale, biodynamic capabilities) relevant to the seating environment. Thus, whether a particular seatpan height is, in fact, an affordance for comfortable seating depends on certain effectivities, e.g., lower leg length. A two year old child cannot sit comfortably in an adult chair, nor can an adult sit in a child's car seat.

Affordances and effectivities are coordinated through *perception-action cycles*. Any integrated behavior pattern (task) can be decomposed into a series of steps in which information about the possibility of action is detected and followed by the action itself; this action, in turn, reveals new information about other potential actions. For our purpose, a particularly important set of perception-action cycles are the actions carried out when a user sits down in an adjustable seat and carries out the adjustments necessary for comfort.

Affordances and effectivities can be considered instances of what Vicente^[14] described as *behavior shaping constraints*. That is, from an ecological perspective, it is important to consider the overall landscape within which any goal-directed behavior is possible. Behavior shaping constraints define the boundaries and shape of this landscape. We call this landscape the *work domain*. It is convenient to define four classes of such constraints: *task*, *environmental*, *organizational*, *individual*. *Task constraints* are those components of the work domain that are directly in service of goal-directed activity. For a knowledge worker, these would include the physical components of the work domain used to organize information, such as the computer keyboard, display screen, input device, telecommunication devices, and associated paper documents, as well as the information itself—either in electronic or print form. *Environmental constraints* include those components of the work domain surrounding or supporting the user as she/he engages in a goal-directed activity. This includes chairs, worksurfaces, lighting ambient temperature, air quality, etc. *Organizational constraints* include those psychosocial attributes of the organization which have the potential to affect goal-directed activities. These include specific constraints such as time pressures, interruption by colleagues, or more general influences from management and coworkers. *Individual constraints (effectivities)* include both physical components (anthropometry, physical status (health, strength, disability) and psychological components (knowledge, motivation).

Ongoing goal-directed activity consists of perception–action cycles in which the actor extracts information about the affordances embedded in the array of constraints and then acts upon that information. The outcome of action will then reveal new

information which in turn serves to regulate new actions. Thus, this perception-action cycle becomes the informational and behavioral context within which seated posture takes place and within which the operational effectiveness of a chair must be assessed. Task and organizational constraints define the landscape in which the primary task (e.g., writing a document) takes place. Environmental and individual constraints allow us to understand the working postures required to carry out the primary task. For example, if the task requires entering data and text collated from several different documents located on the horizontal work surface adjacent to the computer, visual demands of the task will constrain the head and trunk upright while requiring sideways reaching actions to bring different documents into the field of view.

The critical question then, as a strategy for scientifically based design, to identify chair characteristics which can support this particular working posture. That is, can the seat dynamics allow a range of users, with a variety of anthropometric attributes, to maintain working postures that minimize biomechanical loading? Because biomechanical loading is the presumed mechanism underlying fatigue/discomfort, and such fatigue/discomfort are known to develop over time, we argue that the most effective way to investigate comfort/discomfort is to utilize a reliable and valid scale of comfort over a period of time sufficient for fatigue to develop. By framing the question in this way, we identify this particular configuration of constraints as one of a limited number of exemplars that can be used to explore the range of work domain for a subject at hand.

This framework also lets us view the user-chair interaction within exactly the same framework as the user-task interaction. That is, the relationship between the user and an ergonomic chair is one of adaptive tool use. To the extent that the user understands the functional actions of the chair controls and their effect on posture, she/he can, upon detecting somatic information (discomfort), interrupt on-going task-directed perception-action cycles in order to adjust the chair in a way that minimizes that discomfort. It follows that certain chair affordances are going to be better than others in terms of (a) physical characteristics that reduce biomechanical loading/minimization of discomfort and (b) perceptual characteristics that make it more likely that the users will actually perceive the relevant chair affordances and be able to execute the perception-action sequences intended by the chair designers. This should be the focus of scientific research in support of chair design.

For example, one set of task constraints may involve only keyboard and display screen interaction, such as searching the web. In this case, a “plushy” chair which affords a backwards leaning posture would be effective in the sense that the user could maintain this work posture for relative long periods of time without discomfort. However, a different set of task constraints—working with an array of paper documents—requires a more complex set of seating affordances. Understanding the reach requirements [14] necessitates understanding the relationships between the geometric layout of the worksurface as well the task demands (number of documents and frequency of use). Reach actions determine certain postural changes, in particular, the relationship of the trunk to the backrest. That is, some reach requirements entail the trunk moving away from the backrest. Hence, the trunk support affordances built into the backrest can not be utilized. Therefore, it becomes important to design of affordances that have a dynamic character in the sense of providing support while

allowing changes of posture. See, for example, Bush et al, Faiks and Reinecke^{[2], [7], [8]}. Chairs with these characteristics have been shown by Amick et al.^[1] to reduce discomfort and increase productivity.

Finally, this approach can be generalized to (almost) any product category intended to be used by humans. In the above example, let us assume the operator interrupted the task again because she needed to create a multi-level numbered outline in her document. In this case the affordances include the relevant entries in the help menu. A different perception-action cycle now is executed, but the effectiveness can be assessed in a similar fashion.

3 A General Ecological Framework for Comfort

A hallmark of Gibson's ecological theory is that it insists on the complementarity between attributes of the external environment specified in terms of the individual organism (affordances), and attributes of the individual specified in terms of the external environment (effectivities). At the same time, ergonomics can be conceptualized in terms of person-environment fit. Accordingly, theory and methods derived from ecological psychology provides a natural foundation for a scientifically based ergonomics.

Within this framework, comfort can be regarded as the product of the fit between the worker's capabilities (anthropometric, biomechanical and cognitive), the actions supported by the environment and the task demands of the work. Specifically, we can define comfort as the subjective expression of a generalized physiological state of optimization in which discomfort/pain are absent. Comfort, therefore, is necessarily a product of the entire worker-environment-work system.

Optimization can, in turn, be approached in terms of asking whether an appropriate set of affordances which match the effectivities of the user are available. Thus, we can define comfort as the *fit* of the user to the environment in the context of the work to be done. Within the ecological approach, we can clearly state that when the affordances for the work to be done are present, we get a fit of the worker to his/her environment.

There are clear implications for strategies for scientific research and the translation of that research to design principles. Contextual variables must be systematically incorporated into research design. (See, for example, the above discussion regarding the interaction of use of documents, reach, and dynamics of the chair support surface.) This adds to complexity (and difficulty) of conducting ecologically-oriented research. However, findings from such context-relevant investigations ought to be more easily and directly translated to design principles. This is the ultimate goal of ergonomic research.

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Effects of the Office Environment on Health and Productivity 1: Auditory and Visual Distraction

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Abstract. A pilot experiment was conducted to evaluate the effects of visual or auditory distraction in an office environment on productivity, concentration and emotion. Ten subjects performed a simple, standardized computer task in five conditions (undisturbed, 3 variations of auditory distraction and visual distraction). Results showed no effects of visual and auditory distraction on productivity, concentration and emotion. This implies that typical problems of open office environments, like noise and other types of distraction, are of no influence on productivity while performing simple computer tasks. However, it is possible that the used method and factors like habituation, type of distraction and type of task were of influence on the results.

Keywords: health, productivity, office, distraction.

1 Introduction

Developments in Information and Communication Technology and more flexible ways of organizing work processes has changed the work environment of office workers substantially [1]. An example of these changes is the growing number of organizations that move to working in open plan offices. Open plan offices seem to meet the needs resulting from these technological and organizational developments, for example the needs of employees for working in teams. However, many problems of open plan offices have been reported, such as noise, lack of privacy and other kinds of distraction [2]. New office concepts may affect office workers performance, well-being and health [1]. Several studies show negative effects of noise or distraction in open plan offices on work performance, wellbeing and health [2],[3]. Furthermore, distraction is also expected to be related to a negative perception of the physical work environment [2],[3].

Auditory distraction or noise in the office environment is often mentioned as the most problematic distracting factor in relation to concentration [2]. Less is known about visual distraction. Visual distraction is different from auditory distraction, because the responses from the brain differ. The mechanism that helps to re-orientate to the working task again that is presumed to occur after long duration auditory distraction, does not occur after long duration visual distraction [4]. With auditory distraction, a process of three mechanisms is activated. First, the distracting stimulus

is detected. Then, an involuntary attention switch occurs to the distracting stimulus. Finally, the attention is turned back to the primary task (reorientation), using information kept in the short term memory. This series of mechanisms takes place within 1,5 seconds and is visible in EEG activity. During long duration visual distraction, the first two mechanisms are visible in the EEG, but the mechanism of reorientation does not occur, indicating a difference between auditory and visual distraction. Moreover, this suggest that reorientation after long duration visual distraction may be more difficult than reorientation after auditory distraction [4].

According to Hongisto [5], auditory distraction is particularly a problem of complex tasks. It remains unclear if it applies to simple tasks.

Therefore, a pilot is conducted to study the effect of auditory or visual distraction on simple tasks. The research question was:

Does visual or auditory distraction in the office environment affect performance, concentration and emotion, performing a simple computer task?

Visual distraction was defined as walking through the visual field, auditory distraction was defined as telephone conversations within hearing distance.

2 Methods

Five men and five women participated in the study (age 35 ± 10 years, height 177 ± 12 cm, weight 76 ± 12 kg). All subjects were experienced computer workers. They spent on average $5 (\pm 1)$ hours a day computer work.

In five conditions, the subjects performed a standardized typing task with a duration of 15 minutes. In four conditions, the subjects were exposed to different types of distraction: 7 times walking past the visual field of the subject, and telephone conversations of 5, 10 and 15 minutes within hearing distance. In one condition the subjects performed the standardized task with no distraction. In all conditions, performance, emotion and concentration were measured.

Preceding the experiment, subjects gave informed consent. The subjects were informed about the goal of the study: to evaluate the effects of duration of typing tasks on performance and emotion. The subjects were not informed about the distractions they would be exposed to during the experiment.

The standardized task consisted of copying a text as accurate as possible (including punctuation marks like quotation marks, commas and apostrophes) in Microsoft Word 2000. At the same time, lay-out (like bold, italic or tabs) did not have to be copied. It was not allowed to use the mouse.

Typing speed and accuracy were used as performance measures. Typing speed was derived from the number of characters typed during 15 minutes (excluding the characters that were removed with delete and backspace keys). Accuracy was measured by the amount of typing errors, calculated by counting the differences between the original text and the copied text added up with the number of times the delete or backspace key was used. All missing or incorrectly typed characters were counted (letters, commas, full stops, interspacing, quotation marks, etc). To measure

the number of times the delete or backspace key was used, the rest break software Workpace 3.0 was used (Niche Software Ltd.).

To measure the effects of distraction on emotion, the EMO-cards were used [6],[7]. This method was developed to measure emotion in relation with products. In this pilot study, the method was used to measure perception of the office environment. The EMO-cards measure two dimensions of emotion: 'pleasantness' and 'arousal' (Fig.1).

Concentration was measured by using a Visual Analogue Scale (VAS). Subjects were asked to place a mark on a line, ranging from 0 (extreme poor concentration) to 10 (extreme good concentration).

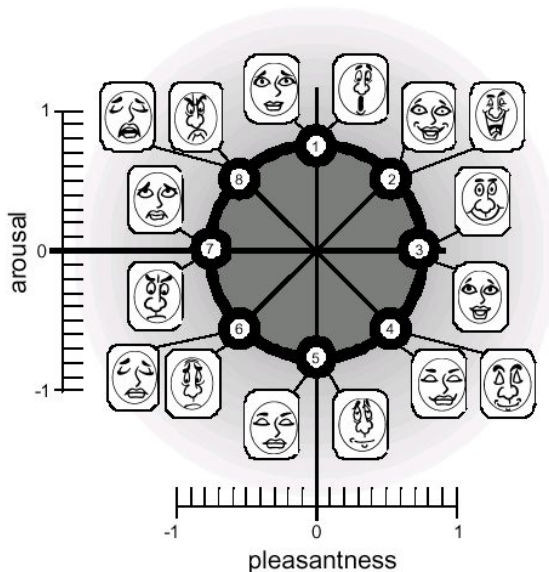


Fig. 1. EM O-cards

Differences in performance and concentration between the conditions without distraction and visual distraction were tested with a T-test for repeated measures. Differences in performance between the condition without distraction and the conditions with auditory distraction were tested with ANOVA for repeated measures, followed by a posthoc test (Bonferroni).

Differences in emotions were tested non-parametric. A Friedman test was used to evaluate differences in emotion (divided in 'pleasantness' and 'arousal') between the condition without distraction and the conditions with auditory distraction. The Wilcoxon signed ranks was used to evaluate differences between no distraction and visual distraction.

Also, the frequency of occurrence of emotions (combinations of 'pleasantness' and 'arousal') was determined for the five conditions. The frequency was not statistically tested.

Significance level was set at 5% (two-sided).

3 Results

No effects of auditory distraction on typing speed (Fig. 2) and accuracy (Fig. 3) were found. For visual distraction (walking through the visual field) comparable results were found.

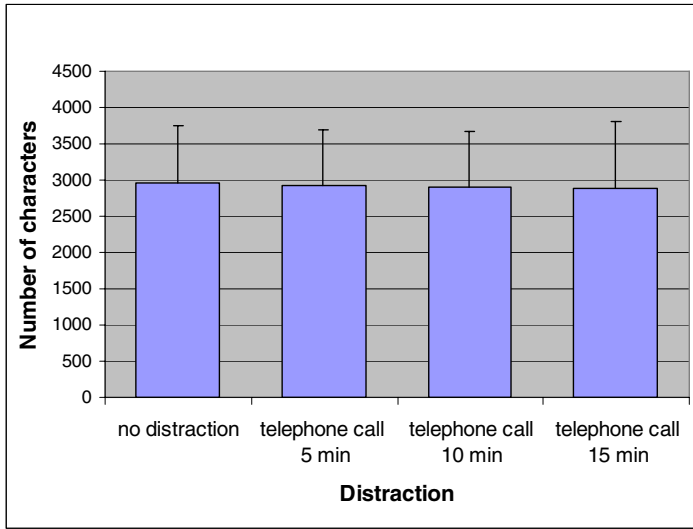


Fig. 2. Typing speed auditory distraction

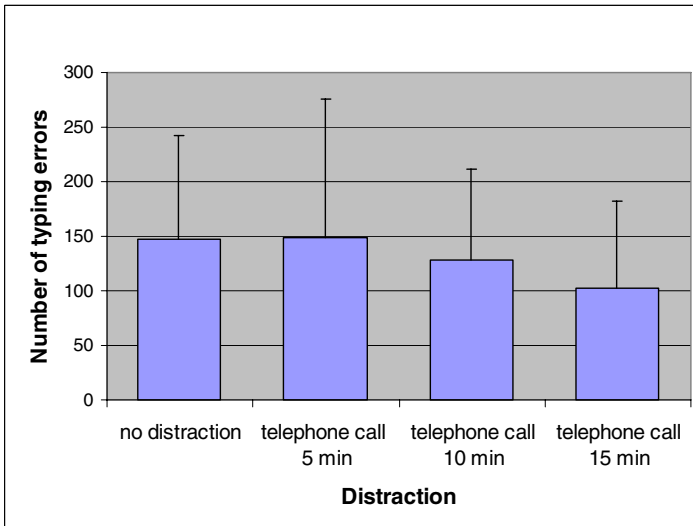


Fig. 3. Accuracy auditory distraction

No differences were found in self reported concentration between the conditions with distractions and the condition without distraction. These results were found for visual distraction (Fig. 4) as well as for auditory distraction.



Fig. 4. Self reported concentration visual distraction

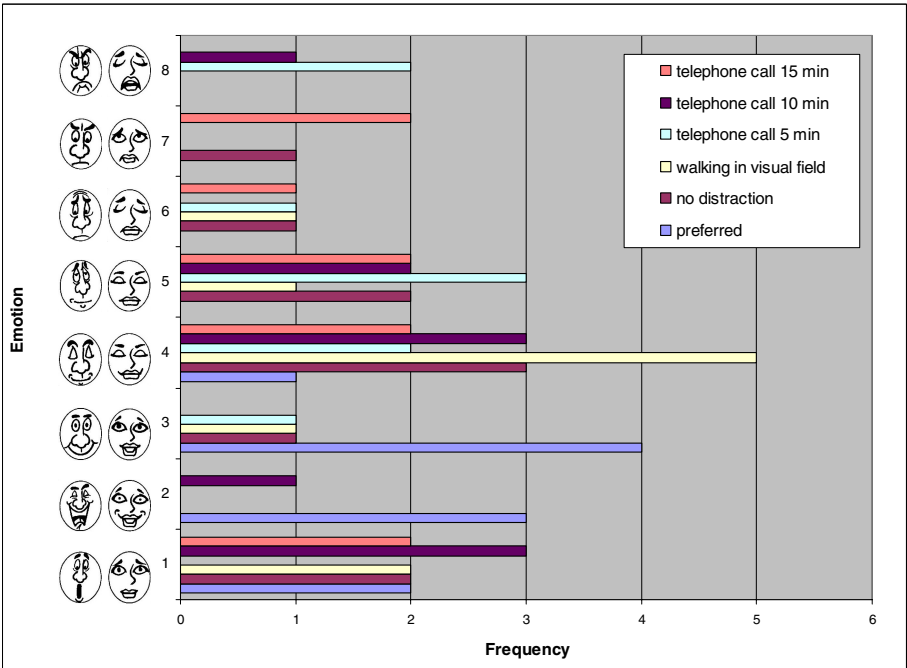


Fig. 5. Frequency of occurrence of emotions

Figure 5 shows the frequency of occurrence of emotions. Visual and auditory distraction were not of influence on the degree of 'arousal' and an 'pleasantness'. A notable result is that emotion 2 and 3 are rated as most preferable emotion. The subjects were asked to report the most important factors affecting their emotions at work. The following factors were reported:

- Task (boring, interesting text, remembering and searching through text) n=7
- Distraction (because of telephone conversation or wandering thoughts) n=6
- Interior/ design (keyboard, desk, reflections) n=4
- Physical discomfort (stiff muscles, pain) n=4
- Fatigue (because of task or early morning hours) n=3

4 Discussion

Subjects were mainly workers or students familiar with planning and performing research projects. Some subjects indicated that they suspected the real goal of the pilot study during the experiment (evaluating the effect of distractions). This may have influenced the results; it is not known in what way. On the one hand, subjects may have paid more attention to suspicions of the real goal of the study, instead of concentrating on the task. On the other hand, subjects may have ignored the distractions more easily, suspecting the real goal of the study.

The experiment did not take place in a laboratory setting, but in a real office to simulate practice as much as possible. However, the situation was not completely comparable to a real office, because the room where the pilot study took place was not accessible for other employees than the subjects, to be able to control the distractions. The fact that the simulated office was not completely comparable to real practice may have been of influence. For example, noises in a laboratory setting may have another meaning for a person than the same sound in a real office setting, according to Banbury and Berry. Where subjects try to neglect a noise in a laboratory setting, they may tend to focus on the same noise in a real office setting [3].

Furthermore, subjects may have become more or less habituated to the distractions they were exposed to. In addition, most of the subjects are used to working in an open office space. Hongisto [5] reported that, to some degree, habituation to noise is possible, especially when someone has been exposed to it shortly before the experiment. However, because sounds in an open office space are usually unpredictable and of varying intelligibility, it is assumed that it is not possible to permanently habituate to office noise. Banbury & Berry [3] found no proof of habituation to noise in the office. On the basis of (inconsistencies in) literature, it remains unclear if habituation effects occurred in this pilot study.

In a telephone call certain topics of conversation may distract more than others, because it has a special meaning or is of special interest to someone. Literature shows that noise with relevant information has more influence on performance than irrelevant information. Especially background speech affects concentration, to a lesser degree distinctive or salient sounds and not so much the level of noise [5],[3]. In this pilot study, the speech intelligibility was high in the conditions with auditory distraction with telephone conversations. Therefore, it is not likely that the way the telephone conversations were performed influenced the results in this pilot study.

Less is known about visual distraction in offices. No studies were found evaluating effects of visual distraction in offices. Probably, visual distraction is less present than auditory distraction in open office spaces. Berti & Schröger [4] describe different reactions to visual distractions compared to auditory distraction. However, in this study, no differences were found between no distraction or visual distraction. Further research on visual distraction is needed.

No effects on performance were found. It is assumed that copying a text is a simple task and demands little concentration. Hongisto [5] reported that for simple tasks, performance may even increase with background noise, compared to the absence of background noise. The results of this pilot study suggest that the distractions in the work environment are less important in relation with productivity when simple tasks are performed. Moreover, this indicates there are no adverse effects on performance of open plan offices.

In addition, situational and personal factors may play a role in responses to distraction [8]. Some behavioural strategies to compensate effects of noise lead to a decrease in performance, while other strategies do not.

In literature, distraction is related to a negative perception of the work environment [2]. In the study of Banbury & Berry [3], noise is associated with irritation. In this pilot study, no effects of distraction were found on emotion. To measure emotions, EMO-cards were used [6],[7], which measures two dimensions of emotion: pleasantness and arousal. Possibly, the level of distraction was too low to measure effects on emotion. Perhaps, pleasantness and arousal are not emotions associated with distraction. In addition, EMO-cards are developed to measure emotions in relation with products and might not have been applicable for the purpose in this pilot study. In future research, it is important to pay attention to methods which measures other aspects of perception (e.g. irritation), as other studies did find effects of distraction on perception [2],[3].

5 Conclusion

Visual or auditory distraction in the office environment does not seem to affect performance, concentration and emotion, while performing a simple computer task. This implies that performing simple tasks in open office environments have no negative effects on performance. In future research, it is important to study the effects of distraction in complex tasks. In addition, is it important to study the effects of exposure to combined types of distraction and to study effects on a larger variety of emotions.

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Effects of Using Dynamic Office Chairs on Posture and EMG in Standardized Office Tasks

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Abstract. In the paper a measuring system for the comparative posture and EMG analysis of office chairs is presented. With the system four specific dynamic office chairs that promote dynamic sitting and therefore aim to prevent musculoskeletal disorders (MSD), were analyzed in comparison to a reference chair in two different standardized tasks (intensive mouse use and sorting files). Exemplary results of the ongoing study suggest that postures and the electrical activities of the erector spinae and trapezius muscles depend more on the tasks performed than on the use of a particular type of office chair. This still has to be proved by statistical analysis.

Keywords: office chair, EMG, posture, measuring device, dynamic sitting.

1 Introduction

Working frequently and continuously in static sitting postures at visual display unit (VDU) workplaces can cause muscular tension and musculoskeletal disorders [1]. Static muscular workloads particularly of the shoulder and neck can occur as well as functional underuse of certain muscle groups, such as the back and abdominal muscles [2]. In the development of office chairs, the concept of dynamic sitting has therefore been encouraged in recent years. By introducing structural elements that give the seat pan a dynamic mounting or active rotation of its own, some manufacturers of office chairs have created special chair characteristics that promote dynamic sitting with the aim of preventing musculoskeletal disorders at office and monitor workstations.

Various measurement methods for the quantification of the musculoskeletal load situation during seated activities at office workplaces and VDTs have been described in the literature. One example of this is stadiometry, in which the decrease in body height over the course of a day is adopted as the parameter for spinal loading [3], [4]. Other methods include electromyography (EMG), in which the muscle activity, e.g. of the back muscles, is taken as a measure of muscular stressing [5], or the measurement of body posture and movement as a means of quantifying spinal postures in particular [6], [7].

In the context of the study presented here, a measuring system has been created that combines posture and EMG measuring methods in such a way that the load situation during seated office work can be ergonomically analysed in both laboratory and real-life environments. Comparative posture and EMG measurements were conducted for four dynamic office chairs and one conventional reference office chair in two standardized office tasks (intensive mouse use and sorting files). Herewith the effects on posture and EMG depending on office task type and chair characteristics are analysed.

2 Methods

The study was carried out at a realistic VDU office workplace in laboratory. 10 test subjects (5 men and 5 women) took part in the laboratory tests. The mean ages were 35.4 years (SD 12.1 years) for the men and 34.8 (SD 12.7) for the women. Body heights ranged from 1.75 to 1.86 m for the men and from 1.62 to 1.68 m for the women. Body weights varied from 76 to 100 kg for the men and from 47 to 78 kg for the women. Each subject tested a total of five office chairs (4 particularly dynamic ones labelled A, B, C and E and 1 reference office chair – labelled D) during the performance of the following standardized tasks (duration of activity in brackets):

- Intensive use of the mouse (20 minutes)
- Sorting files (10 minutes)

Body postures and movements were measured with the CUELA system [8]. This person-centered measuring system consists of movement sensors (3D accelerometers and gyroscopes) as well as a miniature data storage unit with a flash memory card, which can be attached to the subject's clothing [9], [10]. In this study a special version of the system adopted for sitting postures was used [11] and the sensors were attached to the subject's skin.

From the measured signals, the following body/joint angles were calculated: Head inclination (sagittal and lateral), flexion/extension and lateral flexion of the spine in the thoracic (Th3) and lumbar spinal regions (L1 and transition to L5/S1), trunk inclination and the spatial position of the upper and lower legs (right and left).

From the kinematic measurements at the thoracic spine Th3 and lumbar spine L5/S1 physical activity intensities (PAI) were determined by calculating a sliding standard deviation of the high-passed filtered vector magnitude of the 3D acceleration signals (time window: 1 s).

Surface electromyography (EMG) was used for measuring the muscle activity of the trapezius muscle (right/left) and erector spinae muscle (right/left) with the CUELA EMG signal processor for long-term analysis [12], [13]. To assess the EMG signals, the root mean square values (RMS values) were calculated from the raw EMG data over consecutive time windows (0.3 s). To normalize the RMS values, reference activities are performed at the beginning of all measurement so that all muscle activities stand in relation to a reference voluntary contraction (% RVC). The 100% RVC values for each muscle were defined as the 50th Percentile RMS values of

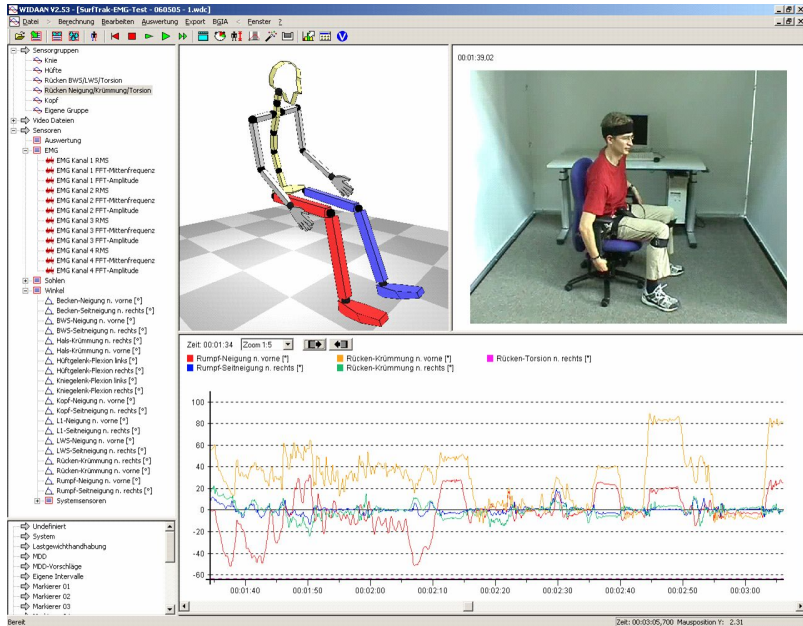


Fig. 1. Data representation with the CUELA software by video (right, above), animated figure (left, above) and selected data time graph (below)

a calibration interval at the beginning of each measurement (duration: 3 s), where the subjects were standing with their arms abducted at 90° holding a weight of 5 kg (females) or 10 kg (males). The 0% RVC values for each muscle were set as the minimum values of another calibration interval at the beginning of each measurement (duration 3 s), where the subjects were standing upright in a neutral relaxed posture.

All the measured data were synchronously recorded at a sampling rate of 50 Hz in a data logger of the CUELA measuring system. They can be depicted with the CUELA software together with the digitalized video recording of the workplace situation and a 3D animated figure (Figure 1). For statistical evaluation the software includes a calculation of the characteristic values of the frequency distributions (5th, 25th, 50th, 75th and 95th percentile) of each joint/body angle, physical activity intensity (PAI) and EMG recording. The frequency distributions of each measurement can be depicted in a box-plot diagram. From the box-plot diagrams for each subject, task and chair type the mean values for all subjects of the characteristic frequency distributions (5th, 25th, 50th, 75th and 95th percentile) were calculated and displayed in box-plot diagrams (mean for ten subjects, see e. g. Figure 2).

3 Results

In the following exemplary results of the ongoing study are presented. The frequency distributions are depicted as box-plot diagrams. The boundaries of the box are defined by the 25th and 75th percentile of the measured frequency distribution. The median (50th

percentile value) of the distribution is given as the central value in the box. The edge values of the distributions (5th and 95th percentile values) are marked with whiskers.

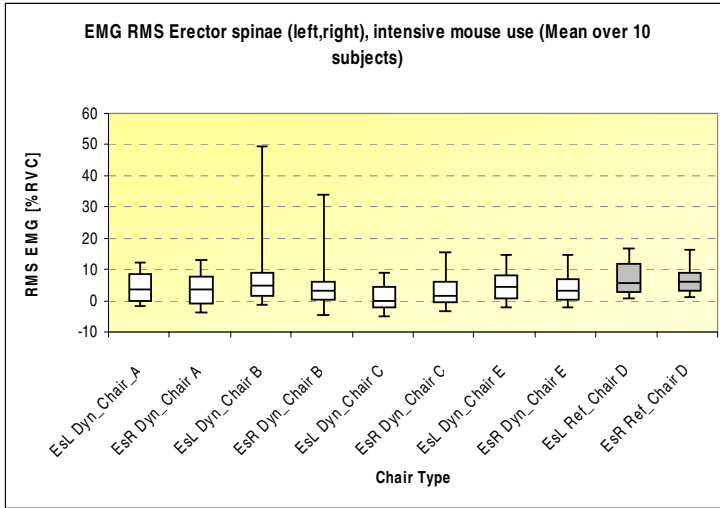


Fig. 2. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the EMG RMS values (in % RVC) for the erector spinae muscle left (EsL) and right (EsR) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “intensive mouse use”

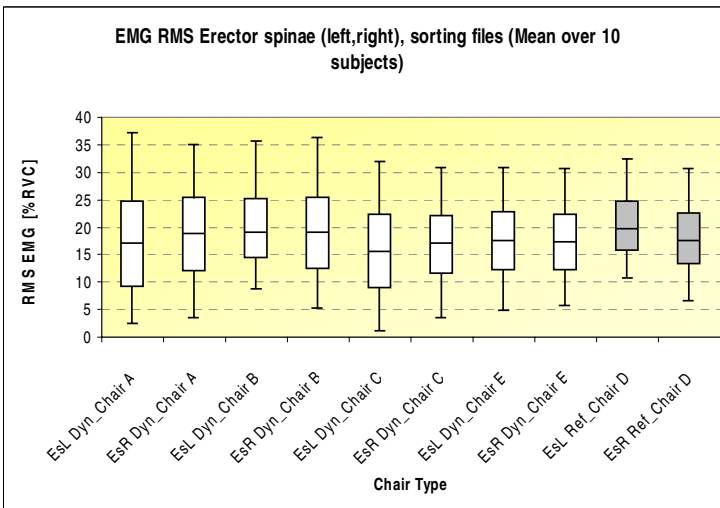


Fig. 3. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the EMG RMS values (in % RVC) for the erector spinae muscle left (EsL) and right (EsR) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “sorting files”

Figure 2 and Figure 3 show the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the EMG RMS values (in % RVC) for the erector spinae muscles left and right for all chairs in the tasks “intensive mouse use” (Figure 2) and “sorting files” (Figure 3). The RMS values of the erector spinae muscle are not high for both office tasks and all chairs. As expected for the more dynamic task of sorting files the RMS values for the erector spinae muscle are generally higher for all chairs ($> 15\%$ RVC at the 50th percentile for all chairs and $> 20\%$ RVC at the 75th percentile). There is not much difference between the frequency distributions of the dynamic chairs in comparison to the reference chair (exception: dynamic chair B for the task “intensive mouse use”).

Figure 4 and Figure 5 show the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the EMG RMS values (in % RVC) for the trapezius muscles left and right for all chairs in the tasks “intensive mouse use” (Figure 4) and “sorting files” (Figure 5). The RMS values of the trapezius muscle are much dependant on the task performed. The static mouse task yield to low RMS values of less than 5% RVC for the 50th percentile ($< 7\%$ RVC for the 75th percentile), whereas for the dynamic task of sorting files high RMS values of up to 50% RVC (50th percentile) and 65% RVC (75th percentile) were measured. A comparison of the frequency distributions of the dynamic chairs and the reference chair shows differences for the dynamic chair B in the static mouse task and for the dynamic chairs A, B and C (trapezius muscle right) for the sorting file task.

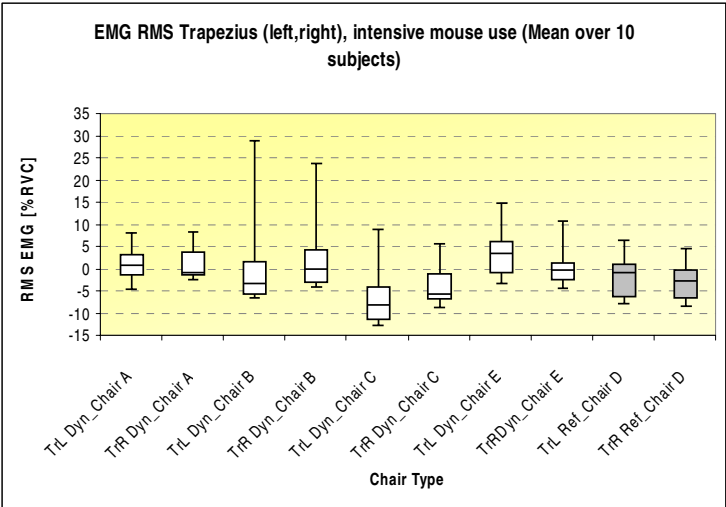


Fig. 4. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the EMG RMS values (in % RVC) for the trapezius muscle left (TrL) and right (TrR) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “intensive mouse use”

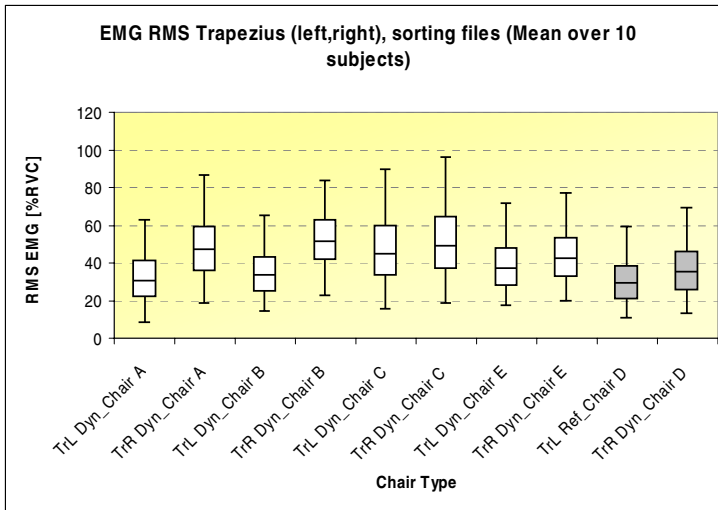


Fig. 5. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the EMG RMS values (in % RVC) for the trapezius muscle left (TrL) and right (TrR) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “sorting files”

Figure 6 and Figure 7 show the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the calculated physical activity intensity (PAI) (in %g) for the thoracic spine at Th 3 for all chairs in the tasks “intensive mouse use” (Figure 6) and “sorting files” (Figure 7). For the mouse task all PAI values are very low (< 0.21 %g for the 75th percentile and < 0.15 %g for the 50th percentile). For the task of sorting files the PAI values are higher (> 0.6 %g for the 75th percentile and > 0.4 %g for the 50th percentile). A comparison of the box-plot diagrams of the dynamic chairs and the reference chair show not many differences for both tasks.

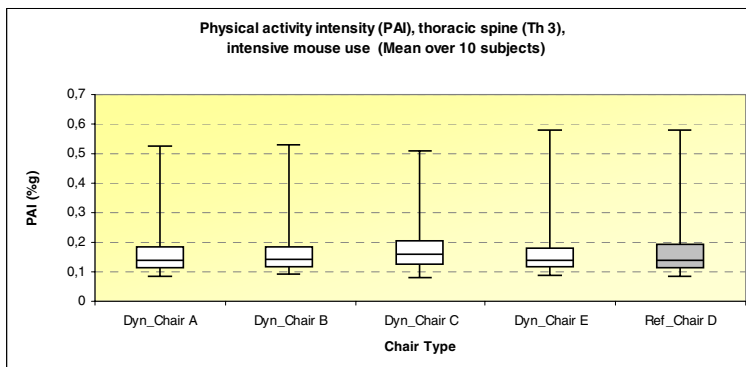


Fig. 6. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the physical activity intensity (PAI) in %g (%acceleration of gravity) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “intensive mouse use”

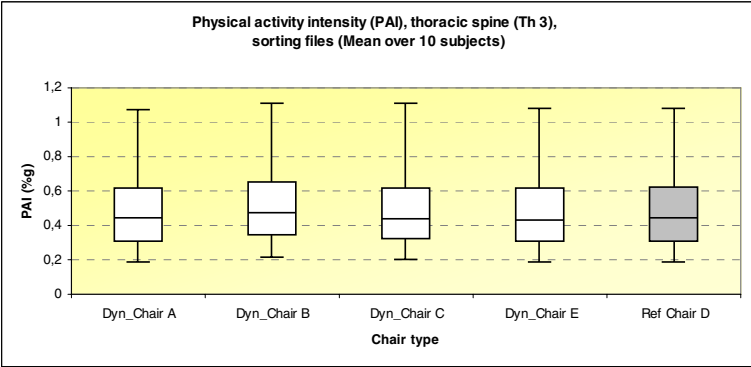


Fig. 7. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the physical activity intensity (PAI)) in %g (%acceleration of gravity) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “sorting files”

Figure 8 and Figure 9 show the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the trunk inclination angles (in °) for all chairs in the tasks “intensive mouse use” (Figure 8) and “sorting files” (Figure 9). The mouse task was performed with the trunk mainly inclined backwards. The trunk inclination angles range from -2° to -6° for the 50th percentile. The sorting file task was performed with the trunk inclined forward most of the time. Here trunk inclination angles range from less than 2° to more than 5° for the 50th percentile. For both different tasks and all chairs the differences of the trunk inclination angles at the 95th percentile and the 5th percentile are less than 15° . There is not much difference between the frequency distributions of the dynamic chairs and the reference chair.

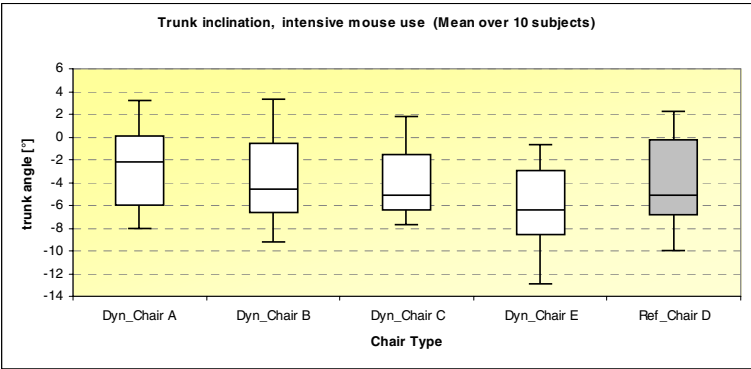


Fig. 8. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the trunk inclination angle in (°) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “intensive mouse use”

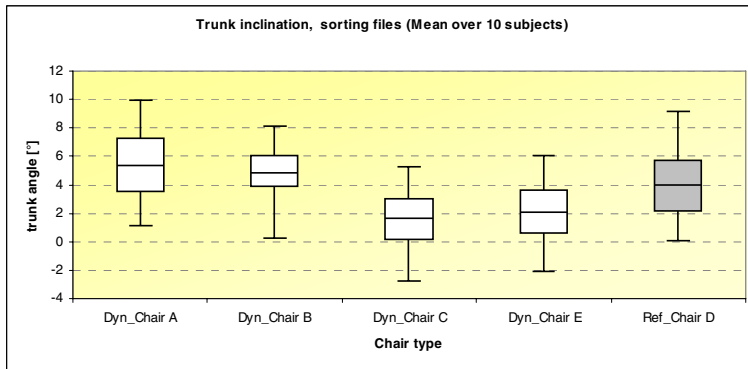


Fig. 9. Box-plot diagram of the mean values (over 10 subjects) of the 5th, 25th, 50th, 75th and 95th percentiles of the trunk inclination angle in (°) for all dynamic chairs (Dyn_Chair A, B, C, E) and the reference chair (Ref_Chair D) for the task “sorting files”

4 Conclusions

The measuring system developed permits the synchronous capture of different musculoskeletal load parameters. With the aid of the CUELA software, it is then possible to obtain, among other things, a very good general impression of muscle activity, body postures and movement for all test subject in relation to standardized tasks and different chair types. An initial evaluation of the ongoing study suggests that the load situation depends more on the tasks performed than on the use of a particular type of office chair. This still has to be proved by statistical analysis.

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Video Display Terminals and Neck Pain: When Ophthalmology Explains the Failure of Biomechanical Intervention

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Abstract. This case report presents a video display terminal (VDT) user complaining of neck pain. It was suggested that her complains would be due to the low position of her computer display. However, raising the monitor actually worsened the discomfort. Being presbyopic and wearing varifocal lenses, she actually was undercorrected — wearing new lenses (with higher reading addition) improved her symptoms. The role of refraction errors as a cause of neck pain and the importance of eye examinations for VDT users are discussed.

Keywords: neck pain, video display terminals, refractive errors, ergonomics.

1 Background

The neck, back, and brachial plexus seem to be a primary site of musculoskeletal discomfort among video display terminal (VDT) users. [1] Pain symptoms in the neck and shoulder may coexist, overlap and quite frequently no tissue damage can be revealed. [2] Several studies have documented a relation between trapezius load (in particular, static load) and development of musculoskeletal discomfort in the upper part of the body. [3] As with most chronic diseases, musculoskeletal disorders have multiple risk factors. [4] A relation between visual discomfort and pain in the neck has been described. [5] Uncorrected refractive errors lead to postural changes of the head and the cervical spine that, in turn, put more stress on the neck muscles and elicit myofascial pain. [6]

Work posture and postural load of the neck and shoulder muscles during VDT work when correcting presbyopia with different types of multifocal lenses where studied by many authors [7, 8] Single-vision lenses lead to a larger head flexion angle, which is usually considered to be an advantage compared with extension of the neck often observed when wearing multifocals. [9]

This case report illustrates how correct spectacles prescription is important to avoid neck pain in VDT users.

2 Case Report

ID: AML, female, 51, administrative officer.

In June, 2005, she requested the Occupational Safety and Health Service (OSHS) a support for her computer's VDT. She claimed she had pain in the backside of her neck and was under physical therapy. She said her physical therapist had suggested that her pain would be due to the position of her computer display — which would be way too low.

The safety technician inspected the workplace and confirmed the hypothesis of the low position of the display. He installed a monitor raiser, compatible with the user's anthropometry — the top of the display aligned with her eyes aiming the horizon. Although optimal monitor height placement is still under debate, [10] in our service we recommend that for VDT work, the center of the monitor should be located within a viewing angle of 0° to $-17,5^\circ$ as described by Sommerich *et al.* [11].

One week later, the safety technician paid her another visit to check if the problem was solved. However, he was astonished to find out that she had spontaneously taken the monitor stand off, and had put the display back to its original low position. Eventually, she claimed the support made her work “extremely uncomfortable.” At that moment, she was referred to the Occupational Physician.

At the doctor's office, she claimed feeling recurrent neck pain for about three months. She had already seen an Orthopedist who diagnosed myalgia, prescribed non-steroidal anti-inflammatory drugs and physical therapy. She also had hypothyroidism (controlled under thyroxine $75\mu\text{g/day}$) and wore varifocal glasses.

When asked about her last visit to the Ophthalmologist (which had been three months before), she said he had prescribed new glasses — but she was still wearing the old ones (prescribed two years before) because the new lenses were “too expensive.”

Her physical examination showed no more than tender trapezium muscles.

The hypothesis that she had undercorrected presbyopia — which would explain all her complains — was made.

She was then asked to bring her new glasses prescription to confirm the hypothesis.

Her old glasses' prescription was:

$$\text{OD: } -3,00 \diamond -1,25 \times 180^\circ \text{ ad } +1,50$$

$$\text{OS: } -2,75 \diamond -0,75 \times 180^\circ \text{ ad } +1,50$$

i.e., she had mild compound myopia with presbyopia.

And her new prescription was:

$$\text{OD: } -2,75 \diamond -1,00 \times 180^\circ \text{ ad } +2,00$$

$$\text{OS: } -2,75 \diamond -0,75 \times 180^\circ \text{ ad } +2,00$$

which revealed a progression of her accommodation deficit.

Hypothesis confirmed, she was oriented to wear new glasses, after what she became comfortable with her VDT and, moreover, without pain.

3 Discussion

To fully understand what happened in this case, it is necessary to understand both the natural history of presbyopia and how varifocal (or progressive) lenses work.

Presbyopia is the progressive failure of the eye lens to focus nearby objects due to aging. It usually shows up in the mid-40's. As the individual gets older, the eye lens becomes harder and progressively loses its capacity to alter its antero-posterior diameter (*i.e.*, its capacity to higher its power and focus nearby objects decreases, resulting in the condition where the field of focus is very limited). [12] As years go by, the presbyopic individual needs more and more positive powered lenses to see nearby objects clearly.

In order to correct presbyopia, convex (for near vision), bifocal (for near and distance vision) or varifocal (for close, mid-range and long-distance vision) lenses are prescribed. Convex are single vision lenses. Bifocals and varifocals are lenses which have different powers in their upper and lower halves (Fig. 1). The lower halves contain an reading addition, which is

$$x = (1/y) - (z/2) \quad (1)$$

where x stands for the reading addition (in diopters), y stands for the reading distance (in meters) and z stands for the amplitude of accommodation (in diopters). [13]

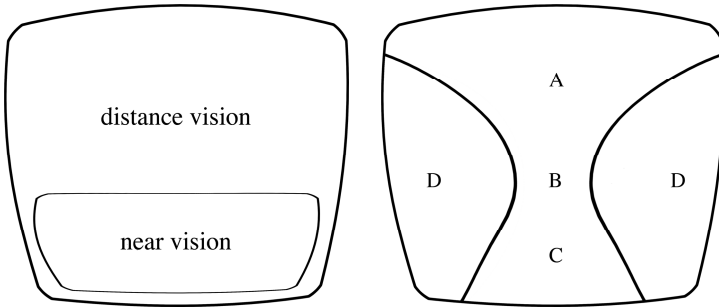


Fig. 1. Bifocal (on the left) and varifocal (on the right) lenses. Note the areas designed for long-distance (A), mid-range (B) and near (C) vision in the varifocal lens and its unwanted peripheral astigmatism (D).

Unlike bifocals, varifocal lenses have no visible dividing lines between the different corrections. Instead, they have a graduated section in which the power of the lens progresses smoothly from one prescription to the other, allowing the wearer to see clearly at all distances. They are not only intended to give the subject a clear vision of nearby and far objects (what is easily obtained with bifocal lenses), but also of objects situated at intermediate distances. However, in order to achieve that effect, any lens with multifocal optics comes with unwanted peripheral astigmatism. [14]

In correcting the vision of VDT users, it is of primary importance to remember that the viewing distance for VDT images is usually greater — in the neighborhood of 48 to 65 cm — than the distance for reading hard copy. [15]

Two years before, when the first glasses were prescribed, the old glasses' lenses provided clear vision for far, intermediate-distance and near objects. As the years went by, the patient became more presbyopic — or, in other words, her glasses could provide her clear vision of far and mean-distance objects only. And, to achieve that (focus intermediate-distance objects, such as the VDT), she had to look through the lower third of the lenses. Doing that, she had to tilt her head back extending her neck.

When the support was added, she had to extend her neck even more — worsening the pain.

Possible solutions for the uncomfortable head position adopted by those wearing bifocals or varifocals to view the screen through the appropriate portion of the lens include lowering the screen or prescribing a separate pair of single vision spectacles adjusted for the VDT viewing distance. [16]

In this case, just wearing new multifocal lenses with an adequate reading addition provided the worker comfort.

4 Summary

This case enforces both the importance of the Occupational Physician evaluation as well as the necessity of assuming a holistic approach of the individual and his workplace, taking account of workstation design, workpractices and psychological factors as well as optometric data when establishing an ergonomic intervention.

As recommended by the World Health Organization [17] all VDT operators beyond age 40 years should have eye examinations — including both refraction and visual acuity — by examiners trained in visual ergonomics, especially for persons who report musculoskeletal or eyestrain symptoms.

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Performance Monitoring, Supervisory Support, and Job Characteristics and Their Impact on Employee Well-Being Amongst Four Samples of Call Centre Agents in South Africa

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Abstract. This paper reports a descriptive comparison of selected aspects of work experience reflected by four groups of employees drawn from four contrasting call center environments based in the Gauteng Province of South Africa. The call centers were selected as representing distinct business and management practices in terms of the envisioned market and the service model enacted within each call center. Participants were call center agents who completed a questionnaire survey of aspects of their work life experiences and context free life satisfaction. In addition, interviews were conducted with supervisors in each call center to assess supervisory practice, and some follow up interviews were conducted with call centre agents. Findings do not fit neatly into a Tayloristic-Empowerment continuum, but rather point to a more complex balance between the unfavorable work demands experienced and wider feelings of self worth. Implications for job design and enhanced well being are summarized.

Keywords: Call Centers. Job Design. Electronic Performance Monitoring. Well-Being.

1 Introduction

South African management practices have a historic disposition towards control and Taylorism, as part of the practice and legacy of apartheid social structuring and education [1]. The emphasis on production and control has been largely shaped by the need to harness a low skilled, poorly educated workforce by breaking work down into manageable units and retaining strong supervisory direction. This historic disposition creates vulnerability that technologies like those that underpin call centres will follow what has been termed the mass service call centre model [2]. In this classification call centre management and work demands can be placed on a continuum from 'Tayloristic' at one end, to 'Empowerment' at the other [3]. Low skill levels, highly repetitive tasks and monotony characterise Tayloristic call centre work environments, whilst Empowered call centre environments involve professionals who have a high

level of job control and varied skill demands. The general assumption is that as the work environment migrates to the Tayloristic end of the continuum it will re-percuss in poor feelings of satisfaction and well-being on the part of employees, whilst Empowered work environments should evoke greater feelings of satisfaction accomplishment and self worth [4].

The usual connotation with the Tayloristic-Empowerment continuum is that at the Empowerment end, call center agents will possess a higher level of education or technical qualification or skill and will be engaged in more flexible interaction with callers; practicing their skills over a wide range of problems and being challenged to extend their problem solving skills as a consequence of this richer engagement of clients' problems. At the Tayloristic end of the continuum, caller-agent exchanges are brief and highly structured; often agents work from pre prepared scripts on the presumption that caller questions and problems are highly standardised. When unusual problems are presented by callers, the expectation is that these should be referred to supervisors or another better qualified colleague. Little encouragement is given to interaction with co-workers and enhanced problem solving strategies is not encouraged. The emphasis is on high volume, short duration interactions with clients.

However this neat conceptualisation is not so clear cut [5]. Some massed service call centers adopt practices that in this conceptualisation would be associated with the high commitment work practices normally associated with the Empowerment end of the continuum, whilst some high commitment service call centers adopt mass market high intensity monitoring [6] [7].

Our interest in this research is to see whether the latent scientific management appeal that call center technology might have to the South African tradition of control and authority manifests itself in the adoption of supervisory and management practices so widely associated with massed service model – even though the nature of the call center business more reflects the needs of a high service model.

This paper reports research conducted in four call centers drawn from four contrasting organisations in Gauteng, South Africa. Each call centre represents a contrasting use of call center technology in that they occupy a different role in their organisation's business model and client servicing strategy. Two of the call centers are directed at servicing the technical needs of retail clients, one directed at trade clients (Call Center A; n=27), one directed at retail clients (Call Center B; n=38), and these represent the Empowerment end of the continuum. The other two are directed at mass volume client service. Both are in the financial services sector. One of these has structured their employee-client interaction on the basis of prepared scripts (Call Center D; n=33), whilst the other does not (Call Center C; n=42) and these represent the Tayloristic end of the continuum. Thus, based on the parameters of the likely need to use flexibility of knowledge in problem solving as part of agent-customer interactions, a reasonable expectation in terms of levels of control and regulation in work design would be $A < B < C < D$.

Details of these samples are set out in section 4 of this paper which presents a summary of the main findings.

2 Aim

The aim of the present research is, using the inherent contrasts in work design presented by the four call centers, to measure, describe and compare the relationships between the key job design features of performance monitoring, supervisory support, the role of performance feedback, and the dimensions of work as assessed by the Job Characteristics Inventory subscales of Skill Variety, Autonomy, Task Identity, Feedback, Dealing with Others, and Friendship Opportunities and dependent measures of employee well-being as characterized by the work related measures of Intrinsic and Extrinsic Job Satisfaction, and the context free measures of well-being of Life Satisfaction and Self Esteem.

3 Methodology

Agents in each call center were volunteer participants and were asked to take part in the study, in full confidentiality and anonymity, by completing a questionnaire that comprised the following sections;

3.1 Biographic Information

Biographic information collected consisted of answers to specified questions about age (in years), sex, marital status, number of dependents, employment history (including tenure in the present job), and education attainment.

3.2 Job Design

Respondents were asked to complete a set of sub sections on the questionnaire to allow identification of core characteristics of their current job. All Items were responded to using a five point scale. The sub sections were;

Performance Monitoring. Respondents' satisfaction with performance monitoring was measured using the Satisfaction with Computer Monitoring Scale [8] Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.86.

Supervisory Support. Respondents' satisfaction with their level of perceived supervisory support was measured using items 4, 12, 17 and 24 from Module 5 of the Michigan Organisational Assessment Questionnaire [9]. Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.78.

Performance Feedback. Respondents' experiences as to whether the feedback that they receive from their supervisors was constructive, formative/ developmental and, supportive was measured using a three item scale developed for the purpose, thereby being more focussed than items in the Supervisory support and JCI measures. Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.89.

Consultation about Job Content. Respondents' satisfaction with extent, frequency and type of consultation about job content was measured using a three item scale

developed for the purpose, thereby being more focussed that items in the Supervisory support and JCI measures. Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.80.

Consultation about Technology Purchase. Respondents' satisfaction with the extent, timing and type of consultation about the purchase of the call center technology that they use was measured using a three item scale developed for the purpose. Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.67.

Job Characteristics. Respondents' feelings about the content of their job was assessed using the six dimensions of the Job Characteristics Inventory [10] Cronbach's alpha coefficient for the combined samples in this study for the global measure was 0.78;

Skill Variety (the extent to which a job requires a variety of employee competencies to carry it out), Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.71;

Task Identity (the extent to which the job requires an employee to complete a whole piece of work from start to finish), Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.68;

Autonomy (the extent to which the employee has discretion in carrying out tasks), Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.75;

Dealing with Others (the degree to which the job requires employees to deal with others to complete tasks), Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.81;

Friendship Opportunities (the degree to which the job requires employees to talk with one another on the job and establish informal relationships with other employees at work), Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.77;

Feedback. The degree to which employees receive information as they work which reveals how well they are performing their tasks), Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.69.

3.3 Well-Being

Respondents were then asked to complete a set of sub sections of the questionnaire to allow assessment of three different aspects of their well-being. Again, all Items were responded to using a five point scale. The sub sections were;

Job Satisfaction. This was assessed by using the Global Job Satisfaction Scale [11] and the integral measures of Intrinsic and Extrinsic Job Satisfaction. Cronbach's alpha coefficient for the combined samples in this study for the global measure was 0.87.

Life Satisfaction. This was assessed by using the Satisfaction with Life Scale [12]. Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.82.

Self Esteem. This was assessed by using Self Esteem Scale [13]. Cronbach's alpha coefficient for the combined samples in this study for the measure was 0.90.

3.4 Interviews

In addition two sets of short, semi-structured interviews were conducted; one set with supervisors at each participating call center and the other set as follow up interviews with a small sub-set of participating call center agents.

Interviews with Supervisors. These were conducted to ascertain their judgement of; their role as supervisor, the planned and intended use of performance monitoring data, the use of feedback of performance data to call center agents, and their judgement about the general quality of work life for call center agents in their call center.

Interviews with Call Center Agents. Supplementary post questionnaire follow up interviews were conducted with sub samples of participant call center agents at each of the four call centres to add to the researchers' general understanding of work demands and experiences.

3.5 History and Local History Effects

In order to minimise history effects and local history effects [14], all data gathering took place during a period of four months characterised by economic growth and high business confidence. None of the participating organisations had recently been involved in take-overs, mergers, downsizing exercises or other large-scale events that might shape the general outlook to job experiences and work related well-being. All participants were informed of the outcomes of the research.

4 Findings

As can be appreciated, the procedure yielded a mass of data; much of which, though of value in characterising the sample need not be reported here. Rather the principle findings are summarised in the following sections.

4.1 Biographical Data

Notable are the similarities in age and tenure across call centers (standard deviations and ranges not reported here) but there are sizable differences in employment history, with technical service call center (A and B) employees having had shorter working lives and fewer previous jobs.

Technical service call centers samples (A and B) were male dominated, with fewer married and smaller numbers of dependents. Mass service call centers (C and D) reflected a broadly equal number of males and females, with an equal proportion of married and number of dependents (not reported here). Educational qualifications

Table 1. Biographic data (main data only)

Variable	Call Center			
	A(n=27)	B(n=38)	C(n=42)	D(n=33)
Age (Years)	26.4	24.3	28.4	27.9
Work Exp. (Years)	6.2	5.1	10.6	10.1
Tenure (Years)	3.7	3.0	4.2	4.3
Sex (% Female)	6	11	62	58
Married/ Partner (%)	17	12	76	69

were patterned differently with technical service call centers preferring staff with a national technical certificate background whilst mass service call centers showing a higher level of matriculated employees (84%) and a high proportion (27%) of graduates in the samples.

4.2 Interviews with Supervisors

Supervisor interviews revealed that each in each of the four call centers, irrespective of the core focus of the business, supervisors reflected the view that their engagement with agents was supportive, concerned with staff development and productivity as equal priority, that performance monitoring was as much for staff development as it was for quality assurance and meeting productivity goals, and performance feedback was supportive, developmental and “correctional”.

For all four call centers, supervisor’s views of the quality of work life for the agents working in their call center were of being generally challenging but rewarding.

4.3 Job Design

In terms of the job design variables, Table 2 sets out the means and standard deviations for each variable. Despite the differences in means, usually in the expected direction, Kruskal-Wallis one-way analysis of variance by ranks [15] revealed no statistically significant differences across the four call centers ($p>.05$).

Technical service call centers reflected slightly higher perceptions of Skill Variety, Autonomy, Task Identity, and Friendship Opportunities. Dealing with Others showed no differences (either meaningful or statistical). Similarly, no differences emerged between feelings of uniformly low Supervisory Support, feelings of punitive feedback, feelings of excessive performance monitoring, and very low feelings of consultation over job content and technology purchase.

4.4 Well-Being Variables

In terms of the data derived from measuring the outcome or impact variables associated with well-being, table 3 sets out the means and standard deviations for Job Satisfaction, Life Satisfaction and Self Esteem.

Table 2. Job design data

Variable	Call Center			
	A(n=27)	B(n=38)	C(n=42)	D(n=33)
[Means (Std.Dev.)]				
Performance Monitoring	1.9 (0.4)	2.1 (0.3)	1.6 (0.7)	1.4 (0.3)
Supervisory Support	1.4 (0.3)	1.7 (0.5)	1.1 (0.9)	1.0 (0.4)
Performance Feedback	1.6 (0.6)	1.9 (0.7)	1.5 (0.7)	1.4 (0.3)
Consultation about Job	1.2 (0.3)	1.2 (0.4)	1.0 (0.1)	1.0 (0.2)
Consultation about Technology	1.3 (0.2)	1.1 (0.3)	1.0 (0.1)	1.0 (0.1)
JCI				
Skill	2.5 (0.4)	2.7 (0.6)	2.1 (0.8)	2.2 (0.9)
Task Variety	2.8 (0.9)	2.9 (0.8)	2.4 (0.9)	2.0 (1.0)
Autonomy	2.9 (1.0)	3.0 (1.1)	2.2 (0.9)	1.9 (0.9)
Dealing with Others	2.6 (0.9)	2.8 (0.9)	2.6 (0.5)	2.4 (0.9)
Friendship Opportunities	2.9 (1.1)	3.1 (1.2)	2.2 (0.9)	2.0 (0.8)
Feedback	2.4 (0.5)	2.9 (0.7)	2.6 (0.6)	2.3 (0.4)

Table 3. Well-being data

Variable	Call Center			
	A(n=27)	B(n=38)	C(n=42)	D(n=33)
[Means (Std.Dev.)]				
Intrinsic Job Satisfaction	2.8 (0.9)	2.7 (0.9)	2.6 (0.7)	2.5 (0.9)
Extrinsic Job Satisfaction	3.2 (0.9)	3.3 (0.8)	2.9 (0.9)	2.8 (1.0)
Life Satisfaction	3.5 (1.1)	3.4 (0.9)	3.6 (1.2)	3.5 (1.1)
Self Esteem	3.8 (0.9)	4.0 (0.7)	3.8 (0.8)	3.7 (0.8)

Once again, despite the differences in means, again, usually in the expected direction, Kruskal-Wallis one-way analysis of variance by ranks [15] revealed no statistically significant differences across the four call centers ($p > .05$).

There was no meaningful or statistical difference in moderate levels of extrinsic job satisfaction, but, though not statistically significant, intrinsic job satisfaction was higher for technical call centres and lowest, together with skill variety, autonomy and task identity, for the script directed mass service call centre.

There was no difference between good positive levels of self-esteem across all four groups. However relationships (correlation coefficients not reported here) between Job Satisfaction, Life Satisfaction and Self-Esteem were not significantly different between groups, suggesting a similar pattern of context free self worth for each group.

4.5 Supplementary Interviews

The general findings were consistent with follow up interviews with sub samples of call center agents who had participated in the questionnaire study. Most insightful

answers came in response to questions directed at the supportive developmental role of performance feedback and the role of the supervisor. One such response, taken from an agent working in call center D, the scripted mass service center was;

“I don’t generally see my supervisor to talk to unless she wants to moan at me. When she comes over or calls me over it’s to tell me that I’m not taking enough calls or I’m too slow. She doesn’t need to tell me this. I know this because she wants now to talk to me.”

An agent from call center B, adds to the insight when asked about the same aspects of their relationship with his supervisor and performance feedback by this statement;

“We are supposed to get regular feedback on our performance – once a week we are supposed to meet as a group – but we are not allowed to log off together so we never meet as a group. Every week we are shown the computer times for our calls, and that kind of thing. I don’t memorise mine. I just get on with what I do.”

An agent from call center A (servicing the technical needs of retail clients), when asked about the level of consultation over the job content or about the technical equipment used, had the following observation;

“I was once asked about the little ear plug and mike stuff. But it didn’t make any difference because we got the ones that no one liked. Mostly we are expected to get on with it. That’s all.”

5 Discussion and Concluding Comments

The findings present a picture of close supervisory control and performance monitoring common to each call center. Interview data points to a gulf between what supervisors portray – at least to interviewers from an academic institution – and their practices; at least as reflected by the low mean scores and small standard deviations of all key questionnaire data, as well as the more robust comments of the sub sample of agents interviewed.

Agents typically reflect responses that indicate, low skill variety, even in the high commitment service call centers (A and B), with each of the four samples of agents reflecting modest to low feelings of autonomy and task identity.

Feelings of Job Satisfaction, and the context free measures of Life Satisfaction and Self Esteem, show good to strong positive feelings amongst agents from all four call centers. The findings do not fit neatly into the Tayloristic – Empowerment continuum but point to individuals being able to form a dissociation or recognition that although they work in an unfavourable work environment – one in which self-actualisation might not be a deliberate or sought after goal – it does not negate the larger feelings of self worth that come from doing a dispiriting job to the best of ones’ abilities.

Moreover, though the levels of Intrinsic Job Satisfaction are moderate, the higher levels of Extrinsic Job Satisfaction across all four call centers suggest that the extrinsic value of work, together with other aspects of life, reinforce the feelings of self worth. It must also be considered that, at the time that the research was conducted, the South African domestic economy was in expansion, yet unemployment rates amongst the less well educated are high. In such times, having a job is prestige, and of itself fuels self belief and self worth.

Findings show support for the view that the pervasive application of call centre technology in South Africa attracts a managerial and supervisory disposition that is Tayloristic in its root and this seems to be so whether the conceptual service model is of the massed market type or high commitment service type.

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Mechanisms for Work Related Disorders Among Computer Workers

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Abstract. Work related musculoskeletal disorders are common among computer workers, especially in the neck/shoulder region and the upper extremities. The relation between physical and psychosocial work load and generation of pain is still unclear. In this paper we describe five models. According to the often addressed Cinderella hypothesis, the pain is due to an overuse of low threshold muscle fibres. In a series of studies including intramuscular electromyography from the trapezius muscle, we have found several motor units that were active throughout coarse arm movements, during prolonged computer work tasks, and in both voluntary and stress induced contractions. Furthermore we have seen that motor unit statistics varies significantly between repeated measurements in one individual, hence the method would be inappropriate for group comparisons. Finally, we discuss a model based on a general model, literature studies, and own research.

Keywords: Mechanisms, chronic pain, Cinderella hypothesis, intramuscular electromyography, motor units, trapezius muscle.

1 Introduction

Work related musculoskeletal disorders are common among computer workers, especially in the neck/shoulder region and the upper extremities [1, 2]. The work tasks are often monotonous, and the muscle loads are normally relatively low and static. Although the question of how the pain is generated has been in focus in several research projects, there is still not one model that is generally accepted or proven. Instead the research has lead to several suggestions of mechanisms (for recent reviews see [3-5]). In this paper we shortly described proposed models for the generation of pain among i.a. computer workers. Then, we summarise our own work concerning the Cinderella hypothesis. Finally, we discuss a model based on a general model [6], literature studies, and own research.

2 Models for Pain Generation

In this chapter, five models for pain generation are described. They are all assuming the causes of static work at low muscular load, and cognitive tasks/psychosocial work factors as the original sources for the pain generation.

2.1 The Blood Vessel-Nociceptor Interaction Hypothesis

According to a model proposed by Knardahl [7], the pain may originate from nociceptive interactions (stimulation of pain receptors) in the connective blood vessels that supply the muscle fibres. Three potential mechanisms may interact: (1) extraction of blood vessels (vasodilatation), (2) vascular production of pain producing substances, e.g. prostaglandins and nitric oxide, and (3) blood vessel inflammation. Concerning (1), Knardahl refers to an association between vasodilatation and pain in migraine patients, and on the pain effect of different vasodilating drugs.

2.2 The Hyperventilation Theory

A hyperventilation theory was developed by Schleifer and co-workers [8]; hyperventilation causes a drop in arterial CO_2 , which causes a decrease of carbonic acid in the blood, which results in respiratory alkalosis, i.e. a rise in plasma pH above 7.45. This disruption in acid-base equilibrium will then in turn trigger a neuronal excitation, causing increased muscle tension and muscle spasms, with adverse effects for muscle tissue health. In support of the model, Schleifer and Ley [9] found low end-tidal CO_2 during sustained repetitive computer work, and with discrimination between high and low mental demands.

2.3 The Vicious Circle Hypothesis

A model describing the genesis and spread of muscular tension in patients with musculoskeletal pain syndromes was suggested by Johansson and Sojka [10], and further developed by Johansson [11] and Bergenheim [12]; a repetitive, static muscle contraction (in primary muscles) causes a production of metabolites, which activates gamma-motoneurons projecting to both primary and secondary muscles. This activation increases the static and dynamic stretch sensitivity and discharges of primary and secondary muscle spindle afferents (MSA). The increased primary and secondary MSA activities will increase the reflex-mediated component of the muscle stiffness, which in turn causes a further production of metabolites in primary and secondary muscles. An increased primary MSA activity will also hamper the proprioception, which could possibly lead to increased co-contractions. The result is a vicious circle that spreads and increases the sensations of pain throughout a body region.

There are e.g. proprioception-studies that support the hypothesis as well studies that contradict parts of the model.

2.4 The Nitric Oxide/Oxygen Ratio Hypothesis

Eriksen [13] assumes that neck myalgia is evoked when low-level contractions in the trapezius muscle are combined with psychological stress or prolonged head-down neck flexion at work; increased sympathetic nerve activity leads to arterial

vasoconstriction, which causes reduced capillary flow and reduced intracellular O_2 in the skeletal muscle. The sympathetic vasoconstriction seems to be preserved as long as the muscle activity is of low intensity. The vasoconstriction will also reduce the vascular removal of NO produced during the muscle fibre excitation-contraction process. A sharp rise in the NO to O_2 -ratio will occur, which via biochemical processes will cause myalgic pain.

2.5 The Cinderella Hypothesis

The pain may be due to an overuse of low threshold muscle fibres causing damage at the muscle cell level. These fibres belong to low threshold motor units (MUs), which are recruited at the onset of muscle activation and which are firing continuously until the muscle is relaxed completely. This so-called Cinderella hypothesis [14,15] is based on a prescribed MU recruitment and de-recruitment size-principle order [16] and is supported by findings from cell morphology studies in myalgic muscles.

3 Our Own Investigations of the Possibility for the Cinderella Hypothesis to Explain the Pain Generation

When the Cinderella hypothesis was formulated the empirical data were taken from experiments including short term static contractions. One condition, among others, that should be met for the hypothesis to be accepted is that there are MUs that are continuously active under occupationally relevant conditions. Our group has in a series of experiments including intramuscular electromyography (EMG) from the trapezius muscle investigated the presence of continuously active low-threshold MUs.

We have also investigated the reproducibility of the method and its possibility to e.g. to be used in future studies comparing Cinderella MUs in different populations, for example in pain and no pain groups.

3.1 Intramuscular Electromyography in Experiments

Electrodes made of 0.05 mm diameter Teflon isolated stainless steel wires were used for intramuscular EMG from the right trapezius muscle. Figure 1 shows the setup in an experiment of computer work. A semi-automatic classification program was used for MUAP decomposition [e.g. 3, 17]. It utilises the entire signal complexes in each channel and compares MUAP morphologies. The algorithm has been developed facilitate tracing of MUAP that change shape over time. All experiments were carried out with the subject sitting in a chair. Maximal voluntary surface electromyographic activity (MVE) were measured in the end of the experiments.

In the reproducibility tests, MU activity from two neighbouring measurement points was measured in three repetitions (with at least two weeks in between) of 20-minute static contractions (trapezius) in 12 subjects. The intra- and inter subject variability in terms of e.g. number of C MUs was analysed.

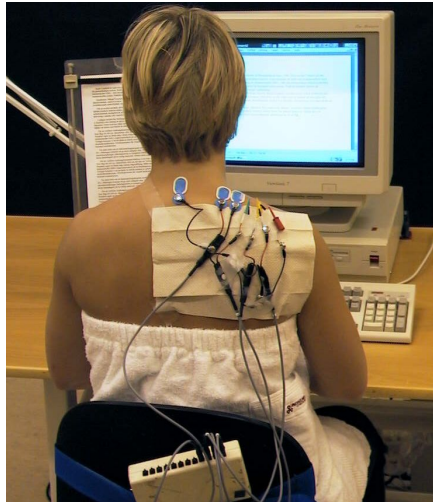


Fig. 1. The experimental set-up in a study of computer work

3.2 Results from Our Intramuscular Experiments

In our experiments including intramuscular EMG, we found motor units (MUs) in very small pick-up volumes, which were active throughout coarse arm movements, at different movement speeds [18]. In a study including mental stressors, we found, in 12 out of 14 subjects, MUs that were active both in voluntary and stress induced contractions (Lundberg et al 2002). In an other experiment including one hour of static low level contraction we found in 3 out of 8 subjects MUs that were continuously active the full hour [17]. Also in one hour computer work there were MUs active for one hour [20]. In most of the experiments there were a close relation between continuous MU activity and a static surface EMG level.

In the reproducibility tests, the intra-subject variances were very high for all MU parameters studied, which indicates low test-retest repeatability. Averaging MU activity results from two measurement points only moderately decreased the variances.

4 Discussion

In our own studies, we have found continuous MU activity (and “substitution”) not only in a large variety of pure lab experiments, but also in 1h-computer work sessions. The findings support the Cinderella hypothesis, but they do not represent a final proof. The link from continuous MU activity to pain generation needs still to be further investigated.

The findings of the reproducibility tests show that decomposition of intramuscular wire EMG is an inappropriate technique for comparative studies between groups of individuals and that intra-subject comparisons should be restricted to the same recording point and test occasion.

Each one of the mentioned hypotheses may serve as a relevant explanation for, or contribute to, the mechanisms behind muscle pain in the context of computer work, i.e. monotonous work often under stressful conditions. But none is yet generally accepted. There are additional hypotheses suggested in the literature [4].

The nitric oxide/oxygen ratio hypothesis is still “young”; instead of traditionally hampered blood macrocirculation, it concerns insufficient blood supply on an active muscle fibre level. Since insufficient muscle fibre rest will intensify and speed up this mechanism, there might be a connection between this model and the implications of the Cinderella hypothesis. Findings of mitochondrial disturbances and reduced capillarisation in women may, together with our own findings of continuous and sustained MU activity, support the theory that prolonged low-level workloads and psychological stress lead to localised muscle cell ischemia and lactic acid evoked muscle pain, as described by Eriksen [13].

We here propose a pathway (also described in [3]) between computer workloads and chronic muscle pain. It is based on the more general model proposed by Winkel and Westgaard [6], is schematically described in Figure 2. In many aspects, this pathway independently resembles the conclusions given in a recent review article by Visser and van Dieën [4].

Computer work is often characterised by prolonged, monotonous tasks and with low physical demands. These external exposures can lead to an internal exposure of prolonged low-level muscular activity with few periods of muscle rest. Computer work may also include psychological stress. This exposure primarily lead to an internal exposure/response of mental strain and secondarily to prolonged low-level muscular activity with few periods of muscle rest.

We saw, as described, that prolonged low-level muscular activity and few periods of muscular rest can lead to continuous and sustained activity of selective MUs. As a reaction to the induced mental strain, sympathetic nerve activity may be increased, leading to arterial vasoconstriction and reduced capillary flow, and since the muscular activity is of a low-level character, this sympathetic vasoconstriction can be preserved [21]. That is, a combination of low-level muscular activity and induced mental strain can lead to prolonged vasoconstriction. Furthermore, during low-level muscular activity, the K^+ concentration is maintained close to the resting level [22]. Release of intracellular K^+ is one important feedback mechanism in fatigue [23]. Thus, low-level muscular activity can lead to an absence of muscular fatigue perception.

The continuous and sustained MU activity may constitute, together with the prolonged vasoconstriction, a risk for localised ischemia in selective muscle fibres. Localised ischemia may, via mitochondrial deficiencies, lead to ATP insufficiency and lactic acid evoked muscle pain [13]. An insufficiency of ATP may also affect the homeostasis of Ca^{2+} released from the sarcoplasmic reticulum during the muscle fibre excitation-contraction phase [23], leading to skeletal muscle damage; [24, 25]. Thus, the combination of continuous, sustained MU activity and prolonged vasoconstriction may, via an acutely impaired energy metabolism for selective muscle fibres, lead to a production of nociceptives and acute muscle pain.

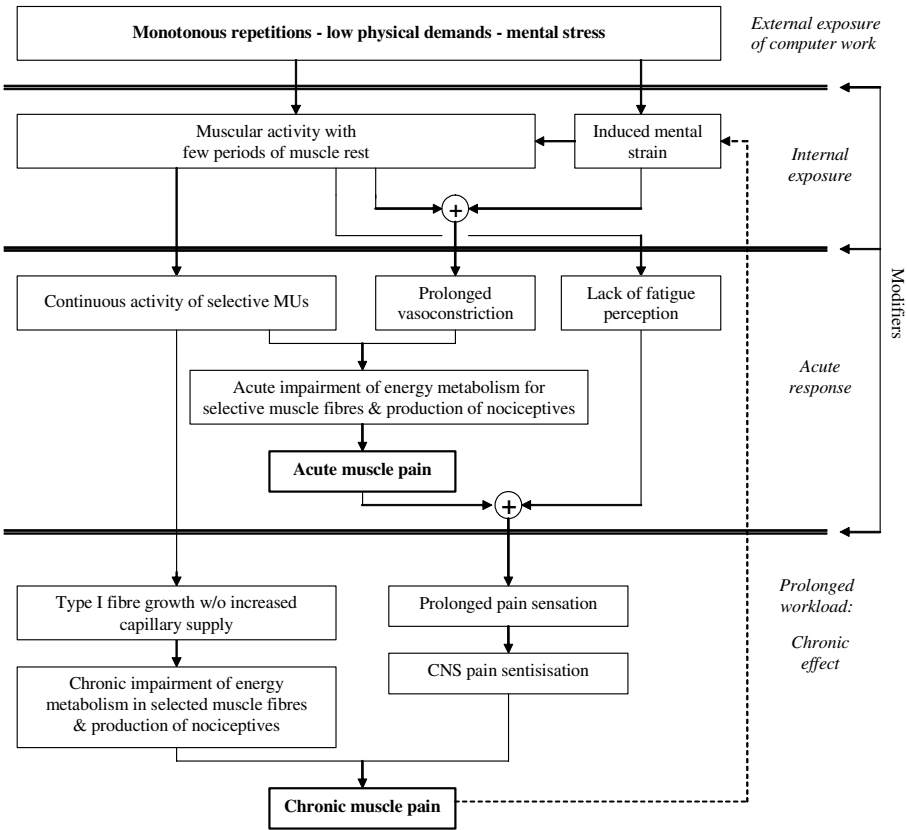


Fig. 2. Proposed pathway between computer work and chronic muscle pain. Double lines indicate areas susceptible to modifiers, e.g. individual factors. The dashed line indicates a feedback loop.

Two ways to chronic pain are suggested, in the case that the workload described above is prolonged. First, there is a risk that an acute pain sensation is prolonged, especially as a perception of muscular fatigue may not be present. Eventually, the prolonged acute pain sensation can, via CNS pain sensitisation, turn into a chronic pain behaviour [26], which does not necessarily need pain stimuli to be maintained. Second, a prolonged workload can also lead to a growth of type I muscle fibres without increased capillary supply, as inferred by Hägg [15]. This is supported by findings of deteriorated microcirculation of blood through specific muscle fibres [27-29], in myalgic trapezius muscles. Rosendal [30] demonstrated that trapezius myalgia was associated with locally increased anaerobic metabolism and increased levels of substances potentially activating peripheral nociceptive processes. Thus, a prolonged workload may, through type I fibre growth and deteriorated microcirculation, lead to a chronic impairment of energy metabolism in selected muscle fibres, production of nociceptives and chronic muscle pain.

Finally, a chronic pain may induce feedback loops that potentially aggravate muscle pain further. Musculoskeletal complaints may also increase the motor response to psychological stress, decreasing the muscle rest [31].

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Do Background Luminance Levels or Character Size Effect the Eye Blink Rate During Visual Display Unit (VDU) Work – Comparing Young Adults with Presbyopes?

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Abstract. Eye blink rate for 19 healthy young adult volunteers (non-presbyopic) (15 females, 4 males; mean age 21.1, SD 5.9 years, range 19 to 29 years) were measured while working at an optimised VDU work station with two different character sizes (8 and 12 points Times New Roman). Two background luminance levels (approx. 100 cd/m² and 6000 cd/m²) were used as glare sources. A marked reduction in eye blink rate from approx. 24 blinks per minute during easy conversation in between VDU work sessions to approx. 5 blinks per minute during active visually demanding VDU work was found. The results were compared with the results from a previous similar study on 16 healthy presbyopic volunteers (8 females, 8 males; mean age 57.1 SD 7.2 years, range 46 to 67 years) [1]. For both groups a marked reduction in eye blink rate was found for VDU work compared with a rest situation. This was true whether the character size on the screen was “normal” (12 points) or fairly small (8 points), or whether the work was done under good and recommended visual conditions, or under a glare situation.

Keywords: VDU-work, eye blink rate, luminance levels, character size.

1 Introduction

The objective of this study was to determine if glare from the surroundings of a VDU and the size of the characters used on the screen influenced the users eye blink rate. In a former study it was shown that in a group of presbyopic workers (mean age 57.1 years), an introduction of a moderate glare source in the surroundings of the VDU screen and the use of small characters (8 points), did not have a great influence on the eye blink rate while performing VDU work [1]. However, studies have shown that lighting conditions and optometric corrections are important factors in reducing visual discomfort [2]. The effect of optometric corrections on visual discomfort and musculoskeletal pain in VDU workers is also documented by

Horgen and Aarås [3]. Glare has significant correlations to eye focusing problems and tired eyes [4]. The recommendations in Norway are that the ratio of luminance contrast distribution in the work area, near surroundings and periphery, should not exceed 1:3:10, and that maximum luminance contrast in the visible field should not exceed 1:20 [5]. In a laboratory study by Sheedy and Bailey [6], glare from a luminarie in the upper visual field was examined. Subjective rating of light discomfort was strongly related to the luminance level of the glare source. Further, the glare magnitude was significantly related to asthenopic symptoms ($p=0.004$) and musculoskeletal symptoms ($p=0.017$). In field studies, and during interviews of VDU-workers at their own workplace, the authors of this paper very often see a worktable and computer placement where the screen either is placed in front of the window, or in the corner of the office with a window close to the screen. This may increase the risk of glare problems. We also frequently experience that VDU-workers, in particular if young of age, select a combination of screen resolution and character size resulting in very small details on the computer screen. This seems to be driven by a desire of including as much information as possible at the screen at any given moment, instead of having easily legible text and numbers. However, the latter situation may require more switching between different screens/programs.

2 Aims of the Study

The purpose of this study was to determine how glare from the near surroundings of a VDU, and reduced character size on the screen, influence the operators eye blink rate among optimally visually corrected young VDU-users. Further, to compare the results for young non-presbyopic VDU-users with the results from a group of optimally visually corrected presbyopes evaluated in a former study. For this group all demonstrated a marked drop in the eye blink rate for all test situations [1].

3 Design of the Study

The lowest luminance level of the surroundings of the screen (70 to 100 cd/m^2), and the normal size of the characters on the screen, (12 points New Roman), were defined as baseline. This baseline was recorded for each participant at the start and the end of the trial. The mean of these two measurements was used as a baseline in the statistical analysis [3]. The combination of high luminance/normal character size, high luminance/small character size and low luminance/small character size was tested according to a 3×3 orthogonal Latin square design [7]. Independent variables were the different luminance levels and the different sizes of the characters on the screen; the dependent variable was eye blink rate.

4 Materials and Methods

4.1 Subject Population

The young group consisted of 19 healthy student volunteers recruited from Buskerud University College (15 females, 4 males; mean age 21.1, SD 5.9 years, range 19 to 29 years). The eye blink rate for the non-presbyopic group were compared with the results from the presbyopic group from the previous study of 16 healthy presbyopic volunteers (8 females, 8 males; mean age 57.1 SD 7.2 years, range 46 to 67 years) [1]. All subjects gave informed consent to a protocol approved by Buskerud University College, and were free to withdraw from the study at any time, giving no reason. All subjects were experienced VDU-users, using computers daily as part of their work.

Inclusion Criteria. All subjects had a minimum distant and near best corrected binocular visual acuity of 1.0 (6/6 or 20/20) and normal eye status at the optometric examination.

Exclusion Criteria. Spectacle correction stronger than ± 6.00 DS (spherical equivalent), having active eye disease, or systemic disease with eye complications. Subjects with known anterior eye segment diseases like conjunctivitis, Sjögren's Sydrome, blepharitis etc., and subjects who had any evidence of tear film abnormalities were also excluded. Furthermore, subjects taking drugs that might influence either eye functions or muscle functions were also excluded.

4.2 Illuminance and Luminance

Two "glare" luminaries made up of an translucent acrylic diffusing fronts of 1.25 m $\times$ 0.57 m, equipped each with six 60 W fluorescent tubes, were placed behind and a little to the side of the computer screen. This was to simulate a VDU-screen placement in an office, with a window behind or near the screen. The intensity of the luminance was higher for the young non-presbyopes than for the presbyopic group, because very little effect was seen from the 2000 cd/m² used in the previous study [1]. In this study 5500 – 6000 cd/m² (measured across the screen) was used because such values are closer to natural luminance levels from a window on a sunny day. The illumination level was approx. 300 lx on the work table. The lowest luminance level of the surroundings of the screen was between 70 and 100 cd/m². These levels occur most frequently for VDU-workers when the gaze direction is parallel to the window wall. The light measurements were done by a Hagner Universal Photometer – type S3.

4.3 The Workplace

The experiment was conducted at an optimised VDU workplace with forearm support on the tabletop [8, 9]. The seat height, table height and monitor/eye distance were all positioned in accordance with anthropometrical dimensions of the subject. The line of sight to the midpoint of the computer screen was adjusted to approximately 15° below

horizontal. A constant visual distance from the eyes to the midpoint of the screen was set to approximately 60 cm [10-12]. Two large “glare” luminaries were mounted vertically on the right side of the VDU, at approximately 45° horizontal angle from the sightline to the centre of the screen, simulating windows as they very often appear in a normal work station set up. All measurements took place in a 6.6 × 6.5 meters research laboratory with an air exchange of about 3.5 changes/h, but without any perceivable airflow (drafts). The temperature (mean 23° C) and relative air humidity (RH) levels (mean 36 %) were measured every 5 minutes during all registration sessions with a data logger (TinytagPlus). For any subject the range of temperature and humidity did not exceed more than $\pm 1^\circ\text{C}$ and $\pm 2\%$ RH. The test set up is shown in figure 1.



Fig. 1. The test set up, with workplace, glare source, and test person (to the right)

4.4 The Work Task

The work task was interactive work on the VDU screen. The VDU screen was a 15 inch LCD screen, with 1024 × 768 pixels resolution. Both the non-presbyopic and the presbyopic groups were investigated in relation to the use of two different character sizes (8 and 12 points Times New Roman), and two luminance levels (approx. 100 cd/m² and 6000 cd/m² for the young group, and approx. 100 cd/m² and 2000 cd/m² for the presbyopes) while working at an optimised VDU work station. The 12 points characters (capital letters 3 mm and small letters 2.2 mm in height) subtends a visual angle of approximately 16 minutes of arc for the capital letters, app. 12 minutes of arc for the small letters, when viewed at 62 cm distance. This represents a visual acuity demand of approximately 3 minutes of arc (2.5 for small letters), or 0.3 (6/18 or 20/60). This size is recommended for ordinary reading tasks, for subjects with visual acuity of 6/6 (20/20) or better. The 8 points characters (capital letters 2.4 mm and small letters 1.7 mm in height) subtend approximately 13 minutes of arc (capitals), and 9 minutes of arc (small letters) at 62 cm viewing distance. This represents a visual acuity demand of approximately 0.5 (6/12 or 20/40). This letter size is smaller than recommended for ordinary reading tasks. To support the selection of letter size, an interactive questionnaire were displayed at the website of the Norwegian Optometric Association. All visitors on the website were requested to measure the actual size of a capital letter as seen on their screen. They were recommended to use an ordinary ruler and estimate to the nearest tenth of a millimetre. This approach gives a realistic measure for the actual letter size seen on a VDU user's screen, since it is independent of screen resolution and image magnification. A total of 169 people responded. The results indicated that some VDU users select a screen/text setup resulting in letter size

down to approximately 1 millimetre. However, most responders had a preference giving capital letters around 3 millimetres of height. The work task was to read an English scientific text, not familiar to the participants, shown on the screen. All e's in the text should be marked and bolded using the computer mouse only. The higher luminance from the large surface luminaries may in this way affect the eye blink rate.

4.5 Measurement of Eye Blink Rate

To record and investigate the eye blink rate a digital video camera (Sony DCRTRV22) (figure 2) and a video editing program (Pinnacle Studio DV8) were used. An eye blink was defined as any major movement of the lids where the upper and lower lids actually touched each other, or a significant movement of the upper lid to partly or fully cover the pupil area. For each subject five consecutive 10 minutes sessions were recorded including rest periods of approx. 5 minutes in between each active task session. All videotapes were



Fig. 2. The video camera used to record eye blinking is seen below and to the left of the VDU-screen

later analysed by visual inspection while counting eye blinks using a mechanical counter. The counted number of eye blinks during each session was then converted to eyeblinks/min. Eye blinks were also counted during 3 to 5 minutes for the first break period in between session one and session two. The total number of eye blinks was then converted to eyeblinks/min. For most patients almost 100 % of the blinks were complete blinks. For this reason both complete and incomplete blinks were grouped together to give the blink rate per minute.

4.6 Test Duration

There were five test sections. Each section lasted 10 minutes of active recording, with a period of rest in between. The reason for 10 minutes active recording for each session is the recommendations by Mathiassen, who observed marginal information beyond approximately 10 minutes sampling of EMG of stereotyped work [13]. EMG measurements were done on the same subjects in parallel study both for the presbyopes [14], and for the young adults. The rest period was about 5 minutes.

According to Zaman and Doughty eyeblink monitoring of at least 3 minutes is required when assessing the spontaneous eye blink frequency in man [15]. The initial calibration procedure before the test sequences lasted about 90 minutes.

4.7 Optometric Examination

All subjects underwent an optometric eye examination some time before the investigation. Details of the procedures and criteria for correction are discussed elsewhere [16].

4.8 Background Factors

All participants were interviewed before inclusion in the study. During this interview, background factors such as age, gender, and extent and type of VDU work, as well as inclusion and exclusion criteria were discussed. The whole test procedure was explained for the participants.

5 Statistical Analysis

The study was set up with a Latin square design. The independent variables were the two different luminance levels and the two sizes of the characters. The dependent variable was eye blink rate. Results are given as group means with standard deviation and with confidence intervals (C.I.) based on the t-distribution. Comparison of the two groups was done by non-parametric tests (Mann-Whitney tests). Comparison within a group was done by using the non-parametric Wilcoxon Signed Rank test. Differences are considered statistical significant with a p-value <0.05 .

6 Results

Both young adults and presbyopes showed a marked and similar reduction in the eye blink rate during VDU work, compared with a rest situation. For the non-presbyopic young adults the mean blink rate was reduced from 23.9 (SD 11.1) eye blinks per minute during easy conversation to 4.4 (SD 3.3) blinks per minute during active visually demanding VDU work. For the presbyopes the average blink rate for rest periods was 24.7 (SD 13.3) eyeblinks per min and 5.0 (SD 4.9) blinks per min for visually demanding VDU work. The results are represented as group means with 95% C.I. in table 1 and figure 3.

No significant differences between the two groups were found. This was true whether the character size on the screen was “normal” or fairly small, and whether the work was done under good and recommended visual conditions, or with glare in the near surrounding of the screen.

Table 1. Mean spontaneous eye blink rate (blinks/minute) for all test situations (young/presbyopes)

	Baseline ^a	12 points With glare ^b	8 points Without glare ^b	8 points With glare ^b	“Rest” after first recording
Group Means	4.4/5.0	5.6/5.7	4.4/5.7	5.0/5.4	23.9/24.7
Standard Deviation	3.3/4.9	4.3/6.7	4.1/5.2	3.2/5.0	11.1/13.3

^a Baseline - the test situation with 12 points characters without glare, run before and after the three test situations in the Latin square design, were defined as baseline.

^b These three test situations were administered in a Latin square design.

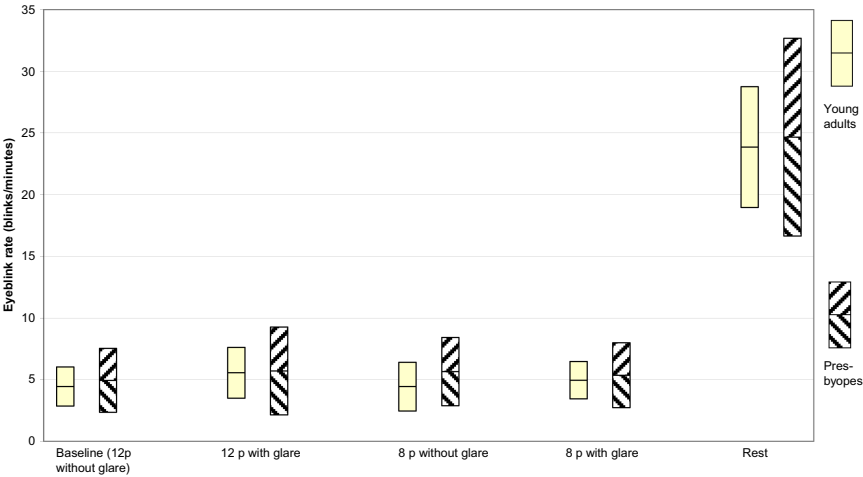


Fig. 3. Eye blink rate - results for both young adults and presbyopes as group means with 95% C.I.

7 Discussion

Normal and regular eye blinking is of uttermost importance to maintain the integrity of the ocular tear film, both to ensure optimal refractive properties of the anterior segment of the eye, and to prevent ocular discomfort. Blinking contributes to the maintenance of eye surface humidity, continuous rebuilding of the tear film structure into stable layers with unique protective and optical functions, and the drainage of the tears into the lacrimal drainage system. The human spontaneous eyeblink rate show considerable variability from 1.4 to 32.5 eyeblinks/min in different visual, mental and environmental conditions [17]. Typical blink frequencies at “rest” range from about 12 to 20 eyeblinks/min. In one study on 150 healthy volunteers the mean eyeblink rate at rest was 17 eyeblinks/min [18]. However, for the same group of subjects the eyeblink rate increased to 26 eyeblinks/min during conversation, and was as low as 4.5 while reading. The age of the subjects ranged from 5 to 87 years, but no

age-related differences were found. In an other study on 41 grown up subjects the eyeblink rate during silence was 19.0 eyeblinks/min, while speech showed an increase to 24.7, and reading a decrease to 12.3 eyeblinks/min [19]. This is in line with our results showing that the average eyeblink rate for the “rest” period was approximately 25 blinks/min. Some major determinants of the blink rate at rest are extrinsic factors like dehydration, room temperature, relative humidity, and illumination. Both high temperature and high relative humidity reduce blink frequency [20]. In our study the room temperature varied less than 1° C, and the relative humidity less than 2 % RH for each individual participant.

High visual performance demands like VDU work is an important factor that reduces blink frequency. According to Acosta and co-workers [21] the reduced blink rate appears to depend on central neural mechanisms that are quite independent of peripheral sensory inputs. In their study the mean eyeblink rate at rest (12.4 eyeblinks/min) was reduced significantly by about 40% during performance of a VDU task [21]. Patel and co-workers [22] found a 5-fold drop in the eyeblink rate during VDU use. In their study the mean eyeblink rate before VDU use (18.4 eyeblinks/min.) was reduced to 3.6 during a card game play task at the computer. The results in our study were in line with the beforementioned studies. The average eyeblink rate was approximately 5 blinks/min for both young adults and presbyopes. Glare and the size of the characters did not influence significantly on the eyeblink rate. The tasks were performed with a distance of 60 cm and a gaze angle below horizontal to the midpoint of the screen of 15°. The distance was checked manually several times across the different sessions of the study. Further the study imitated the recommended position of the workers relative to the screen [23]. There was a great demand of precision when marking and bolding the e’s.

8 Conclusion

Neither small characters nor glare in the near surrounding of a VDU work station seems to have any significant influence on the eye blink rate. This applies both for non-presbyopic young adults and for presbyopes. However, visually demanding VDU work is associated with a very low eye blink rate. From our findings we conclude that highly visually demanding tasks at a VDU screen is an important factor reducing the eye blink rate.

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Do the Luminance Levels of the Surroundings of Visual Display Units (VDU) and the Size of the Characters on the Screen Effect the Accommodation, the Muscle Load and Productivity During VDU Work?

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Abstract. This study aims at quantifying how much a background glare situation of a VDU, and different text sizes influence muscle load and production. Production was evaluated both as quantity of work, and number of errors that were made. The results showed no significant changes in the postural load in terms of electromyographic (EMG) measurements of m. trapezius and m. infraspinatus. However, a significant decrease in working speed and productivity was seen. There were no significant changes in the number of errors that was done. The transient myopic shifts (TMS) observed in an earlier study among presbyopic users [1] were not as clear in this study.

Keywords: VDU-work; Luminance; Muscle load; Myopia; Optometric corrections; Lighting.

1 Introduction

The objective of this study was to determine if glare from the surroundings of the visual display unit (VDU) influenced the users work productivity, state of refraction or muscle load. In a former study, we showed that in a group of presbyopic workers, an introduction of a moderate glare source in the surroundings of the VDU screen had an influence on productivity, but not on the postural load of the user [1]. Studies have shown that lighting conditions and optometric corrections are important factors in reducing visual discomfort [2]. The effect of optometric corrections on visual discomfort and musculoskeletal pain in VDU workers is also documented [3]. Glare has significant correlations to eye focusing problems and tired eyes [4]. High levels of background luminance have a negative effect on accommodation and increased visual fatigue [5]. The recommendations in Norway are that the ratio of luminance contrast distribution in the near, near surroundings and peripheral, should not exceed 1:3:10, and that maximum luminance contrast in the visible field of vision should not exceed 1:20 [6]. In a laboratory study [7], glare from a luminarie in the upper visual field was

examined. Subjective rating of light discomfort was strongly related to the luminance level of the glare source. Further, the glare magnitude was significantly related to asthenopic symptoms ($p=0.004$) and musculoskeletal symptoms ($p=0.017$). The same researchers found that accumulated reading time was positively related to asthenopia ($p=0.0001$) and musculoskeletal symptoms ($p=0.0001$), indicating a fatigue effect. More detailed information of a correlation between visual discomfort and musculoskeletal pain is given by [8]. In a 6 years intervention study, a relationship between visual discomfort and pain in VDU workers was reported [2]. Average pain intensity in the neck and shoulder in previous month, previous six months, and the frequency of pain previous month and visual discomfort showed a relationship ($0.30 < r < 0.40$). A correlation was found between median trapezius load measured by electromyography (EMG) and average pain intensity and frequency in neck and shoulder and in visual discomfort. The correlation coefficient was between 0.25 and 0.30 ($p=0.03$) [2]. In another epidemiological study [9], a relationship was found between neck pain and visual discomfort, $r=0.40$, ($p=0.0003$).

2 Aims of the Study

Do the luminance levels of the surroundings of visual display units (VDU) and the size of the characters on the screen effect the accommodation, the muscle load and productivity during VDU work among young, non presbyopic workers? Are there differences in the above parameters when comparing with an earlier presbyopic study group? [10]

3 Design of the Study

The combination of high luminance/normal character size, high luminance/small character size and low luminance/small character size was tested according to a 3×3 orthogonal Latin square design [11]. The lowest luminance level of the surroundings of the screen, was 70 to 100 cd/m^2 , and the normal size of the characters on the screen, 12 points New Roman, were defined as baseline. This baseline was recorded for each participant at the start and the end of the trial. The mean of these two measurements was used as a baseline in the statistical analysis [3]), except for subjective refraction, where an initial measurement was taken before the subject was introduced to the work task, in order to see if a change in the focusing distance alone could lead to alteration in the visual system. Independent variables are the different luminance levels and the different sizes of the characters on the screen; the dependent variables are accommodation, muscle load and productivity. The study group consisted of young VDU workers (students).

4 Materials and Methods

4.1 Subject Population

Nineteen young, healthy volunteers (15 females and 4 males) were recruited from Buskerud University College. Age ranged from 19 - 29 years, with a mean of 22.1 years. All subjects gave informed consent to a protocol approved by Buskerud University College, and were free to withdraw from the study at any time, giving no reason. All subjects were experienced VDU-users, and using computers daily as part of their study work.

Inclusion Criteria. All subjects had a minimum distant and near best corrected binocular visual acuity of 1.0 (6/6 or 20/20) and normal eye status at the optometric examination.

Exclusion Criteria. Spectacle correction stronger than ± 6.00 DS (spherical equivalent), having active eye disease, or systemic disease with eye complications. Furthermore, taking drugs that might influence either eye functions or muscle functions. Subjects suffering from physical handicaps to a degree that make it difficult to do electromyography (EMG) recordings and postural angles measurements.

4.2 Illuminance and Luminance

The illumination level was approximately 300 lx on the work table. The lowest luminance level of the surroundings of the screen was between 70 and 100 cd/m². These levels occur most frequently for VDU-workers when the gaze direction is parallel to the window wall. The two “glare” luminaries each was equipped with six 60 W fluorescent tubes, with a diffusing screen of opal acrylic sheet. A variable rheostat made it possible to adjust the light emittance to different levels. The size of the diffusing screen was 1.25 m x 0.57 m, giving a luminance between 5500 – 6000 cd/m² (measured across the screen). This luminance is reached in an ordinary office environment when sunshine falls on thin, white curtains. The light measurements were done by a Hagner Universal Photometer – type S3.

4.3 The Workplace

The experiment was conducted at an optimised VDU workplace with forearm support on the tabletop [12]. The seat height, table height and monitor/eye distance were all positioned in accordance with anthropometrical dimensions of the subject. The line of sight to the midpoint of the computer screen was adjusted to approximately 15° below horizontal. A constant visual distance from the eye to the midpoint of the screen was set to approximately 60 cm [13]. The large “glare” luminaries were mounted vertically on the right side of the VDU, at approximately 45° horizontal angle from the sightline to the centre of the screen, simulating windows as they very often appear in a normal work station set up.

4.4 The Work Task

The work task was interactive work on the VDU screen. The VDU screen was a 15 inch LCD screen, with 1024 x 768 pixels resolution, The normal sized text (Times New Roman 12, capital letters 3 mm and small letters 2.2 mm in height) subtends a visual angle of approximately 16 minutes of arc for the capital letters, app. 12 minutes of arc for the small letters, when viewed at 62 cm distance. This represents a visual acuity demand of approximately 3 minutes of arc (2.5 for small letters), or 0.3 (6/18 or 20/60). This size is recommended for ordinary reading tasks, for subjects with visual acuity of 6/6 (20/20) or better. The small text size (Times New Roman 8, capital letters 2.4 mm and small letters 1.7 mm in height) subtend approximately 13 minutes of arc (capitals), and 9 minutes of arc (small letters) at 62 cm viewing distance. This represents a visual acuity demand of approximately 0.5 (6/12 or 20/40). This letter size is smaller than recommended for ordinary reading tasks. The work task was to read an English scientific text, not familiar to the participants, shown on the screen. All e's in the text should be marked and bolded, looking directly on the screen all the time. The higher luminance from the large surface luminaries may in this way affect the visual parameters and muscle load. The whole test procedure was explained for the participants.

4.5 Refractive Measurements

Refractive power of the eyes was measured 6 times, before the experiment started, then between each test sequence and finally at the end to the Latin square period. The measurements were taken from both eyes without fixation of the head position, with a photo-refracting unit (PowerRefractor, Plusoptix AG). (More details about the PowerRefractor in [1])

4.6 Measurement of Load on the Musculoskeletal System

The postural load on the neck and shoulder muscles was quantified by EMG, using surface electrodes [14]. The load in m. trapezius (descending part) and m. infraspinatus was used as indicators of load on the neck and shoulder areas. The load on the m. trapezius muscle is selected because there are often complaints of pain and other symptoms from this area [12]. Furthermore, m. infraspinatus is chosen as an important stabilizer for the shoulder joint. Load on m. erector spina lumbalis was measured at L3 level. The Physiometer was used to measure the muscle load (figure 1). To perform continuous measurement of postural angles, three dual axis inclinometers are used. Angles were measured relative to the vertical by inclinometers attached to the upper arm, head and back.

The posture was controlled for by recording body movements. The static (0.1), median (0.5 and peak (0.9) values of the amplitude distribution function (ADF) were analysed. The EMG and the postural angle methods are described and the methodological limitations discussed by [15], [14].

4.7 Test Duration

There were five test sections. Each section lasted 10 minutes of active recording, with a period of rest in between. The reason for 10 minutes active recording for each session is the recommendations by Mathiassen (2002), who observed marginal information beyond approximately 10 minutes sampling of EMG of stereotyped work [16]. The rest period was about 5 minutes. The initial calibration procedure before the test sequences lasted about 90 minutes.

4.8 Optometric Examination

All subjects underwent an optometric eye examination some time before the investigation. Details of the procedure and criteria for correction are discussed elsewhere [17].

4.9 Background Factors

All participants were interviewed before inclusion in the study. During this interview, background factors such as age, gender, and duration of VDU work as well as inclusion and exclusion criteria were discussed. The whole test procedure was explained for the participants.

5 Statistical Analysis

The study was set up with a Latin square design. The independent variables are the two different luminance levels and the two sizes of the characters. The dependent variables are the accommodation power, load of the m. trapezius, m. infraspinatus and m. erector spina lumbalis muscles at L3 level. The postural angles were measured in order to control for body posture. A minimum of 16 subjects was needed in order to detect a difference in muscle load between 0.5 to 1 % maximum voluntary contraction (MVC) at a power level of 80 %. All results are given as group means with standard deviation using paired sample T-test, and repeated Wilcoxon Signed Ranks test. Pearson's Correlation Method was used for correlation statistics. Differences are considered statistical significant with a p-value = <0.05.

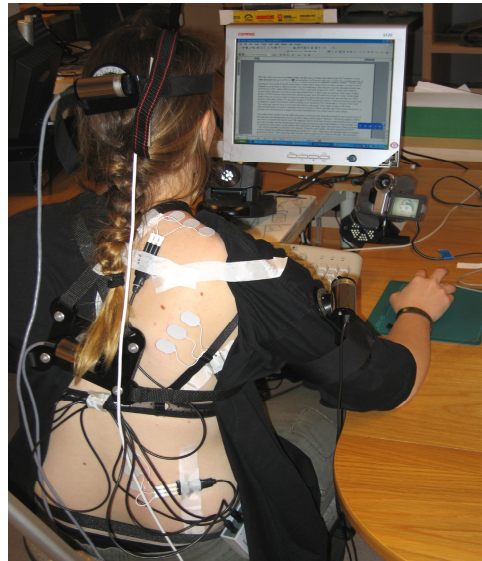


Fig. 1. Electrodes and angles sensor used by the Physiometer

6 Results

6.1 Postural Load

In the young group, static m. trapezius activities did show small, but significant decrease when working with small characters without glare compared with baseline measurements. ($p=0.05$). When comparing m. infraspinatus from baseline to working with small print and glare, the static load also decreased ($p=0.01$). These changes are however small, and probably not of clinical significance. The differences of muscle activity within subjects between the different sessions were small. The maximal difference in static m. trapezius activity within subjects between the baseline and the measurements when the subjects were glared and worked with small characters was 1.0 % MVC.

6.2 Refractive Changes

Accommodative after-effects in terms of TMS during the test period were measured. There are only small changes in refraction over the test period, and only two of these reach near-significance level. There are, however, no significant changes within the Latin square period. The accommodative induced myopic shift takes place during the first test sequence. When checking for change from baseline to measurements within the Latin square period, only one reach near significance level ($p=0,057$). The changes are small, and probably not of clinical importance.

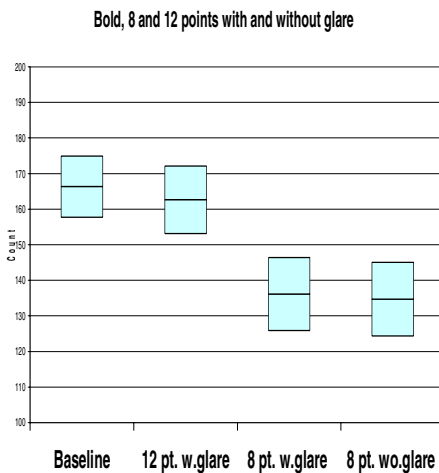


Fig. 2. Number of e's bolded per task unit

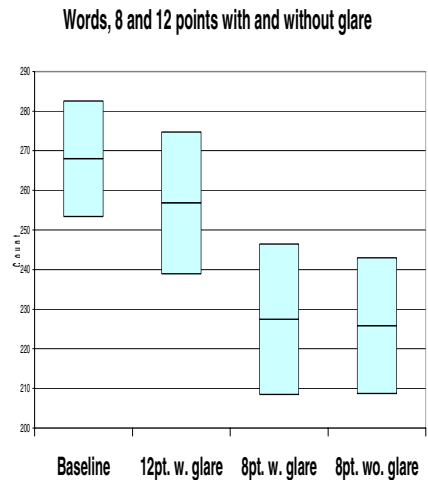


Fig. 3. Number of words processed per task unit

6.3 Productivity

Productivity in terms of the number of words processed over the testing period is shown in figure 2. The results demonstrates that the amount of work done is significantly reduced when working with the 8 points letters versus 12 points letters without glare ($p=0.00$).

The number of e's that were bolded went down significantly when introducing glare ($p=0.01$), and went even more down when going from large to smaller letters ($p=0.00$). (Fig. 3).

Errors are defined as not bolding an "e", or bolding another letter. There was no significant difference between the test situations when looking at the number of errors done per task unit.

7 Discussion

The illumination level was set as high as possible according the recommendations for traditional office work included computer work. The IES (1989) has recommended office lighting levels, depending of age profile of the workforce, between 500 and 1000 lx [18]. In order to get the most effective accommodation measurements, the highest illumination was limited to 300 lx. When taking the refractive measurements, the glare source had to be switched off. The level of luminance of the glare source was 6000 cd/m² measured across the screen.

The task was demanding, both visually and physically, because of the static work situation. The initial static muscle loads of m. trapezius and m. infraspinatus was 3,0 % MVC and 4,0% MVC respectively, as group mean values. These values did not change much during the test duration. Among a group of adults computer users tested, a much higher static infraspinatus load (13,1 %) was found, so these values are not in line with the former study [1]. Other studies indicate that high precision seems to increase muscle load [19]. They showed that musculus infraspinatus had a high precision-dependence during tracking work. The m. infraspinatus seems to be acting as a responder to precision demands in the shoulder region, which may be a consequence of its function as shoulder joint stabilizer. This is supported by high muscle activity in m. infraspinatus during cleaning. Søgaaard reported more than 10 % EMG max for mopping activity [20].

In this study the participants supported their forearms on the table top. When supporting the forearms during work with the mouse, the m. trapezius load is reduced [21]. In a study by Palmerud et al (1995), they showed that by voluntary reducing the trapezius load, the load in infraspinatus muscle increased [22]. The static levels of m. infraspinatus activity showed great individual differences between the subjects with the highest values of approximately 20 % MVC. The reason may be that in order to obtain sufficient positional accuracy of the hand and arm, the shoulder girdle need to be stabilised by means of muscular activity. This is achieved by co-contraction of muscle spanning these joints [23]. In high precision movements, the noise effects in neuro-motor control are counteracted by means of increased co-contraction. The stiffness of co-contraction is expected to filter out noise effects. The level of co-contraction will be even higher under stressful tasks conditions due to increased

neural noise [24] which may be the case in such testing situations. In this study precision demand was extensive. It has been shown that precision has an effect on m. trapezius load during an aiming task on computer by using mouse [25].

The accommodative induced TMS observed when working at the VDU-screen are small and not statistically significant. TMS is reported in earlier studies [26] [27]. However, in a 6 years follow up study of 692 VDU users no such effect was established. [28]. The age of this study population (mean age = 22,1 (19 – 29) years) is such that a TMS could be expected. However, in a former study the subjects had a mean age of 57 years (46 – 67) and it is interesting to observe that the myopic shift was higher in that presbyopic group [1]. One possible explanation could be that the TMS observed in the presbyopic group normalized slower than in the young group. In a group of non presbyopes, most of the TMS normalized within 2 minutes [29], and Rosenfield (1992) found that most of TMS disappeared in 20 – 50 s. post task [30]. Myopic shifts are thought to be one factor in myopia development [31], although in several studies no myopia development following VDU-work has been found [32] [33]. To follow this myopic shift over time was not within the scope of this project.

8 Conclusion

Working with small characters and/or glare did not impose clinically significant changes in muscle load in term of EMG values. M. infraspinatus was not so heavily loaded in the young group compared with the presbyopic group, who showed a relatively heavy infraspinatus loading during this type of computer work. A very small myopic shift were registered in the young group, a significantly higher myopic shift is seen in the older group, in spite of these test subjects being presbyopic. Productivity, in terms of less amount of text processed and an increased number of errors, went significantly down for both groups when working with small characters and glare. However, the young group scored higher both in the total amount of work done and the young group also made less errors per time unit. The results indicate that a recommendation to use font sizes of about 3 mm for 60 cm. working distance is appropriate. Further, background glare should be avoided.

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Complexity and Workload Factors in Virtual Work Environments of Mobile Work

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Abstract. This article concentrates on describing the complexity and work load factors of mobile work done in virtual environments. A qualitative multi case study was carried out. Six mobile employee groups were examined. The data was collected by interviews and questionnaires. A model of complexity factors was used in analyzing the data. The complexity factors interrelated with different types of workload components, i.e. physical, mental and social and, furthermore, they induced distinct workload factors. To reduce the manifestation of the workload factors and to enhance well-being, fundamental requirements for the virtual environment can be presented. At the levels of connection, device and application the issue lies in the transfer capability of communication. Compared to this at the levels of cognitive and cultural factors of the virtual space the question is in the ability of semantic transfer of the message.

Keywords: Mobile work, virtual work environment, work load factor, well-being.

1 Introduction

Mobile work and its practices have attracted the attention of researchers from various research disciplines. However, research on mobile work is in its early stages and definitions of mobility are still emerging. A central problem related to developing types of work, such as mobile work, is that its new working procedures and its new working environments - especially the virtual working spaces - are not known well enough. For example, it is difficult to connect employee well-being outcomes to the unknown characteristics of the work. If environmental complexity factors are well managed in a traditional work environment, they really are a relevant issue with mobile work done in virtual environments. Principally, the virtual work environment of the employee is unknown and not controlled by the managers or virtual environment designers. It is hardly self-managed by the employee and this may cause additional challenge and strain.

The purpose of this article is to show the complexity and workload factors of mobile work done in virtual work environments [11]. The work is defined “mobile”, if the employee works more than ten hours per week outside of the primary workplace

and uses information and communication technology (ICT) for communication [6]. The use of ICT tools generates the virtual work environment.

This paper shows the complexity and workload factors related to the different dimensions of mobile work from the perspective of the virtual work environment. The questions to be studied are:

1. How do the complexity factors manifest themselves in mobile work from the perspective of the virtual work environment?
2. What are the dimension-related work load factors of mobile work in virtual work environments?

This article is organized as follows. First, the background section introduces the complexity approach and the main concepts. Next the methodology, methods and research settings of this case study are presented. Thereafter, the article describes the empirical results illustrating the complexity and workload factors of mobile work done in virtual spaces. Finally, the results are summarized and discussed and some future trends are presented in the concluding section.

2 Definitions of Mobile Work and the Complexity Approach

The physical mobility of employees is realized at least at two levels: individuals move alone as members of a distributed team or organization and teams and projects move as a part of a dispersed organization or network using different sites. Mobile employees establish their “instant office” by adapting to and using the environment at hand, and do so again as quickly. If collaboration with distant workmates is needed, this is only possible with mobile, wireless information and communication technologies.

First discussions on the concept of mobility dealt with employees moving from place to place. Kakiyama and Sørensen [9] described three interrelated aspects of worker mobility: location mobility concerns the workers extensive geographical movement, operational mobility deals with the flexible operations of independent business units and interaction mobility the intense of fluid interactions of actors. Andriessen and Vartiainen [2] expanded the concept to cover also virtual mobility so that it includes stationary actors moving with help of ICT tools in virtual working spaces. Mobile workers are those employees who move a lot and collaborate with others via electrical tools. This article highlights the concept of mobile work from the viewpoints of physical mobility and virtual collaboration.

The complexity factors of the work refer to the wide range challenges, which are inherent in the work and can be examined as its characteristics and demands. The complexity of work is usually considered as a factor related to the task. At one end the task is creative and demanding, and, at the other end, it is simple and routine-like [1]. The expanded complexity concept considers also the working environment that can be a different combination of physical, virtual, social and cultural spaces.

Vartiainen [15] described by six dimensions the complexity of working contexts, which complement the complexity of the task as the two main factors influencing intra-individual and –group processes needed in coping with complexities. They are

geographical dispersion of the working locations, physical mobility, diversity of actors, asynchronous working time, temporary structure of working and mediated interaction as shown in Figure 1 [10]. These six dimensions form in addition to task complexity a set of requirements that can also be considered as workload factors. The workload–strain model draws a distinction between the effects of external sources impinging upon a human being (workload) and the effects (strain) within individuals, depending on their pre-existing conditions [13]. The transactional model of stress for its part states that the interaction between a person and the environment creates a perceived stress on the individual. Stress is not a property of the person, nor the property of the environment, but arises from the conjunction of a particular kind of environment and particular kind of person [12].

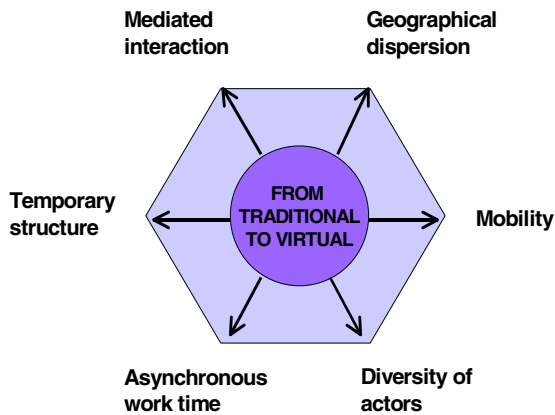


Fig. 1. Complexity factors of working environment [15, pp. 22-23]

According to previous studies [5, 10], geographical dispersion influence on working practices and needs of communication and coordination. It has also been proven that mobile and multi-locational work increases the physical distance of the workers of the main team and hinders the face-to-face communication of the team. On account of this, the need for using wireless technologies increases. Non-verbal cues are usually absent in mediated communication, and this may easily lead to misunderstandings and lack of trust. The global groups in particular have members with different backgrounds, i.e. a different language, culture, values, orientation to work, leadership type, etiquette and punctuality. These may further create communication problems. The temporary nature of their projects leads to loose social engagement due to limited expectations of working together again. Asynchronous work time in relation to the main team makes additional demands on communication.

In this paper, the model of complexity factors [15] is applied to analyse and realize the features of mobile work done in virtual environments.

3 Research Method and Data Collection

The study was carried out as a qualitative multi-case study [16], in which six mobile employee groups were explored; three groups moving globally and three groups moving locally. The number of employees in each group varied between five and eight (altogether 41 employees were met). The data was gathered by interviewing each member of the groups by semi-structured interview. In addition, three different surveys were used: virtual team questionnaire (VTQ1), well-being in dispersed work (WDW) and Job Engagement Survey [14].

A model of the complexity factors [15] was used in analysing the data: the interview data was coded and classified according to complexity factors with the help of AtlasTi programme. A parallel coder was used to confirm the reliability of coding. After parallel coding the parameters of classification were redefined. The variables of the questionnaires were dealt with using the SPSS programme.

After complexity factor coding, each of six factors was examined separately.

4 Results - Manifestation of Complexity Factors and Complexity-Related Workload Factors

Geographical dispersion, i.e. sphere of operations. Both groups did multi-locational work. Global groups worked at home, at the primary workplace, in means of transportation, at secondary places i.e. secondary places of their own company or places belonging to customers and at third places i.e. restaurants, hotel rooms and other places normally associated with free time or leisure time as shown in Table 1. Of the locally mobile group only the maintenance men worked from home on a regular basis. The home was used for planning and organizing work for the next day. Security personnel and community nurses rarely worked at home and they did not construct a virtual connection for a work from home basis as shown in Table 1.

As expected, the geographical dispersion of working places was greatest with those moving globally. Representatives of small and large companies operating globally worked on different continents, and another group traveled within Europe. Locally mobile groups worked in a local area, which varied in size from tens to hundreds of square kilometers. While the globally mobile stayed at least a day in their target area, the locally mobile groups visited several places during their working day.

Table 1 also presents the devices used for constructing virtual space of different workplaces. After that, there is a condensed description of the reasons for using virtual working spaces. Geographical dispersion of the team, multi-locational work as well as the mobility of employee were the reasons for constructing and using the virtual work environment.

The workload factors related to dispersed and multi-locational work were both mental and social in nature (table 2). However, the main cause lay in the communication connections. Challenging duties and demanding human relationships associated with poorly or roughly working virtual connections were a source of stress. The malfunctioning of communication connections, devices or applications at secondary and third workplaces posed even experiences of isolation and loneliness.

Table 1. Workplaces and devices

Case	Global movers			Local movers		
	Case a: small enterprise	Case b: large enterprise	Case c Europe -group	Case d: maintenance	Case e: community nurses	Case f: security
Scape 1: Home	Mobile phone, few lap top computers	Smart phone, lap - top computer, one-way information gathering devices	Smart phone, lap - top computer, one way information gathering devices	Mobile phone, desk top computer	Do not work at home	Do not work at home
Used for	For communication with clients and team members	For communication and collaboration with team members and partners; for tracing continuously changing information	For communication and collaboration with partners and team members; for tracing continuously changing information	For planning the tasks of the next day		
Scape 2: Primary work place	Phone, mobile phone, desk top computer, fax	Smart phone, lap - top, two - way information channels: video conferencing tools, net conferencing tools	Smart phone, desk top or lap - top computer	Seldom visits at primary place - visits are for face to face communication	Phone, mobile phone, desk top computer	Phone, desk top computer, control centre with computers connected to monitoring cameras, GPRS monitoring system
Used for	For communication with clients around the world, for communication and collaboration with team members	For communication and collaboration with team members, partners and clients around the world	For communication and collaboration with partners and team members around the Europe		For communication and collaboration with doctors and pharmacy personnel as well as with social workers; for planning the tasks of the next day	For monitoring the places of clients around the country, for monitoring and advising the partner on the move
Scape 3: Means of transportation	Mobile phone	Smart phone, lap - top computer	Smart phone, lap - top computer	Palm computer completed with mobile phone	Mobile phone	Mobile phone, GPRS devices
Used for	For occasional communication with team members and clients	For planning the upcoming meetings and presentations, for checking and answering e-mail	For planning the upcoming meetings and presentations, for checking and answering e-mail	For receiving urgent duties, for communication with team members	For occasional and urgent communication with team members, doctors and social workers	For ensuring the route and the information of the target
Scape 4: Secondary work place	Mobile phone, lap top computer, fax	Smart phone, lap - top computer, video conferencing tools, net conferencing tools	Smart phone, lap - top computer	Palm computer completed with mobile phone	Mobile phone	Mobile phone, monitoring cameras
Used for	For asking advice from team members, for reporting the executed tasks	For giving presentations, for asking advice from the team members or partners, for checking and answering e-mail	For asking advice from the team members or partners, for checking and answering e-mail	For receiving and reporting the tasks, for asking advice from team members or experts in the field	For occasional urgent duties with team members, doctors, social workers and first aid	For checking the risks, for ensuring own safety
Scape 5: Third place	Mobile phone, occasionally lap top	Smart phone, lap - up computer	Mobile phone, lap - top computer	Mobile phone, palm computer	Do not work at home	Mobile phone
Used for	For communication with family members and friends	For checking and answering e-mail, for planning the upcoming meetings, for getting help from team members	For checking and answering e-mail, for planning the upcoming meetings, for receiving help from team members	For receiving urgent duties		For receiving urgent duties

An integral part of the feeling of well-being was the support one was able to receive through well-functioning channels of communication and collaboration. Good connectivity potential was the “thing” that interviewed mobile employees hoped for and appreciated.

Mobility. Comparison of locally and globally mobile groups showed that local groups considered themselves to be more mobile than global groups. This was due to the frequency of trips: locally mobile groups were continuously on the move during their everyday work. Global movers were traveling for several days during the month but they also stayed in the main workplace for longer periods than the locally mobile. While moving, both groups used ICT tools, mainly mobile phones for communication.

The described workload factors related to the mobility of employee were mainly physical in nature. From the viewpoint of the virtual working environment the quality of the mobile device was emphasized. Because the virtual working environment constructing ICT devices were kept while moving in a pocket or in a backpack, they were expected to be light and tiny. However, problems of visibility emerged when devices were smaller. For example, the maintenance men moved in dark wells and engine rooms and had visual difficulties with the palm computer they used. This dilemmatic question between size and visual requirements as well as portability requirements (table 2) is mainly the concern of the microergonomics discipline.

Cultural diversity. Since the basis of mobile work was to meet clients face-to-face, mobile employees encountered a multitude of different individuals. In particular, the cultural diversity of actors in the globally mobile groups was a complexity factor both in physical and virtual work spaces. The workload factor caused by the diversity of actors was both mental and social.

Time. There were great differences in what employees comprehended as asynchronous work. Representatives of the global company had experiences of asynchronous time having worked in different time zones. Locally mobile employees determined the dissimilarity in working hours as asynchronous working. For example, the security personnel, who predominantly worked at night time, considered their work asynchronous. Asynchronous working increased the need for coordinating one's use of time. In this study, especially in the groups working globally, asynchronous working had the effect of changing the hours and rhythm of the work. Employees did not have uninterrupted working days starting at a particular time and ending at another, but instead altered rhythms of their days as well as their weeks according to the demands of their tasks. Working periods could take place early in the morning, in the afternoon and in the evening. Work might be done to some extent every day of the week. Asynchrony with using a virtual work space caused physical, mental and social strain (table 2). For example, in planning a net meeting it had to be taken into account that members were spread out around the world. This caused an inclination towards unconventional working hours with evening and weekend work. Also the need to be constantly available, affected the experiences of strain. Based on the survey study (VTQ) there was statistically significant ($p < .001$) difference in weekly working hours

between globally and those locally mobile. The globally mobile worked on average ten hours more per week ($m=49h/week$) when compared to the locally mobile employees ($m=39h/week$).

Temporality. When evaluating the permanence of working groups and their collaboration, i.e. the time frame of a project and existence of the team, it became evident that members of large global companies and the Europe group performed more project work than other groups. According to the interviews, the temporary nature of the projects was considered both as a complexity factor and a workload factor. It was hard to forge good and trustworthiness relationships, if the team or partners in cooperation constantly changed. The workload can be defined as mental and social. The main workload factor was related to too many and constantly changing human relations.

The workload factors associated with the complexity factors are summarized in Table 2. The complexity factors interrelated with different types of workload components, i.e. physical, mental and social and, furthermore, they induced distinct workload factors. To reduce the manifestation of the workload factors and to enhance well-being, fundamental requirements for the virtual environment can be presented.

Table 2. Complexity factors of mobile work related to workload factors and requirements for virtual environment

Complexity factor	Workload	Distinct Workload factors	Requirements for well-being in virtual environment
Geographical dispersion	Mental and social	Bad connections	Connectivity
Mobility	Physical	Weight of burden, vs. visibility (compact devices)	Portability
Diversity of actors	Mental and social	Cultural diversity, demanding human relations	Intelligibility
Asynchronous work time	Physical, mental and social	Disorders in work - life balance	Balance
Temporary structure	Mental and social	Too many human relations, lack of confidence	Trustworthiness
Mediated interaction	Mental and social	Messages open to interpretations, misinterpretations	Clarity

Mediated interaction. As the degree of mobility and the geographical dispersion of the workplaces increased so did the demands for mediated interaction, i.e. the use of the virtual working spaces. The workload experiences of the interviewee were associated with the interpretation of messages sent with a means of communication and collaboration: mediated interaction carried many opportunities for misunderstandings, which could even be fateful, for example, in the work of security personnel during dangerous situations the supervisor in the guarding centre directs the movement of a guard in the field. The explicit and shared understanding of messages between them was essential. On that account of this the workload factors related to mediated interaction were mainly mental and social in nature (table 2). The central issue can be consolidated to the question of cognitive abilities, i.e. how successfully one can build up mental and social constructions in virtual working environments.

5 Discussion

Figure 2 shows a systemic generalization of findings concerning the complexity factors of the virtual environment and the possible dissection levels of requirements for virtual communication and collaboration. The levels are presented in a protocol manner (comparable to Internet protocol) to underline the layered nature of the virtual environment, as spatial mobility refers not only to extensive moving of people, but also the global flux of objects, symbols, and space itself [8]. As such it evokes complex patterns of human interaction. When mediated interaction is compared to the face-to-face communication, it is much more layered and therefore susceptible to disturbances and breaks. The employee has to cope with different cognitive skill requirements as well as with the cultural diversity of actors and colleagues when working in a virtual manner. Disturbances at this level lead easily to misunderstandings. Coping with the diversity of actors in mediated interaction environments is not only a complexity factor but also a mental and social workload factor.

In particular, these upper cognitive levels of the virtual working environment are far too less known [1, 4, 7]. Important research topics are expected to be related to questions of decision-making in demanding tasks in virtual environments. This is one of the forthcoming focuses of, for example, macroergonomic research topics. There is an evident need to develop tools both for managers and virtual environment designers to better control the questions related to this cognitive virtual reality.

Dropouts in virtually mediated communication can also be encountered due to time constraints, i.e. asynchronous work. Time constraints and time asynchrony are also questions that place stress on developing both work management styles and the functioning of devices and applications. More effective control of time is both a micro- and macroergonomic concern.

The minimum level required for successful communication and collaboration in virtual environment concerns proper functioning of the connections, devices and applications. The flow of communication and collaboration breaks if this physical level of connections, devices or applications does not work or exist. The inoperative ICT tools could be fatal due to misunderstanding at the upper layers of the virtual environment. In mobile work, there are additional requirements concerning the

devices. The transfer to virtual working space via devices and applications must be attained regardless of the time and place. The operational environment of a mobile employee should be portable as well as easily perceivable.

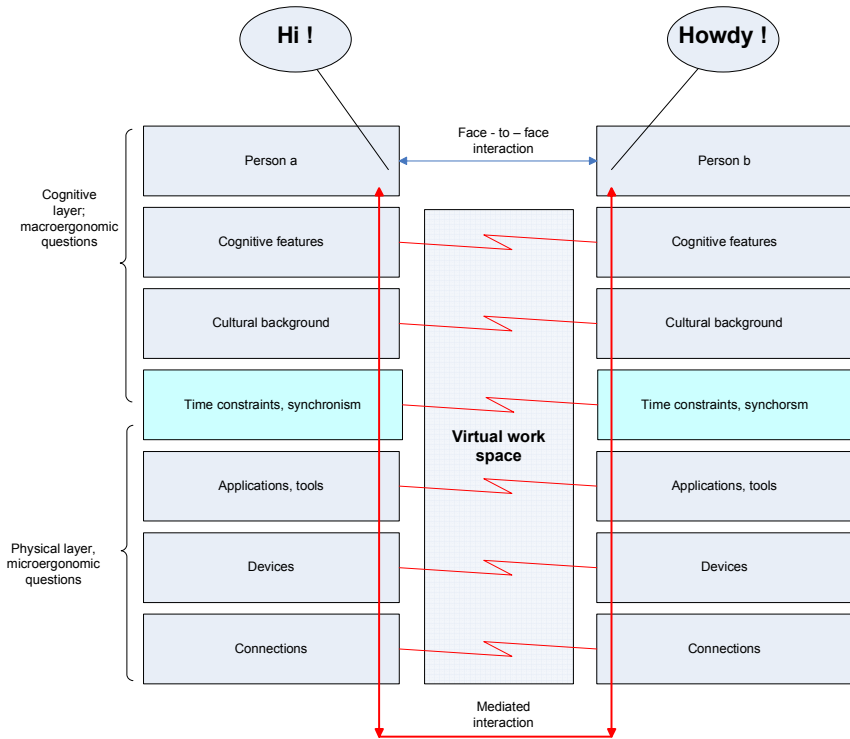


Fig. 2. Complexity of communication and collaboration in mobile and virtual work

In conclusion, with the complexity and workload factors of the virtual environment of mobile work, the question at the lower levels lies in the transfer capability of communication. Compared to this at the upper levels, the question is in the semantic transfer of the message. Although we have the technological capability to work across time and distance, the fact is that we need new competencies and practices to do these things. Working in mobile virtual teams requires much more than computers and technology.

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A Study of Personal Space in Communicating Information

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Abstract. Technologies to ensure information transfer security are being developed, but risks remain when people enter highly confidential information like personal data into systems in public areas. To provide complete security, we need both communication security and physical security. Accordingly, we conducted a fundamental study of environments designed for secure handling of personal information in public spaces. We studied people's personal space when they are using a PC in a public work environment. First, we conducted an experiment to evaluate the degree of reassurance a user feels while inputting personal information into a PC in a public work environment. Using the results, we grouped the degrees of reassurance into four levels of "personal space in communicating information", each for a different type of information. That is, different types of information had different safe sizes. This confirms results from our previous research.

Keywords: Personal Space, Reassurance, Public Space.

1 Introduction

The spread of personal computers and the explosive growth of the Internet now make it possible for users to communicate a wide variety of information regardless of location or time of day. But this also means that even information of a highly confidential nature can be accessed and processed anywhere and anytime. As a result, even highly confidential information can potentially be communicated at any time and in any place. There are, of course, risks in such communication, as the user's personal information could be leaked or seen by outside parties. Of course, services requiring confidential information are equipped with robust security systems such as encryption, digital certification, and authentication technologies such as IC cards and biometric authentication, so we can say that these services are secure to use as far as their functions are concerned. But what about the environments in which these services are used? For example, have you ever found yourself worrying about people catching a glimpse of a display visible from a busy sidewalk? In practice, it cannot be said that highly confidential information such as personal details can be communicated securely in public work environments that are open to anybody.

Guidelines for designing work environments have previously been presented from a human physiology perspective in the fields of architecture and human-factors engineering (Grandjean, 1989; Maruzen, 2001). Many of these guidelines, however, are based on the physiological characteristics of human beings, and there has been no research that takes the information handled in such an environment or feelings of reassurance into account. In short, these guidelines by themselves cannot determine what work environment is best for providing users with a sense of reassurance. There is a need for guidelines and methods that can be applied to the design of public work environments in which users can comfortably communicate personal information. Therefore, we are researching and developing network architectures where IT equipment can be used in many different places and have initiated a study of "secure space design technology" based on the need for physical spaces where people can use these services securely (Iizuka, 2004a; Goto, 2004).

The field of human-computer interaction analysis, moreover, has so far dealt only with interaction between people and computers and between people and people. However, as mentioned above, the popularization of ubiquitous services is expected to make computing all the more active in public spaces. There is therefore a need for research that also focuses on interaction among three parties, that is, user, computer, and another person. Our research focuses on analyzing such three-party interaction. This paper aims to extract knowledge from this analysis as a design aid toward work environments that enable users to communicate personal information with reassurance in a public space.

Since many random people come and go in a public space, users come into random contact with many strangers. To develop an environment where users can communicate information with reassurance, design that considers suitable contact between users and others is required. We paid attention to a stranger's "position and distance" which greatly affect a user's feeling of reassurance and conducted an experiment to measure the user's feeling of reassurance when position and distance were changing. We then created levels of personal space for every information classification based on those results and tried to create a visual image of each one.

2 Personal Space

It is thought that the concept of "personal space" originates with "spacing" (leaving space between individuals) of ethology. "Personal space" was studied by Sommer as one index of people's space behavior and was defined as "a domain of a certain size demarcated by an invisible boundary line" which surrounds an individual and into which others may not come (Sommer, 1959). This personal space has the character of affecting individuals' actions, regulating the relations between people. People are generally comfortable when their personal space is maintained and uncomfortable when other people invade it (Shibuya, 1985). Furthermore, personal space is elastic and is rarely fixed. Elasticity is also seen in relation to inanimate objects (IT

equipment). Harada explained people's displeasure at to use of a cellular phone by another person based on the concept of personal space (Harada, 1997). People who are sharing physical space with a person talking on a cellular phone feel that the personal space of the person talking on the cellular phone has spread. Therefore, people feel a sense of incongruity, that the personal space of a person talking on a cellular phone has suddenly expanded, and think that the talker's space cannot be entered. This causes displeasure. That is, IT equipment and communication of information have the effect of expanding one person's personal space and contracting another's.

When information is communicated in a public space, it is usually done in the presence of strangers. In communicating information in such a situation, the environment inevitably affects feelings of reassurance about a person's personal space in relation to others.

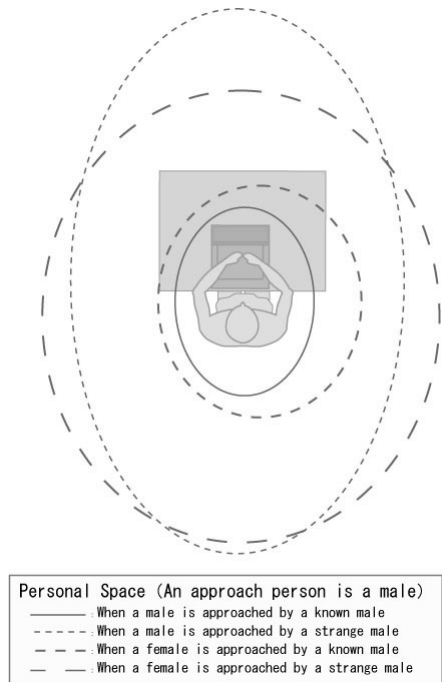


Fig. 1. Personal Space

3 Experiment

We set up an experiment in which a “user” inputs different levels of personal information in the presence of a “stranger”. We varied the distance between the user and the stranger and asked users about feelings of reassurance in different situations. Specifically, we set up work environments where an information terminal (PC) was used in an indoor space and measured a user's feelings of reassurance as affected by the presence of a stranger. The outline and results of the experiment follow. In the experiment, a “user” communicates information and a “stranger” walks or stands around on or inside the perimeter of the user's personal space.

(1) Experimental parameters

As mentioned above, the position of a stranger in relation to the user is a factor in feelings of reassurance about work environments in a public space. Here, we set up a user's hypothesized personal space perimeter, positioned a stranger at different points on it, and measured the user's feeling of reassurance for every position. We used direction and distance as the parameters for the stranger's position and defined them as follows.

- Direction
 - front

- diagonally in front
- side
- diagonally in back
- back
- Distance
 - 1 m
 - 2 m

The ten points at which the stranger was positioned during the trials (five direction times' two distance points) are shown in Figure 2.

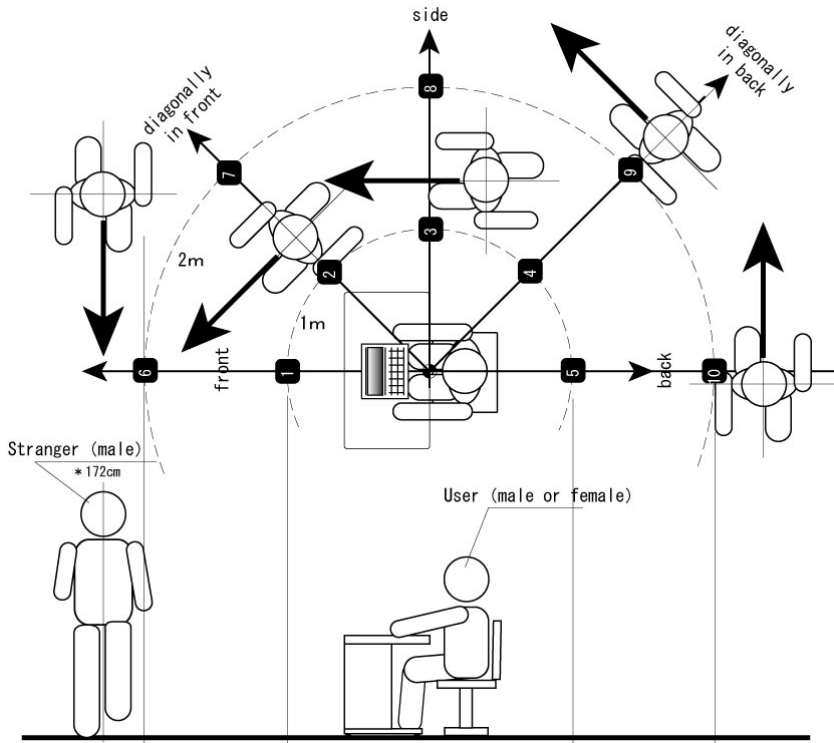


Fig. 2. Experimental set-up

We measured feelings of reassurance for four kinds of information a user might communicate. These four information classifications are based on four information criteria that affect a user's feelings of reassurance when communicating information in a public space and were obtained by our previous research (Iizuka, 2005).

- Person-specific and money-related information
 - Name, address, credit card number
- One's present circumstances and history-related information
 - Occupation, birthplace, education

- Preferences and behavior-related information
 - Hobbies, current destination, favorite stores
- Work-related information
 - Employer name (office), address, phone number, and mailing address

(2) Method

In our experiment, the user was alone, and there was always one other person (the stranger). The four sorts of information mentioned above were presented to the user by displaying them on a PC screen. For each type of information the user was told, “While you are handling this information, there is a stranger nearby” and asked, “How do you feel?”. The four sorts of information were presented in random order and the participant acting as the stranger was positioned at the different evaluation points in a random order. Users answered on a seven-point scale that included the following choices: “very uneasy”, “uneasy”, “somewhat uneasy”, “neither uneasy nor at ease”, “somewhat at ease”, “at ease”, and “very much at ease”.

(3) Participants

The participants were 10 males and 10 females in their 20’s, 30’s, 40’s and 50’s. Each participant rated their feelings of reassurance for all types of information with the stranger at all evaluation points. The goal of this research is to study public space work environments. Though such places are usually frequented by males and females, the participant acting as the stranger was always a male of average height for a Japanese man (172 cm) (Maruzen, 2003). In addition, the participant acting as the stranger and the 20 participants playing the role of the user were trained for the experiment separately.

4 Expression of Personal Information Space

Personal space is created either when a person being approached gauges the distance of an approaching person and judges a suitable distance (stop distance or approach distance) or when a person approaching another person gauges distance between himself and someone he’s approaching and judges a suitable distance (approached distance). This distance is expressed as a domain (boundary line), as shown in Figure 1. However, there are degrees (levels) of reassurance that people feel about personal space. Since we measured these degrees (levels) in this experiment, we tried to determine a personal information space by the expression of which degrees (levels) of reassurance felt by the user can be visualized. We now explain how we determined the different spaces for different levels of reassurance by Figure 3.

1. Each evaluation point was mapped on the x-y plane in 3-dimensional space (the user’s position is used as the starting point).
2. The responses of the 20 users are averaged for every evaluation point and every type of information.
3. The average values of the 10 evaluation points were set as the height (value in the direction of the z-axis) for each evaluation point (Figure 3 ①).

4. Lines were interpolated for each direction
5. Each line is extended until the average reported feeling of reassurance equals three on the seven-point scale ($z=3$).
6. This process is repeated for all lines (Figure 3)
7. 3-dimensional curved surface is generated by interpolating among all lines (Figure 3).
8. The 3-dimensional curved surface is projected on XY plane.

Thus the personal information space determined for each type of information is shown in Figure 4. The following things can be understood from this figure.

- The sizes of these personal spaces show the same tendency as reported in our previous results (Iizuka, 2005; Iizuka, 2006) for information type.
- Users reported no great differences in feelings of reassurance based on information classification when the stranger was in front of them.
- Users reported differences in feelings of reassurance based on information classification when the stranger was in back of them. These feelings were also dependent on the stranger's distance.

It should be noted that that gender differences influence personal space. Users' responses when asked about the stranger's gender were mostly consistent. A user's personal space is usually larger when a stranger is male than when the stranger is female (Akande, A. 1997; Ahmed, S. M. S., 1979; Beck, S. J., & Ollendick, T. H., 1976; Bell, P. A., Kline, L. M., & Barnard, W.A., 1988; Hewitt, J., & Henley, R., 1987; Pedersen, D. M. & Heaston, A. B., 1972; Sanders, J., 1976). In the public space studied in this research, strangers may be male, but they may also be female.

In Figure 5, these male and female personal spaces are halved and the halves placed opposite each other, creating contrasting spaces in which it is easy to see the gender differences.

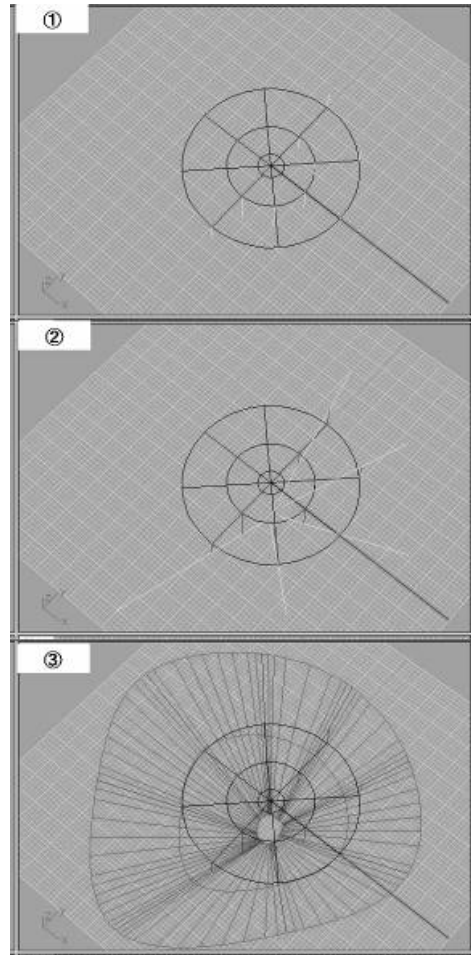


Fig. 3. Procedure for Setting Personal information Space

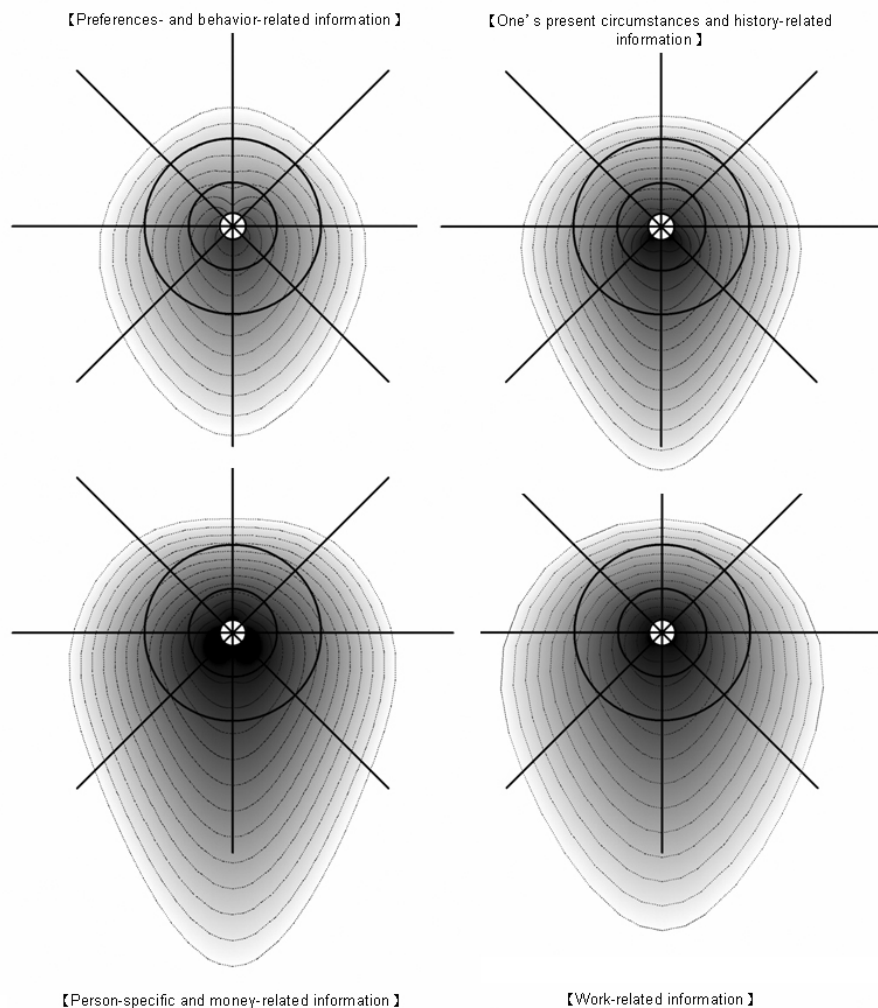


Fig. 4. Personal Space for Communicating Information

As in the previous table, a female user's personal space when a stranger is directly or diagonally in front is larger than a male user's personal space in similar circumstances. In contrast, male users tend to have larger personal spaces in back of them. However, considering; how small our sample was; that the personal information space was determined by a linear interpolation process, and; that personal space might become a little larger, we cannot say for sure whether the male-and-female difference was significant. However, we were able to check a possibility that the tendency out of which such a difference comes among male and female would come out. In future work we plan to test a larger group of people, increase the number of points of evaluation, and try to determine a more exact personal information space.

Table 1. Differences in Personal Space with Male and Female Strangers

Information type	Evaluation point	Total	Female	Male	Difference
Preferences - and behavior	1	0.70	0.20	1.20	1.00
	2	0.20	-0.10	0.50	0.60
	3	-0.25	-0.40	-0.10	0.30
	4	-0.80	-0.90	-0.70	0.20
	5	-1.15	-1.70	-0.60	0.90
	6	2.05	1.80	2.30	0.50
	7	1.95	1.70	2.20	0.50
	8	1.40	0.90	1.90	1.00
	9	0.70	0.70	0.70	0.00
	10	-0.05	0.10	-0.20	-0.30
Present circumstances and history	1	-0.20	-0.90	0.50	1.40
	2	-0.55	-0.90	-0.20	0.70
	3	-0.95	-1.20	-0.70	0.50
	4	-1.80	-2.10	-1.50	0.60
	5	-2.00	-2.40	-1.60	0.80
	6	1.90	1.50	2.30	0.80
	7	1.50	1.20	1.80	0.60
	8	0.90	0.30	1.50	1.20
	9	0.05	-0.10	0.20	0.30
	10	-0.90	-1.00	-0.80	0.20
Person-specific and money	1	-1.30	-2.10	-0.50	1.60
	2	-1.40	-1.60	-1.20	0.40
	3	-2.10	-2.40	-1.80	0.60
	4	-2.65	-2.80	-2.50	0.30
	5	-2.60	-2.70	-2.50	0.20
	6	1.40	0.80	2.00	1.20
	7	0.75	0.40	1.10	0.70
	8	-0.15	-0.40	0.10	0.70
	9	-1.00	-0.80	-1.20	-0.40
	10	-1.75	-1.60	-1.90	-0.30
Work	1	-0.95	-1.70	-0.20	1.50
	2	-1.25	-1.70	-0.80	0.90
	3	-1.65	-2.10	-1.20	0.90
	4	-2.05	-2.20	-1.90	0.30
	5	-2.20	-2.40	-2.00	0.40
	6	1.55	0.90	2.20	1.30
	7	1.05	0.70	1.40	0.70
	8	0.20	-0.20	0.60	0.80
	9	-0.60	-0.50	-0.70	-0.20
	10	-1.30	-1.20	-1.40	-0.20

Difference: (male average) – (female average)

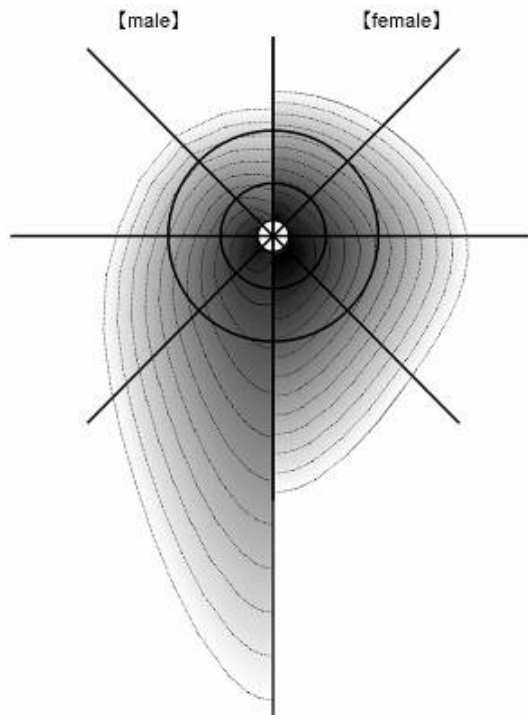


Fig. 5. Comparison of Male and Female Personal Information Space

5 Conclusion

In this paper, paying attention to a stranger's position and distance, which are considered to greatly affect a user's feelings of reassurance, we conducted an experiment measuring a user's feelings of reassurance as position and distance of a stranger changed. Using the results, we expressed a user's degree of reassurance as a personal information space.

In this experiment, by visualizing relations between feelings of reassurance and position and distance of a stranger (personal space when information is being communicated), we can intuitively understand how personal space is affected by these factors. We also think that this information can be used in the design of actual work environments. To make these findings on personal space more credible, we plan to increase the size of our sample, and conduct an experiment in a real-world environment. We also want to develop a structure that automatically visualizes personal information space.

Furthermore, we used only one stranger in this experiment, but in actual public spaces there are often two or more strangers within a user's personal space. Research on the size of personal space, when there are two or more strangers around has been done (Knowles, ES, Kreuser, B., Haas, S., Hyde, M., & Schuchart, GE, 1976). Therefore, in our research on public spaces, it will be necessary to study personal space when two or more strangers are within the user's personal space.

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Musculoskeletal and Performance Effects of Monocular Display Augmented, Articulated Arm Based Laser Digitizing

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Abstract. Processes of capturing solid geometry features as three-dimensional data for analysis, simulation, or reverse engineering require the use of laser-based reverse engineering hardware, commonly known as digitizers. The most common digitizers used within manufacturing contexts are articulated arm-based coordinate measuring machines, which have been augmented with a laser-head probe. Typical usage times for the digitizing equipment can range into the hours, thereby placing operators at risk for the development of musculoskeletal disorders (MSDs), though exact load magnitudes of exposure to risk factors for MSDs during object digitization are unknown. Further, other technologies (such as monocular/heads-up displays) may be combined with laser digitizers that may reduce load magnitudes. This paper explores the possibility of an occluded monocular display augmentation, results and discussion are presented.

Keywords: Monocular Display, Head Mounted Display, HMD, Augmented Reality Interface, Laser Digitizing.

1 Introduction

Processes of capturing solid geometry features as three-dimensional data for analysis, simulation, or reverse engineering require the use of laser-based reverse engineering hardware, commonly known as digitizers. The most common digitizers used within manufacturing contexts are articulated arm-based coordinate measuring machines, which have been augmented with a laser-head probe. Typical usage times for the digitizing equipment can range into the hours, thereby placing operators at risk for the development of musculoskeletal disorders (MSDs), though exact load magnitudes of exposure to risk factors for MSDs during object digitization are unknown. Further, other technologies (such as monocular/heads-up displays) may be combined with

laser digitizers that may reduce load magnitudes. Additionally, operators must constantly monitor feedback from the system via a traditional computer monitor to ensure that certain conditions are being met and sufficient data are collected to construct the virtual part. Thus, the existing visual feedback system introduces additional rotation loads on the neck musculature. Further, other technologies (such as monocular/heads-up displays) may be combined with laser digitizers that may reduce load magnitudes.

Monocular displays are a potential technology that may be combined with laser digitizers to reduce injury risk as well as improve operator performance. Problems typically associated with using a monocular display include simulator sickness, binocular rivalry, and accommodation issues. All of these adverse side effects are caused cognitively, in that the user's brain cannot resolve the differences in what each eye is viewing. Peli (1990) noted that most of these problems can be overcome by positioning the monocular display in the lower region of the user's field of view; specifically, 15 degrees below the users line of sight (the bifocular region). To the users, the display appears to be in the same position as a piece of paper would if the user was holding it close to his or her chest, allowing the display to operate within the users peripheral, however it is not large enough to disrupt normal vision (Peli 1990).

Laser digitizing equipment performs satisfactorily, though this emerging technology forces the operator into non-neutral postures for prolonged periods of time, specifically for the upper extremities, back, and cervical spine. The incorporation of other commercially available technologies (such as monocular displays) may improve ergonomic exposures and operator performance. Therefore, the objectives of the study were to: (1) quantify musculoskeletal loads associated with articulated arm usage for the neck, shoulder, and back, and (2) quantify the impact of incorporating heads up (monocular) displays during object digitization on musculoskeletal loads and digitizing efficiency.

2 Methods

2.1 Experimental Design

A repeated measures design was used to test for the effects of task condition (2 levels) on muscle activity, posture, performance, and discomfort and usability perceptions. Participants performed a digitizing task using the FARO brand laser digitizer with and without the use of an augmented, monocular display. Participant exposure to the task conditions was counterbalanced.

2.2 Independent Variable

The independent variable for this study was task condition: with and without the use of the monocular display. A MicroOptical brand (SV-6 PC, 33 Southwest Park, Westwood, MA 02090) occluding monocular display was selected for use in this study. The display accepts a standard 800 X 600 resolution and outputs an image at 600 X 480 pixels. This display was chosen because literature suggest that using an

occluding monocular display is not significantly different than using a traditional monitor for simple reference tasks (Peli, 1998; Laramée and Ware, 2002). Also, an occluded monocular display enabled users to place the image within their bifocular region. The current technology for transparent monocular displays offers limited freedom with this respect.

2.3 Dependent Variables

Four general dependent variables were considered: muscle activity, posture, performance, and discomfort and usability perceptions. Details for each of these are provided.

Muscle Activity. Muscle activity was collected using surface electromyography (EMG) during each test session using standard clinical procedures. EMG surface electrodes (10mm, Ag/AgCl pregelled bipolar electrodes) were attached in a bipolar arrangement over the sternocleidomastoid in the neck; the trapezius, levator scapule, and rhomboid major muscles of the shoulder blade region; and the multifidi-erector spinea complex muscles of the lower back of the dominate side of participants according to recommended procedures (Perotto, 1994). Preparatory procedures included shaving excess hair from the electrode attachment site, slightly abrading the skin with a polishing stone, and cleansing the area with alcohol. Electrodes were attached and following a 10-minute stabilization period impedance was checked (required to be less than 10k Ω for each electrode pair) using a standard multimeter. Resting EMG signals were captured while the participant stood relaxed for a 6 second period. For the neck muscle, a submaximal exertion was performed by having participants bend 90° from the waist (with the back and neck in alignment) while supporting a 3 lb weight that was suspended from the head. For the shoulder muscles and back muscles, participants completed maximum voluntary contractions (MVCs). Participants grasped a height adjustable handle, stood erect with their arm resting at their side, and performed a shrugging motion with their shoulder to elicit shoulder muscle activity. For the low back, participants were seated in a backless chair with a strap around the chest attached to a wall, and performed an extension exertion (leaned backwards from the wall). For all MVCs and the neck submaximal exertion, three, five second exertions using a ramp-up, ramp-down procedure with a 30 second rest period between exertions were performed. The maximum value obtained for each muscle, regardless of MVC task was used as the MVC for that muscle. Task EMG data were collected continuously during digitizing. All data were sampled at 256 Hz, pre-amplified, RMS converted, and filtered using a Butterworth filter (Noraxon Telemetry 2400R and MyoResearcher Software, 13430 N. Scottsdale Road, Suite 104 Scottsdale, Arizona 85254). Task EMG data were normalized before analysis. Again, the maximum value observed for each muscle will be used in data normalization. Mean percent of maximum was used to investigate muscle activity differences between task conditions.

Posture. A 12-camera motion capture system (Motion Analysis, EVaRT 4.6, 3636 N. Laughlin Road, Suite 110 Santa Rosa, CA 95403) was used to capture operators' motions. Participants wore a suit that allowed for the attachment of markers via

Velcro. A standard full-body marker location protocol was used to facilitate analysis using ergonomics analysis software and methods. Motion data was collected at a rate of 60Hz.

Performance. Data collected by the subjects using the laser digitizer was analyzed using the companion software Geomagic, developed for post processing of digitized data. Specifically, the amount of missing data (holes) in terms of area and number of missing elements were used to determine differences between scanning sessions. Time to capture data was monitored and the number of bumps was recorded. While digitizing, it is important that the operator not bump the specimen, specimen support, or the digitizer itself. Doing so translates into a shift of the actual geometry of the specimen, thus creating a digital shift in pre vs. post disturbed geometry. Any disturbance classified as a bump will require the operator to start over at the beginning of the digitizing process. For this study, bumps were recorded, however the participants were instructed to continue digitizing as though the bump had not occurred.

Discomfort and Usability. Participants completed a body discomfort map at the end of each task condition, and completed a usability questionnaire at the end of the test session. The body discomfort map included a picture of the human body divided into regions (eg, head/neck, upper back, lower back, etc.) with associated visual analog scales (VAS) 10cm in length with the anchors of “No discomfort” to “Extreme discomfort”. Participants placed a vertical mark on each VAS scale to indicate the level of discomfort they were experiencing. Participants completed a usability questionnaire that contained questions pertaining to their perceptions of the digitizing equipment and the use of the monocular display. Participants rated a series of questions on a 5 point Likert-type scale ranging from 1 = strongly disagree to 5 = strongly agree.

2.4 Task

The task consisted of digitizing a small teapot using both task conditions. Participants continued digitizing until they indicated that they were finished. No feedback was provided to participants on performance during testing.

2.5 Participants

Ten participants (6 males and 4 females), ranging in age from 19 to 31 years completed study protocols. Participants were required to be free of arm, neck, and back injuries as evidenced by self report and have no history of motion sickness to be eligible to participate.

2.6 Procedure

Participants completed informed consent documents prior to data collection. EMG electrodes were applied and impedance checked prior to the attachment of the motion capture suit. Following motion capture calibration, a familiarization session was conducted in which participants practiced using a FARO brand articulated digitizer to

scan a small object both with and without the use of the monocular display. Feedback on performance was provided. Participants then completed the two test conditions, were debriefed, and monetarily compensated for their time.

2.7 Data Analysis

Appropriate descriptive statistics were computed. A repeated measures ANOVA was performed to tests for differences between task conditions on the dependent variables. SAS 9.1 software was used for all analysis. As this was an exploratory study, an alpha level of 0.10 was used to determine significant findings.

3 Results

Table 1 presents the descriptive statistics for this study. In general, there is a trend for more favorable readings for the monocular display (i.e., mean muscle activity was lower for the monocular condition.

Table 1. Descriptive statistics. Values are mean (standard deviation).

Variable							
EMG (% MVC)	Mono	Trad	Sterno	Trap	Leva	Rhom	MES
	30.81 (24.73)	34.94 (37.48)		37.07 (48.85)	24.57 (13.07)	51.94 (28.48)	29.42 (24.11)
Posture							
Body Discomfort	Data analysis ongoing						
	Mono	Trad	Sh/Am left	El/Fo arm left	Hip	Wrist /Hand left	Thigh/ Knee left
	13.38 (18.91)	12.57 (17.52)	8.76 (11.12)	15.47 (23.22)	4.42 (6.00)	9.80 (14.15)	5.83 (5.62)
	Leg/Foot left	Head/N eck	Sh/Am right	Lower Back	El/Fo arm right	Wrist/H and right	Thigh/ Knee right
	5.16 (7.98)	9.29 (10.49)	18.65 (14.56)	20.99 (22.04)	26.62 (25.43)	26.71 (27.48)	11.23 (20.38)
	Leg/Foot right						
	5.76 (9.43)						

Mono = monocular display, Trad = Traditional Display, Sterno = sternocleidomastoid, trap = trapezius, Leva = levator scapule, Rhom = rhomboid major, MES = multifidi-erector spinea complex.

3.1 EMG and Posture

No significant differences were found between the task conditions for any muscle investigated ($p=0.6253$). There were differences found among the muscles ($p=0.943$), with the rhomboid major being the most active and the sternocleidomastoid being the least active. At this time, posture data is unavailable.

3.2 Usability and Discomfort

Discomfort ratings were not found to differ significantly across conditions or for any condition ($p=0.6491$) by body part interaction (0.9355). There were significant differences across body parts, though this was expected. In general, lower back, elbow and forearm right, and wrist and hand right were found to have significantly higher ratings of discomfort than the other body parts.

3.3 Performance

The data collected by the participants was shown to be almost identical to one another. This is not surprising, because the participants were instructed to digitize the models as completely as possible. Bumps were recorded, however there was not enough data collected to be analyzed in any meaningful way.

3.4 Discomfort and Usability

Usability ratings are presented in figure 1 below. Six questions were found to have significantly higher usability ratings. Four of these questions asked participants if they preferred the monocular display over the traditional laptop, or that the faro arm was more comfortable to use with the monocular display. The remaining two questions asked about improved performance with additional practice for the monocular and traditional display, and both received ratings well over 4 (agree). Two additional

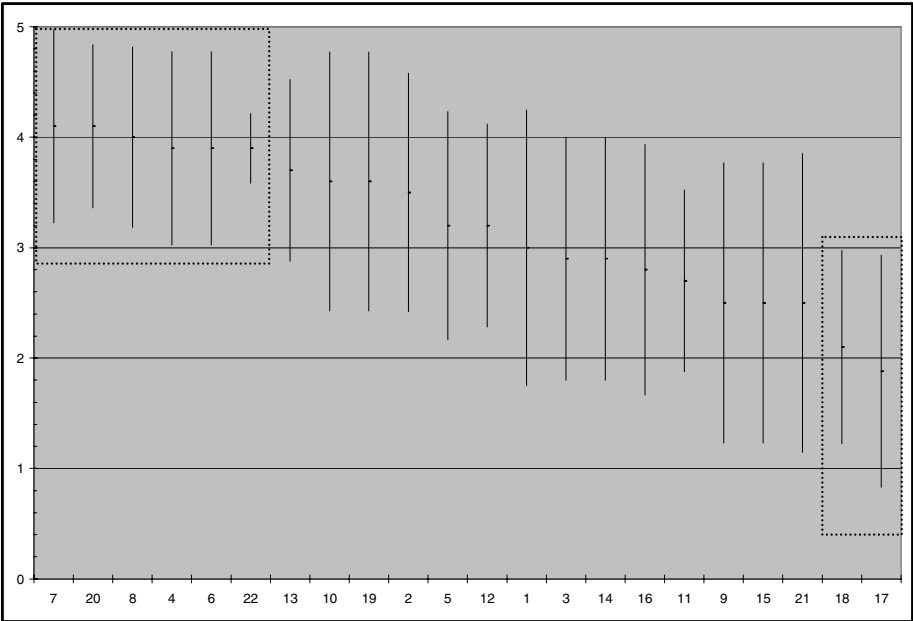


Fig. 1. Participants Responses to Survey

questions received significantly lower responses than the others. These two questions, which had average ratings near 2 (disagree) asked participants if they would be comfortable scanning with the FARO arm for 8 hours a day.

4 Discussion and Conclusions

The objectives of this study were to quantify ergonomic exposures associated with laser digitizer use and to assess if the use of an augmented monocular display would improve exposures and performance. Results of this study indicated that significant ergonomic loads are placed on the shoulder, neck, and back musculature. In general, muscle activity levels were near 25% MVC or greater. Studies have found localized muscle fatigue to occur at low levels of muscle activity, particularly when the tasks are static in nature (e.g., Veiersted et al, 1993; Forsman et al, 2001). Further, these levels of activity were associated with relatively static postures and positions. Subscribing to the Cinderella hypothesis (Hägg, 1991), damage to the muscle fibers is likely given this task. Further data processing of the EMG data will investigate localized muscle fatigue rates associated with this job task. These findings are supported by the discomfort findings.

Discomfort results indicate that simply using the FARO arm, regardless of display type, results in significant levels of discomfort. Changes in the FARO arm display are needed based on anecdotal participant comments relating to the difficulty in using and supporting the digitizer during task performance.

In general there is some support for the use of an augmented display to improve user perceptions and ergonomic exposures. The sample size for this study however is insufficient to detect differences between the task conditions with sufficient power. Perhaps if experts, rather than novices, had been investigated differing results may have been found. A more comprehensive study is planned to further evaluate the ergonomic and usability effects of augmenting laser digitizers. This type of monocular display seems very appropriate for this type of task as it requires:

1. Frequent to real-time referencing of a visual feed back device.
2. Hands-on application.
3. Environment awareness (in this case, avoidance of the specimen/Faro arm).
4. Physical mobility.

Ultimately, the findings of this study were mixed, with some indication that augmentation to laser digitizers provides benefits to users. However, further studies are needed to explore these findings.

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Work Environment and Health Effects of Operators at Light-on-Test Process in TFT-LCD Plants

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Abstract. TFT-LCD (thin film transistor liquid crystal display) industries have been grown-up in Taiwan. Many workers are at light-on test workstations in TFT-LCD factories. At the light-on test station, the operator has been exposed to the lower ambient illumination (105.10 lx) for a long time (12hour/1day). There are few researches discussed about health effect of workers of TFT-LCD workers. The aim of this research is to measure the illumination of the light-on test station and to collect the work environmental data for exposure assessment. The work environment information of test workstations has been measured such as ambient illumination and illumination of the five types of test color of LCD (red, green, blue, white, gray), visual angle, and visual distance between worker and LCD test board. The results shows that: 1) the light-on test was a long-term operation of lower ambient illumination (4.00 lx to 105.1 lx) and shorter visual distance (28.04 cm to 34.43cm); 2) the means of illumination of LCD board of different test color are 10.90 lx in red, 41.20 lx in green, 18.00 lx in blue, 67.30lx in white, and 13.80 in gray. Light-on test is a task of low ambient illumination, short visual distance and long-term job in TFT-LCD factories. Some workers complained about visual fatigues. Under this working environment, the more working duration workers have the more visual discomfort they complain. Some administration controls have been suggested such as more time of rest, lubrication of eyes by appropriate solution and job rotation.

Keywords: work environment, Light-on-test, TFT-LCD, health effects.

1 Introduction

The TFT-LCD (thin film transistor-liquid crystal display) industry has been quickly rising in Taiwan. Moreover, the Taiwan's global market share of LCD panels has reached about 36% in 2003, which made Taiwan the second leading panel producer, next only to the South Korea¹. The manufacturing of TFT-LCD includes array process (array), panel process (cell) and module assembly process (module). The manufacturers exercise stringent quality assurance and quality control measures, and

the careful inspection of panels plays a very important role in the whole manufacturing process to ensure a high yield rate of products and reduce the costs,. Panels with defects or imperfections can be picked up through strict inspections and then repaired or recycled. Methods of inspecting the panels include: optics instrumental examination, electric instrumental examination, and eyes check²⁻⁴. The eye check (light-on test) is to inspect panel's defects by human eyes. In general, it includes the gross inspection of the panel first, which is followed by inspection of the surface of panel, modules, and the panel's picture display quality by microscopy.

The light-on test is a key of quality control steps during the panel process and module assembly in the manufacturing of TFT-LCD. The test is performed by human eyes, and workers, mostly women, generally carry out the task in a dark environment, which may cause eye strain and even lead to poor eyesight, throughout the shift with limited resting time⁵⁻⁶. At the light-on test station, the operator has been exposed to the lower ambient illumination (105.10 lx) for long time (12hour/1day). There are few researches discussing about health effect of workers of TFT-LCD factories. The aim of this research is to measure the illumination of the light-on test station and to collect the work environmental data for exposure assessment.

Moreover, to make sure high quality and high yield, the TFT-LCD industry places most manufacturing processes in "clean rooms." In clean rooms, the dust particles in the air are controlled to extremely low levels, and the temperature and the humidity are maintained at relatively lower levels in comparison with the general ambient environment in Taiwan. In addition, to prevent the contamination of dusts, clean room workers have to put on special clothing covering the whole body from head to toes⁵. Many operators have complained about eye disorders such as dryness and soreness, but the ophthalmic effects of working in such strictly controlled environments are not clear. To evaluate whether the clean room workers performing light-on tests have a high risk of developing tear secretion dysfunction and eye symptoms, we conducted a study in a TFT-LCD company in Taiwan.

2 Methods

We recruited workers engaged in light-on tests in the company during their periodical health examination. In addition to a questionnaire survey of demographic characteristics and ophthalmic symptoms, we evaluated the tear secretion function using the Schirmer's lacrimal basal secretion test. The work environment information of test workstations has been measured such as ambient illumination and illumination of the five types of test color of LCD (red, green, blue, white, gray), visual angle, and visual distance between worker and LCD test board.

3 Results and Discussion

The white and gray are the original colors or background lights of LCD boards. Operators need to turn on the different colors of LCD to examine the errors or problems on the boards. Meanwhile, the ambient illuminations of the workstations are very low. Table 1 shows the ambient illumination levels of workstations. In LCD

area, the ambient illumination is the lowest (mean = 4.00Lux, SD=0.00Lux). In LCD area, the ambient illumination is very low (mean = 5.5Lux, SD=3.7Lux). The Table 2 shows the operators' visual angles and distance of workstations. The range of mean operators' visual angles is from 18.50 to 26.98 degrees. The range of mean operators' visual distance is from 28.04 to 35.53 cm. The different colors of Liquid Crystal illumine different illuminations levels. In table 3, the means of illuminations levels are 10.90lux in red, 41.20lux in green and 18.00lux in blue at LCD test stations, and 36.49lux in green, 53.35lux in green, and 36.22lux in blue at LCM workstations.

Table 1. Illumination of the workstations

Location of workstation (Number)	Local illumination (LUX)Mean (SD)	Ambient Illumination (LUX) Mean (SD)
LCD (43)	5.50(3.70)	4.00(0.00)
LCM –LOT (28)	639.80(70.02)	32.00(16.12)
LCM –PCBI (15)	106.00(11.66)	119(17.49)
LCM –C test (55)	93.63(33.45)	146.38(33.56)
Sub-summary (98)	161.44(84.28)	129.76(48.46)
Total (141)	130.86(76.29)	105.10(66.50)

Table 2. Operators' visual angles and distance of the workstations

Location of workstation (Number)	Operators' visual angles (degree) Mean (SD)	Operators' visual distance (Cm) Mean (SD)
LCD (43)	22.12(1.05)	34.51(1.52)
LCM –LOT (28)	18.50(4.32)	28.04(7.72)
LCM –PCBI (15)	26.93(8.79)	42.13(5.89)
LCM –C test (55)	24.75(5.41)	35.53(5.3.)
Sub-summary (98)	22.30(6.52)	34.40(7.71)
Total (141)	22.94(5.48)	34.43(6.47)

But, at workstations in LCM-PCBI area, the illuminations levels of colors from LCD boards have not been measured.

In table 4, the means of illuminations levels are 67.30lux in white and 13.80lux in gray at LCD test stations; and 36.49lux in green, 53.35lux in green, and the means of illuminations levels are 83.71lux in white and 41.32lux in gray at LCM workstations.

All the 319 qualified workers agreed to participate in this study, and they were all females working by 4-shift rotations. The average age was 24.15 years old (standard deviation [SD] =3.78), and the average employment duration was 13.63 months (SD = 5.65). Among the 11 ophthalmic symptoms evaluated, eye dryness was the most prevalent (prevalence = 43.3%). In addition, the prevalence of tear secretion dysfunction was 40.1% (128 cases), and contact lens users had a relative risk of 1.73 (95% confidence interval = 1.02—2.94) in comparison with non-contact lens users. Comparing the Schirmer's test results of those who also participated in the screening in the previous year, we found 40 of the 156 participants (17.2%) with normal test

results in the previous year turned abnormal in 2001. In contrast, only 21 of the 76 participants (9.1%) with abnormal test results in the previous year turned normal, and the difference was statistically significant ($p = 0.02$ for McNemar's test).

Table 3. Lamination level of red, green & blue colors from LCD board

Location of workstation (Number)	Lamination level of red	Lamination level of green	Lamination level of blue
LCD (43)	10.90 (2.60)	41.20 (10.21)	18.00 (5.29)
LCM –LOT (28)	10.80 (3.56)	21.00 (6.71)	8.80 (4.09)
LCM–PCBI (15)	-----	-----	-----
LCM–C test (55)	40.50 (13.62)	58.41 (20.82)	40.50 (15.81)
Sub-summary (98)	36.49 (16.35)	53.35 (23.35)	36.22 (18.38)
Total (141)	31.04 (17.96)	50.77 (21.75)	34.34 (18.07)

Table 4. Lamination level of white & gray colors from LCD board

Location of workstation (Number)	Lamination level of white	Lamination level of gray
LCD (43)	67.30(22.27)	13.80(3.39)
LCM –LOT (28)	57.20(23.91)	16.20(7.60)
LCM –PCBI (15)	129.20(38.66)	-----
LCM –C test (55)	80.75(35.66)	45.25(16.16)
Sub-summary (98)	83.71(38.72)	41.32(18.24)
Total (141)	80.56(36.54)	35.47(19.81)

4 Conclusion

The results shows that: The light-on test was a long -duration operation with lower ambient illumination (4.00 lux to 105.1 lux) and shorter visual distance (28.04 cm to 34.43cm); 2) the means of illumination of LCD board of different test color are 10.90 lux in red, 41.20 lux in green, Eighteen lux in blue, 67.30lux in white, and Thirteen and eight tenths lux in gray. Light-on test is a task with low ambient illumination, short visual distance and long duration in TFT-LCD factories. Some of the workers complained about visual fatigues. Under this working environment, the more working duration it is, the more visual discomfort the workers complain about. Some administration controls have been suggested, such as more time of rest, lubricating eyes with appropriate solution and job rotation.

The prevalence of tear secretion dysfunction in woman workers engaged in light-on tests is high and increases with the duration of employment. The use of contact lens may further increase the risk.

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Techno Stress: A Study Among Academic and Non Academic Staff

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Abstract. In the 21st century, the technological momentum has increased far beyond our expectations. Thus, there is a growing perception that rapid advancements in technology are responsible for inducing stress into our lives. Reuters Business Information Services conducted a study of 1300 managers throughout United States, England, Australia, Hong Kong and Singapore, and found out that 33% reported ill-health as a result of information overload and 66% reported increased tension with work colleagues and diminished job satisfaction caused by information overload. The literature suggests that while new technologies may offer many benefits, they may also contribute to increased job stress and strain. Information overloads and multitasking, both associated with ICT (Paoli [1]), may create stress by contributing to work overload. The adoption, rapid diffusion and evolution of ICT have introduced a number of new demands into workplace that leads to job stress. Technology stress (Techno Stress) can be defined as a modern disease of adaptation caused by an inability to cope with new computer technologies in a healthy manner. Clear symptoms of Techno Stress include inability to concentrate on a single issue, increased irritability and feeling of loss of control. The study was conducted among academic and non academic staff in order to measure the level of their stress. Besides, it aims to identify the difference of stress level between academic and non academic staff, and the difference of gender in term of stress. Looking at the negative impact of ICT, this study is very important that enables the researcher to identify the stress related its usage. Furthermore, findings might be used to guide psychologist, counselor and other professional to outline strategic planning dealing with Techno Stress. 80 respondents from Pulau Pinang and Terengganu completed questionnaires comprises demographic section (8 items) and 47 items on Personnel Techno Stress Inventory (PTSI) previously used by Weil & Rosen [2] with reliability 0.71. Domains of Techno Stress can be classified as learning, border, communication, time, family, workplace and community. The instrument was revised, simplified and finalized according to the result of pilot test. The result reliability using Cronbach's reliability was 0.61. Result shows a moderate level of stress among the respondents. There is no significant difference of stress in term of gender and occupation (academic and non academic staff). Limitations of the study and suggestions for further research are discussed.

Keywords: Technology, Stress, Academic, Non Academic, Staff.

1 Introduction

In this information technology era, computer acted as an important tool in our daily life. Advance technology and computers ease our daily activities and life without it seems so troublesome. Schwerm and Benedict [3] state that 50-70 % of job in US are related with computer use and no doubt the figures double in 21 century.

However, working with computer can sometimes be stressful. Selye [4] states that stress is unavoidable in life and no individual will spare from stress. Much of our stress in life comes from conflicts and interpersonal difficulties we encounter with other people. While the computer world may give us the illusion of working alone and isolating ourselves from others, this is not really the case. There are many types of computer related conflicts and stress could arise on any of these conflicts. Symptom of stress may vary and numerous studies showed that used of computer would definitely cause stress. Besides, Ekman, Andersson, Hagberg & Toomingas [5] found that computer use was associated with both physical and psychological complaints. For instance, increase report in depression has been found among internet users, Kraut et al [6].

1.1 Definition of Techno Stress

Craig Brod [7], a psychologist consultant in new technology adaptation field, introduced a new terminology related to stress due to computer use. It is call techno stress. In his book, entitle Techno Stress: The Human Cost of the Computer Revolution, techno stress is defined as a “modern disease of adaptation cause by an ability to cope with computer technologies in healthy manners”. Symptoms of techno stress start with apprehensive feeling toward computer use that may lead to anxiety and stress. Unattended, anxiety may evokes psychosomatic symptoms such as muscle cramp, headache, joint pain, insomnia and other physical well being.

Furthermore, Arnetz & Wikholm [8] described techno stress as the state of mental and physiological arousal observed in persons who are heavily dependent on computers in their work. The term ICT stress also has been used in related study (Johansson Hiden et al [9]) to describe the stressor related to ICT that is information overload.

1.2 Definition of ICT

The term ICT consists of a variety of technologies, techniques and equipment. Bakker [10] defined technologies are among the most widely diffused, commonly employed and fastest growing media such as cellular telephones, computer, electronic mail, and internet, However, this study focuses primarily on the using of computers during the work.

1.3 Objectives of the Study

This study aimed to:

- i) Examine the level of stress among non academic and academic staff in dealing with computer in their daily work

- ii) Examine the difference of stress level between non academic and academic staff
- iii) Identify the difference of stress level among male and female respondents.

2 Materials and Methods

Subjects

The data for this study were collected from 63 non academic staff but fully involved with information and technology task and 30 respondents are IT lecturers. The study adopted random sampling approach. Both respondents fulfilled the research criteria which needs the respondents that exposed to technology in their daily work.

Research Instruments

Data was collected by using closed ended questionnaire comprises of two sections. The first section includes 8 items on demographic background of the respondents such as gender, age, educational status, and tenure. The second section aimed to measure technology and stress correlation. The technology stress questionnaire was adapted from Personal Techno Stress Inventory, Weil & Rosen [2] with reliability of 0.71. This section contains 47 items from 7 different domains such as learning, border, communication, time, family, workplace and community. A pilot test was conducted to 50 staff. The questionnaires was revised, simplified and finalized according to the result of pilot test. The result reliability using Cronbach's reliability was 0.61.

Analysis

The Statistical Package for Social Sciences (SPSS) was used to analyze the data. Descriptive statistics were used to provide respondents' profile. The correlation was applied to look at the relationship between chosen demographic variables such as education with stress working with information technology. Besides, t-test was conducted to look at the difference on stress level in term of job category (academic and non academic) and gender.

3 Results and Discussion

3.1 Demographic Data

Table 1 revealed the demographic data of the respondents. It indicates that 32.5% (N=26), were male and 67.5% (N=54) were female. The age of respondents, 42.5% (N=34) of them are between 23 to 30 years, 32.5% (N=26) between 31 to 38 years, 6.3% (N=5) between 39 to 46 years, 17.5% (N=14) between 47 to 54 years and 1.3% (N=1) were between 55 years and above. In term of marital status, 77.5% (N=62) were married and 22.5% (N=18) were single. Majority of the respondents (48.8%) passed their Malaysian Certificate Exam (MCE), 3.8% (N=3) were certificate holder,

11.3% (N=9), 8.8% (N=7), 27.5 % (N=22) were diploma, degree and master respectively. Most of the respondents involved in the study had joined their profession 5 years and above (78.8%). 8.8% (N=7) between 1 to 2 years, 6.3% (N=5) between 3 to 4 years and 1.3% (N=1) between 4 to 5 years. 70% (N= 56) were non academic respondents and the rest 30% (N= 24) were lecturers.

Table 1. Composition of respondents with respect to gender, age, marital status, educational background, tenure and job category

Variable	Percentage (%)	Number of respondents (N)
Gender		
Male	32.5	26
Female	67.5	54
Age		
23-30	42.5	34
31-38	32.5	26
39-46	6.3	5
47-54	17.5	14
55 and above	1.3	1
Marital Status		
Married	77.5	62
Single	22.5	18
Educational Background		
MCE	48.8	39
Certificate	3.8	3
Diploma	11.3	9
Degree	8.8	7
Master	27.5	22
Tenure		
Below 1 year	5	4
1-2	8.8	7
3-4	6.3	5
4-5	1.3	1
Above 5	78.8	63
Job Category		
Non Academic	70	56
Academic	30	24

3.2 Level of Stress Among the Respondents

Table 2 illustrates the level of stress among non academic respondents. Majority of respondent, 66.1% (N=37) reported having moderate level of stress. 8.9% (N=5) of non academic staff have low stress level and the rest 25% (N=14) with high stress level. As same as non academic respondents, majority of academic staff, 79.2% (N=19) also demonstrates moderate level of stress. Whereas, 8.3% (N=2) and 12.5% (N=3) reported having low and high level of stress respectively.

Table 2. Stress Level for academic and non-academic respondents

Stress Level (non academic)	Percentage (%)	Number of respondents (N)
Low	8.9	5
Moderate	66.1	37
High	25	14
Stress Level (academic)		
Low	8.3	2
Moderate	79.2	19
High	12.5	3

3.3 Difference of Stress Level Among Male and Female Respondents

Result shows that there is no significant difference on stress level among non academic and academic staff, $t=1.627$, $p>.05$. This study was not consistent with Sonya [11] stated that there was weak correlation between the stress level and computer expertise showed that individuals with computer skills tended to have low level of stress.

Besides, researchers have taken a keen interest in identifying the respondents' stress level in term of gender. The study found that there is no significant on respondents' stress level with respect to gender, $t=-1.635$, $p>.05$. The study consistent with Anthony [12] found that techno stress did not imply any difference in term of gender. Furthermore, the result was supported by Sonya [11] stated that there were no significant differences between males and females in term of techno stress. In contrast with the study by Wijk & Kolk [13][14] reported that in several health survey there were gender differences. Women described themselves as having higher symptoms such as stress.

3.4 Correlation of Stress Level with Respondents' Tenure

With respect to tenure, result indicated that there was a moderate correlation between the level of stress and non academic tenure, $r = 0.423$, $p < .05$. In contrary, there was no correlation among the academic staff. Consistent with Sonya [11] found that techno stress and tenure do not differ significantly among the respondents.

4 Limitation of the Study

Researchers could not generalize the study concerned to all non academic and academic staff. It was limited to one university and one non academic organization. Besides, the number of respondents was not persuaded for generalization.

Furthermore, the study depend solely on questionnaires on Personal Techno Stress Inventory that unable the researchers to explore in depth other related stress factors experienced by the respondents.

Finally, as state earlier there are broad aspects of technology, however, this study deliberately focus on computer technology and techno stress.

5 Suggestions for Future Research

There are several suggestions that could be undertaken for future research.

Firstly, a study could be performed to examine the different personalities of the respondents dealing with techno stress. Further explore the type of personality that successfully copes with stress and vice versa.

Secondly, future research could be done by conducting interviews with respondents to identify other variable that might relate to techno stress. The use of semi structured interview also might help the researcher to enhance the standardized questionnaires.

Finally, researcher might focus on other psychological health effects related to techno stress such as anxiety, phobia and depression.

6 Conclusion

The main findings in this study found that the computer use may contribute unhealthy psychological impact particularly stress. Although, there was a moderate level of stress among both academic and non academic staff, it is essential to identify risk and health factors in relating with ICT to enable preventive and intervening approaches. Employers and organizations concerned have to handle this matter seriously by providing training to staff that equip them with ICT exploration. Understanding techno stress and the ways in which computer affects a person individually might decrease the potential physical and psychological harm.

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Call Centres in the Domain of Telecommunications: Ergonomic Issues for Well-Being Improvement

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Abstract. The present work examines the ergonomic issues of a larger interdisciplinary research on well-being, conducted with a systemic approach in a call-centre pertaining to the domain of telecommunications. The research aimed to define the concept of well-being along three lines of investigation: psychological, medical, and ergonomic and, on this basis, to provide an analysis for improving operators' well-being and performance. The paper analyzes the ergonomic issues, which have been investigated in relation to the aforementioned lines, and, in the final phase of the research, included in a common tool of quantitative survey submitted to 421 operators.

Keywords: call centres, well-being, ergonomic work analysis.

1 Introduction

In the latest two decades call centres have rapidly expanded in many countries as a largely adopted communication system between companies and customers, providing not only customer services via inbound calls, but also sales opportunities via outbound calls.

Parallel to call centre development, we have assisted to an increasing demand of enhanced well-being in office work that has encouraged research into available advices and guidelines for improving both physical and psychosocial working conditions [1][2][3].

The focus of our work is on the ergonomic issues of a broader interdisciplinary research (involving also psychological and medical issues) aimed at defining the concept of well-being and promoting the improvement of the well-being and performance of operators in a large call-centre in the telecommunication sector.

The first step was an in-depth analysis of laws, standards, scientific literature, and documents from research centres and international agencies for health and safety, aimed at identifying the main factors influencing working well-being.

We also examined many researches on stress, such as the European Commission document "Guidance on work-related stress - Spice of life or kiss of death?" [4], which suggested considering the Kasl [5] classification of stress factors, and the

Luxembourg Declaration [6] on workplace health promotion, subsequently changed into the Tokyo Declaration [7]. Less frequently in literature are presented studies on the factors that enhance health and well-being work conditions in call centres [8][9].

In the latest years also ergonomics has increasingly shifted focus from the binomial “reliability-safety” to “quality-well-being”. Nevertheless, the definition of organizational well-being in the ergonomic literature is far from univocal and studies on the topic are scarce [10]. In this light, Davis & Moro’s proposal [11] proves particularly interesting in that it is both coherent with normative definitions and easily applicable to the specific topic of call-centres. Their proposal refers to the “Balance Theory” by Smith & Carayon [12], subsequently reworked in Carayon & Smith [13].

The “Balance Theory” suggests a systemic approach and pursues the goal of enhancing performance, health, and safety and reducing stress and its negative consequences on health by balancing the various elements of the work system, i.e. including positive aspects capable of counterbalancing negative aspects that are relatively unchangeable. Due to the fact that physiological and psychological reactions interact and may mutually reinforce one another, considering a limited number of factors might prove misleading and ineffective.

2 Materials and Methods

The research design was structured into 4 main phases:

1. Preliminary interviews
2. Qualitative data collection
3. Preparation and administration of a questionnaire
4. Data analysis

2.1 Preliminary Interviews

To get a better knowledge of the telecommunication call centre analyzed in our research, we carried out preliminary interviews to organizational managers, to the head of the company’s service of prevention and protection, and to workers’ representatives. These preliminary data enabled us to collect information about the organizational structure of the centre, the shift patterns, the selection and training of operators, and possible reasons for discomfort. Furthermore, this information permitted us to fine-tune the following qualitative phase of data collection and to identify operators belonging to homogeneous groups based on their position within the call centre (operators, team leaders, supervisors), on their work activity (front-office, back-office, private or corporate clients) and on their physical location.

2.2 Qualitative Data Collection

This phase was conducted by means of interviews, focus groups, periods of observation, and data collection through checklist.

As far as ergonomic issues are concerned, an analysis of work activities was carried out through interviews and two kinds of observations, the former focusing on cognitive and organizational aspects, the latter on postures and movements.

Individual interviews were conducted with six key professional figures identified in the preliminary phase. We investigated routine activities, non-routine activities, interaction among colleagues and with superiors, customer typologies and procedures for managing the different requests or offers, gaps between expected and actual activities, equipment and software usability, formal and informal information and communication systems.

Four full-time operators were observed throughout their work shift. Such observations of cognitive and organizational aspects provided data on the following areas:

- interaction with the computer: number of programs used simultaneously by the operators, operational fluency, technical or organizational interruptions, difficulty in looking up information, mental-workload indicators (errors, interruptions);
- use of support tools other than the computer, even of a personal type, personalization of the workplace;
- characteristics of the task, work pace and break management;
- communication modes: verbal/non-verbal expressions during communication with the client, exchanges of information among operators and with superiors, shift handover.

Posture and movement observations were conducted on a sample of nine full-time operators, selected in order to represent the full extension of anthropometric variability of the call-centre population. The choice of a reduced sample is due to the need to adjust intervention to the time and resources allotted, and to the explorative character of this qualitative research phase, useful to fine-tuning the quantitative tool.

The following tools were employed for collecting information:

- a general checklist in which are analyzed the working environment (number of workplaces/rooms, room dimensions, colours, curtains etc), general and local lighting, noisiness, microclimate, tools (seat, footrest, table, monitor, keyboard, mouse, headphones), service and refreshment areas.
- an observation grid for operators' postures and movements, sampled at one-minute intervals throughout the working day.
- a file for each workplace containing information on the seat adjustment, on the positions of the monitor, keyboard, mouse, footrest and also reports of any physical pains or problems with a number of body parts experienced by operators.
- ethnographic notes on the behaviour both of the nine operators and of their room colleagues in relation to the built environment.

The aforementioned observation grid was prepared based on the analysis of the literature and reference laws in order to ascertain whether operators tend to assume an incorrect posture and whether they tend to vary their postures during work shifts. We decided to observe at fixed intervals whether operators: look at the screen, keyboard, papers or focus at a distance $>2\text{m}$; keep their neck straight, hyperextended, lateral flexed or rotated, and their head supported by the non-dominant limb; keep their trunk straight, or rotated; keep their back bent or supported; keep the shoulder of the dominant hand straight, extended, flexed or abducted; keep the forearm suspended or supported by the seat, table or body; keep their elbow extended, their wrist straight extended or flexed; keep their dominant hand on the mouse, the keyboard, or writing

on paper; sit on the edge of the seat, their legs crossed, their knees extended or flexed; interact with other operators, stand or move.

Given the impossibility of observing a complete work shift in one day at one-minute intervals, we decided to split the observation of a full-time work shift into two days: half a work shift in one day and the following half on the next day, in order to enable the observer to maintain attention constant throughout the observation period.

By means of on-the-spot explorations we collected data concerning different characteristics of workplaces, which we compared to the “best practice” characteristics described in the technical ergonomic literature [3].

2.3 Preparation and Administration of a Questionnaire

The analysis of qualitative data enabled us to detect the critical areas to be analyzed in the following phase of quantitative research. The questionnaire was devised based on an in-depth analysis of the scientific literature [14][15][16][17][18][19][20] and on an examination of the detection tools built by research centres and international agencies for health and safety in the workplace (OSHA, NIOSH, I.L.O., T.U.T.B, INRS, Unité Hygiène et Physiologie du Travail dell’Université Catholique de Louvain). We also considered quantitative detection systems used in research into call-centres [21][22][23][24][25][26][27]. From this analysis emerged that the tools available in literature about stress did not allow to tackle exhaustively many of the issues that had proven crucial in the qualitative research phase, e.g. the association between enhancement of competence and well-being, or efficacy of the information system.

As for the usability of technical equipment, we adapted to the call-centre environment some items from three of the most noted and reliable questionnaires in the field of assessment of interface usability. [28][29][30].

The final questionnaire contained a total of 73 questions structured into 8 sections:

1. Personal data: the respondent’s age and gender, family, professional position
2. Psychological well-being, with test items concerning satisfaction with life and emotional experiences at work as well as in life in general
3. Physical well-being, with items concerning general health state (headache, concentration difficulties, fatigue, eyestrain, hearing and voice disorders, skin problems, insomnia, stomach ache, nervousness), specific symptoms and problems in different body parts (neck, shoulder, wrist, back, ...)
4. Coping style
5. Physical characteristics of the working environment (lighting, appearance, temperature, space) and of the workplace (layout and equipment); possibility of adapting the workplace to operator’s specific needs
6. Relations of the individual with the organization and work: meaning of work for the subject and possibility to find an equivalent in the work context, satisfaction with several dimensions of organized life (assessment, communication, equity), trust in relationships, commitment and conflict between work and life
7. ergonomic analysis of work activities
8. assessment of company’s initiatives for promoting well-being.

As far as point 7, we explored the following dimensions: task characteristics (cognitive load, work pace, repetitiousness and parcellisation of the activities,

ambiguous and complex procedures, problem-solving modalities, client management, discretionality and control over one's work); organization (cooperation between colleagues and superiors, availability of adequate resources, adequacy of communication and information, adequacy of training); competences (gap between foreseen and actual activity; role attributed to experience with client management, the company's interest in enhancement of competencies); technical equipment (efficacy, efficiency and satisfaction).

A self-completion questionnaire was administered to the 456 call-centre operators. The questionnaire was filled on paper, in the presence of the research group and during working time, by subgroups of 10 to 20 persons. Most respondents completed the task in less than one hour. The response rate, which turned out to be 92 percent, makes the results highly representative. The data elaboration is yet to be completed: at the moment we propose some descriptive statistics of significant correlations between the main variables in object.

3 Data Analysis and Main Results

3.1 Qualitative Phase

Based on the results of the qualitative phase, the dimensions of the work areas – composed of rooms with 16 workstations, proved adequate. Each operator has the use of 6 m² at disposal, the layout is ergonomically correct and well-organized and the VDT workplaces are at a 90° angle to Venetian-blinded windows. The wall colours are also appropriate, neither too light nor too dark: no contrast or reflection in the operator's visual field emerged from the observation.

Operators can look out the window from their workplaces and focus at infinite distance without changing posture. All subjects reported pain in some body parts, firstly in the lower back and secondly in the upper back, neck, right wrist, right shoulder and knees/legs.

Operators spend most of their working time - 86,1% - in a sitting posture, while they spend the remaining 13,9% standing (still or in motion). The tendency to remain in a sitting posture is higher in the first fraction of the work shift than in the second, as if postural restlessness was a sign of tiredness or impatience with the ongoing activity.

The need to alternate sitting posture with periods of standing or motion is probably due to the tiredness from the day that makes operators impatient with the VDT-posture constrictiveness. The observation of communication styles confirms this hypothesis in that operators speak faster, are less helpful, and reduce the offer of services to the clients while the number of errors (wrong reading of phone numbers, wrong writing of e-mail addresses, unintentional calling up of programs) increases.

We observed how long subjects tend to maintain correct postures, above all those with straight neck and head, straight trunk, back leaning on the seat and dominant shoulder/arm straight, non-suspended forearm, non-extended elbow, straight wrist, sitting not at the edge of the seat, uncrossed legs. Subjects tend to maintain such postures for a limited amount of time (5.1%), while others never do. The main criticalities concern the posture fixity, the generalized assumption of incorrect postures, and the accumulation of fatigue reported in the second fraction of the shift.

Such aspects are typically associated with musculoskeletal disorders and may explain the relevant incidence of muscular problems reported by the operators interviewed.

From the results of the qualitative research emerged that, despite being often compared to assembly-line work, call-centre work is a complex activity, requiring remarkable competencies, from both a technical and relational point of view. The operators point out that their job demands coping with problems and focusing on several tasks and requests simultaneously, without any autonomy in tasks assignment and work-pace regulation.

The time pressure is emphasized by the decrease of after-call working time (ACW). Given that ACW activities need be performed, they end up being included in the phone call, thus giving rise to double-task moments. Another criticality is the update management, a crucial element to ensuring the quality of the response to the client. Operators state not having time to read e-mails containing updates, which are often numerous and extensively written (up to 10 pages), therefore unfit for quick scanning. Sometimes the time available at the start of the shift is not enough to finish reading before phone calls start.

The difficulty to manage the updating of information is confirmed by observations: sometimes operators have to block phone calls in order to read updating e-mails, or sometimes they have a colleague or an assistant/co-coordinator quickly summarize new procedures or offers.

We also observed moments in which expert operators anticipated the task's requirements. For instance, calling up all computer programs at the start of the shift permits to reduce waits between the calls. Furthermore, experience gives rise to the ability to anticipate the client's demands (the operator calls up the right programs even before clients complete their requests), to interpret correctly an unclear question, and to ask the assistant for permission to modify a procedure so as to meet the client's request.

3.2 Quantitative Phase

The results of the quantitative phase show that operators in a permanent position have a less positive view of work than those in a temporary position; the length of service determines an increase in the perception of general (correlation $+0.365$) and specific ($+0.247$) symptoms. Operators in temporary positions have an even better perception of their state of health.

A large percentage of subjects (88.5%) report symptoms of a general type (fatigue, visual tiredness, headache and difficulties of concentration, nervousness, restlessness, anxiety, insomnia), which they ascribe to work. Our research shows a highly negative correlation (-0.525) between the presence of general symptoms and satisfaction with the environment, and a positive correlation between general symptoms and workload ($+0.525$).

Even specific symptoms (pain in the back and neck, hearing and voice disorders, stomach ache), ascribed to work by 64.9% of the operators, have a positive correlation with age ($+0.229$) and organizational seniority ($+0.247$). The highest correlation observed among the variables considered with respect to specific symptoms is a negative one (-0.350) between specific symptoms and satisfaction with

the information system (the shortcomings of which had clearly emerged in the qualitative phase).

As far as mental workload, operators report the necessity of managing simultaneous requests (72% medium or high agreement) and information (88.5%). Nevertheless, 79.2% of the operators do not fully agree on the impossibility of stopping paying attention to work, 74.9% states not having any backlog of work, and only 16% states having to complete unfinished tasks.

We paid particular attention to the domain of competence, left relatively unexplored in the literature, probably because apparently it is not required in this type of work. On the contrary, the quantitative research confirms the results of the qualitative research, i.e. a high relevance that operators assign to competence.

The operators (94.3%) are aware of having to repeat the same operations over and over, and describe their activities as very fast (91.1%) and void of discretionality (88.0%); nevertheless, 91.6% of the operators affirm that their job involves learning new things and a high level of competence (71.2%).

Even if the basic strategy is definite (68.2%), 78.5% affirm that there is not a single way to solve problems; according to 68.2% of the operators, experience gives rise to the best solution.

Even if experience permits to devise better work procedures than those assigned (84.5%), operators play a minor role in defining work procedures (67.6% totally or partially disagrees with this statement). The competence acquired with experience is crucial to ensuring performance quality (92.5%) and to dealing with a large amount of work (80.6%). Only 7.9% mentions the possibility of referring to univocal procedures, both because one often has to face unexpected problems (73.9%), and because one has to be able to assess situations and make quick decisions (80.3%).

These descriptive data are confirmed by the highly negative correlation between perceived well-being and the client's dissatisfaction with the service (-.534), a highly positive correlation between perceived well-being and sense of autonomy (+.602), and a highly negative correlation between resources availability and presence of specific symptoms (-.303).

Time constriction negatively impacts the quality of the relationship with clients: 60.8% state not having enough time to do their job properly, a percentage that rises to 88.5 % if we include the operators who partially agree.

There appears to be no time to manage correlated activities, not included in the service offered to the client: 86.1 % have no time available for e-mails, the main source of update and therefore a warrant of the quality of the relationship with the client (on a rating scale from 1 to 4, the answers on satisfaction about time are 1.49, SD= 0.89); it is necessary to find additional time (3.48 on a rating scale from 1 to 4, SD= 0.82). Only 8.6% agree on having adequate means and resources to do their job properly. Only 9.3 % states being able to find the information they need.

As far as the dominant representation of call-centre work as individual work, 93.1% rate collaboration very important. Besides, 83.4% of the operators rate the initiative of assistants/co-coordinators' crucial to facilitate the operators' work.

These associations are confirmed by the first multiple regressions performed on the main variables examined, using the indicators of psychophysical well-being and discomfort as dependent variables and reporting the intensity of the cause-effect link between independent and dependent variable (β values).

While the learning opportunities and the availability of resources are related with satisfaction with work ($\beta.210$), discomfort over the clients' dissatisfaction ($\beta.295$) and lack of information ($\beta.228$) are related with negative emotions at work. When asked about the most urgent thing to improve, 63.0% of operators rated personnel enhancement first place.

As for the interaction with the computer system, 75.1% rates it useful for efficiently managing activities, even though, according to 67.1%, the organization and availability of relevant information could use improvement. The weakest points are error messages (only 6.4% fully agrees on their efficacy) and the system's slowness: only 3.7% thinks the system enables operators to quickly meet the clients' requests. Only 3.8 % believe the system was designed with a view to meeting users' needs.

In conclusion, despite the need for promptness (86.1%) and the repetitiveness (94.3%), this work does not qualify as stressful, as if such characteristics were taken for granted. As a matter of fact, according to 66.9%, stress does not impact on family life and, according to 79.4 % anxiety does not interfere with the possibility to fulfil the family's requests. 86.8% do not consider workload as a problem, or at least not a major one. Even the occurrence of mistakes is compensated by the possibility to make up for them (79.4%). Finally the use of computer programs does not require strong mental effort (59%), and 87.4% of operators believe having the necessary knowledge and capabilities required for the task.

4 Conclusions

The results of the quantitative research confirm what emerged from the first phase of qualitative research, i.e. a contradiction between the company's goal of achieving a quality relationship with the clients and the resources and learning possibilities attributed to operators. The competence increase, in terms of capability to manage the relationship with clients, is not acknowledged in the formal organization of work.

At the level of descriptive analysis this is confirmed by the fact that a large number of operators rate first place personnel enhancement, together with training and update.

Also from the analysis of the correlation of the various dimensions with the measures of psychophysical well-being and discomfort emerges a significant and strong association between the possibility of learning/having adequate resources and perceived well-being. Multiple regression provides further confirmation: the operators' discomfort is explained by unease over clients' dissatisfaction; such unease is caused by the feeling of not being adequately prepared to fulfil the users' requests.

As regression maps show that dissatisfaction with the working environment and with the workplace contribute to discomfort, based on Balance Theory increasing satisfaction with these aspects (which are compliant with law guidelines, but could be improved), may determine a decrease in perceived discomfort.

The research showed that an interdisciplinary approach is necessary for well-being studies. It is not possible to consider separately the different factors that influence the well-being of persons working in such complex organizations as call-centres, but it is necessary to consider the correlations between them.

The centre is currently being monitored in order to ascertain whether, according to the reference model of the Balance Theory, the improvement of some aspects of the physical and organizational environment will significantly affect the satisfaction about environment and work organization, and also the perceived health.

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Health and Performance Consequences of Office Ergonomic Interventions Among Computer Workers

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Abstract. An investigation of the effects of office ergonomics interventions on musculoskeletal health and group performance among computer knowledge workers was conducted. A flexible workspace and office ergonomics training program were designed and created. It was hypothesized that the training and workplace intervention would allow the worker to more effectively use their workspace through increased office ergonomics knowledge and skills. Following the intervention, there was a significant decrease in self-reported musculoskeletal disorders for the experimental group who had a workplace change and received ergonomic training relative to a workplace change-only group and a control group. Business process efficiency analyses revealed that both the workspace and training interventions significantly contributed to reductions in the time required to complete the business processes that were tracked.

Keywords: office ergonomics intervention, performance, musculoskeletal discomfort.

1 Introduction

Organizations in today's world are seeking ways to effectively use office workspaces to enhance individual and group performance and to reduce psychological and physical stress among computer workers, specifically knowledge workers [1,2,3]. As the dependence on computer use increases, concerns have been raised over the potential for an escalation in the incidence of computer-related Work-related Musculoskeletal Discomfort WMSDs. Computer work has been identified as a risk factor for WMSDs in the working age population [4,5]. Several intervention strategies, such as workplace design changes, ergonomics training programs, work reorganization, adoption of new technologies, and workplace change communication programs [3,2,6] may be employed to create workspaces for office knowledge workers. Each of these strategies may have varying effects on employee perceptions of job and workplace satisfaction, stress, performance, and well-being. Field and laboratory research suggests that ergonomics training, workspace and workstation design can prevent or reduce musculoskeletal injuries in an office environment [7,8,9,10,11,12,13,14]. Systemically designed office ergonomics interventions

contribute not only to enhanced worker health and well-being, but also to organizational effectiveness. When a successful office ergonomics intervention program is implemented, one of the many results is an increased ability for the worker to change his/her work environment, leading to enhanced individual effectiveness and the prevention of WMSDs and injuries [8,12,3].

Several studies have demonstrated that giving people more control over decisions affecting their work can enhance physical health and performance [15]. This concept of environmental control has been expanded to include enhancing workers' control over their physical work environment [11,16].

The study aim was to investigate the effects of an office ergonomics workplace and training intervention on self-reported musculoskeletal discomfort, and group performance and business process efficiency. It was hypothesized that the training and workplace design together would allow the worker to effectively use their workplace through increased office ergonomics knowledge and skills. Moreover, these intervention effects would be expected to translate into behavioral changes, for example: re-arranging workspaces, adjusting furniture and accessories, changing computing work habits, thus leading to a reduction in musculoskeletal discomfort and an increase in environmental satisfaction. Three hypotheses were tested in this study: Hypothesis 1: Self-reported musculoskeletal discomfort will be reduced as a function of increased workspace flexibility; Hypothesis 2: The greatest reduction in self-reported musculoskeletal discomfort will occur as a result of both workspace flexibility and ergonomic training. Hypothesis 3: Group performance and business process efficiency will be enhanced as a function of increased workspace flexibility and training.

2 Methods

2.1 Setting and Participants

The new flexible office work environment was created for approximately 750 employees within a large corporate office building (housing about 1750 employees), for a large U.S. management-consulting firm. Approximately 500 employees engaged in identical work, but remaining in traditional office workspaces on other floors of the building, served as the control group. These employees were classified as knowledge workers who used a computer 4+ hours a day. 1135 participants took part in the study. The sample demographics regarding job level consisted of: Partner, (4%); Associate Partner (4%); Manager (29%); Consultant/Specialist (37%); Analyst (24%); and Assistant (1%).

2.2 Study Design

The study design was a quasi-experimental field study design. The experimental interventions consisted of: 1) a new flexible office space with adjustable workstations and a flexible overall facility layout and 2) office ergonomics training regarding the use of the space that supports employee control over how the overall space is used. There were three treatment conditions: 1) "Control" group consisting of employees

who did not receive a new workspace or training; 2) “Workstation-only” (WS) employees who received the new experimental, flexible workspace, and 3) “Workstation + training” (WS + T) employees who received the new workspace and office ergonomics training.

Employees were randomly selected to participate in the training, however participation was limited to employees on two out of the four building floors to minimize unwanted cross contamination or voluntary sharing of the training materials and ergonomic knowledge with other employees. Data were collected simultaneously from all three groups once prior to the office ergonomics intervention, and twice (3 and 6 months) following the interventions.

2.3 Office Workplace Intervention

There were three defined goals of the new workplace intervention project, which were: 1) Create a new concept for work environments that enables higher worker effectiveness, 2) Provide ergonomically designed workspaces that enhance employees’ health and well-being, and support employees’ needs, 3) Increase communication and collaboration among individuals, groups and departments, and 4) Create operational efficiencies through business process effectiveness. The new workplace was architecturally designed to create a sense of openness and to provide natural lighting throughout the workspace. Design issues related to auditory and visual privacy were addressed by installing white noise and moveable partitions. Overall, the layout of the individual workstations was a soft “U” shape and each workstation had adjustable storage and paper management tools. Each workstation consisted of a highly adjustable chair.

2.4 Office Ergonomics Training Intervention

We used an instructional design model, which is based on a systems approach, to create the office ergonomics training. This instructional model consists of five processes: 1) Analysis, 2) Design, 3) Development, 4) Implementation, and 5) Evaluation [16]. In the analysis phase we collaborated with, and interviewed, the company’s corporate safety and facilities managers to identify existing related office health and ergonomics training programs and to determine if workers had been previously trained.

Using the results from training needs analysis, we customized the design of the training program to support the organizational culture, and the existing health and ergonomics programs and policies. The goals of the training were defined as: 1) to understand office ergonomic principles, 2) to perform ergonomic self-evaluation of workspace, 3) to adjust and rearrange one’s own workspace and 4) to understand how to utilize the various workspaces designed to support individual and group work. Overall, the training was designed to incorporate active adult learning models, which allow for a high level of interaction among the trainers and trainees. Several media were used to deliver the training, including group exercises and break-outs. Developed training materials included: a facilitators handbook and a computer ergonomic guidelines (“Ergo-Guidelines”) handout with recommendations and

solutions. Specifically designed e-mail messages provided feedback to the trainees on the results of the knowledge tests, which also served as reminders of office ergonomics principles.

Training effectiveness was evaluated by a training evaluation framework [17]: 1) Baseline Assessment, prior to training, 2) Trainee reaction, 3) Learning, 4) Behavioral changes, and 5) Organizational results (productivity). Results of the second and last training evaluation levels: learning (ergonomic knowledge) and organizational results (self-reported musculoskeletal health, group performance and business process efficiency) will be presented here.

2.5 Instruments

Three methods of data collection were employed: 1) Work Environment electronic surveys, 2) Ergonomic knowledge tests, and 3) Business Process Analysis (BPA). The Work Environment survey contains 10 sections to measure office environment design issues, individual and group performance, and work-related musculoskeletal discomfort. The scales used were adapted from previous office environment studies [18,19,2] where earlier factor analyses revealed these variables. Self-reported musculoskeletal symptoms were determined based on the standardized discomfort questionnaire using a 5-point Likert-type scale [20].

2.6 Business Process Analysis (BPA)

A series of Business Process Analyses (BPA's) data collection efforts were conducted which included interviews with several internal working groups prior and subsequent to the intervention. The purpose of using the BPA approach was to measure the process step time, resources, and the overall elapsed time of repeatable business process. Two internal groups and three business processes (Global financial Reporting (GFR), Project Scheduling and salary administration/performance review) were identified as part of the experimental groups. For the control group, the Quarterly Financial Reporting process was used. To collect BPA data from internal groups, the research team interviewed participants using a general business process-mapping model. Table 1 lists the specific data gathered from each group and for each process.

Table 1. BPA Data Collection Measurements

<i>Measurement</i>	<i>Description</i>
<i>Process Time</i>	The amount of time that is required to complete a process step.
<i>Resources</i>	The individuals (internal or external) involved in the completion and decision making required to complete each process step.
<i>Supporting Technology</i>	The tools, templates and technology used to complete each process step.
<i>Elapsed Process Time</i>	The overall amount of time required to complete a process cycle.

3 Results

3.1 Response Rates

For those who participated ($n=642$), 68% completed all three Work Environment surveys. Data were gathered from all three groups once before, and twice after, the office ergonomics intervention of workspace change and training.

3.2 Learning: Office Ergonomic Knowledge

Results of the pre/post knowledge test revealed a significant 32% increase in overall office ergonomics knowledge ($p<.01$). Significant increases were also observed in the categories of: 1) improvement of body posture 2) the use of ergonomic workstation, chair features and ergonomic accessories and 3) awareness of company ergonomic practices and resources (all at $p<.01$).

3.3 Organizational Results: Individual Self-reported Musculoskeletal Discomfort

Preliminary analyses of the surveys for all groups revealed that, in response to a yes/no survey item regarding experiencing overall work-related WMSDs, there was no significant change observed over time for the control group ($p>.05$). The WS-only group exhibited a moderate 14.1% reduction in reported WMSDs from Time 1 (pre-intervention) to Time 2 (post-intervention; 3 mos. ($p=.10$); however, from Time 2 to Time 3 (post-intervention; 6 mos.), an increase of 18.9% in WMSDs was noted. A significant reduction (47.6%) in overall work-related musculoskeletal discomforts from Time 1 pre-intervention to Time 2 post-intervention ($<.01$) was revealed for the WS+T group, with a further reduction reported from Time 2 post-intervention to Time 3 post-intervention (23.4%). Post-intervention differences for both the WS-only and WS+T groups were significant compared to the control group ($p<.05$). A significant reduction in the overall rated body discomfort (collapsed across 8 body parts) was found for both the WS-only and WS+T groups over time, compared to the control group ($p<.05$). Similarly, significant reductions in upper limb and lower limb rated body discomforts (collapsed across 6 and 2 body parts, respectively) were observed over time for both the WS-only and WS+T groups compared to the control group. A significant difference between the WS-only and WS+T groups for Time 3 was revealed only for the lower limb rated discomfort.

3.4 Organizational Results: Business Process Efficiency

Table 2 presents the preliminary BPA results based on data gathered from the control group and the experimental groups. For the control group, the Quarterly Financial Reporting process was unchanged in both time and quality. It was observed for this group that at both the pre-move and post move levels, the overall amount of elapsed process time of 123 hours or approximately 15 days remained unchanged. This reflects the amount of time required by the Finance Specialist to complete a quarterly finance report. For the experimental group (workstation only and workstation + training), at the pre-move level, the overall amount of elapsed process time measured

was 38.92 hours or approximately 5 days. This reflects the amount of time required by the Finance Manager and Specialist to complete a monthly finance report. However, at the post-move, the overall amount of elapsed time decreased by 4.28% for a measurement of 37.25 hours or just over 4 days. For the experimental group 2, (workstation only and workstation + training), at the pre move level, the overall amount of elapsed process time measured was 8.25 hours or just over 1 day. This reflects the amount of time required by the HR Specialist to staff an employee on a customer project. However, at the post-move level, the overall amount of elapsed time decreased by 15.15% for a measurement of 7 hours or just less than one day. For the experimental group 3 (workstation-only and workstation + training), at the pre-move level, the overall amount of elapsed process time measured was 397.73 hours or approximately 50 days. This reflects the amount of time required by the HR Specialist to complete both the salary administration and performance review process tasks. However, at the post-move level, the overall amount of elapsed time decreased by 4.52% for a measurement of 379.73 hours or just over 47 days. In addition, to further determine whether changes in process time existed following the redesign of the workspace and training, the research team gathered information about the number of times per calendar year the business process was completed, as well as the number of group members (at the pre-move and post move levels) involved in the process. Each group member also rated the overall quality of the process output.

Table 2. BPA Results by Group

	<i>Control Group</i>	<i>Experimental Group</i>	<i>Experimental Group</i>	<i>Experimental Group</i>
Pre-Move Elapsed Process Time	123	38.92 hrs.	8.25 hrs.	397.73 hrs.
Post Move Elapsed Process Time	123	37.25 hrs.	7.0 hrs	379.73 hrs.
%Time Reduction	0%	4.28%	15%	4.52%
Post Move Process Output Rating	5	4	4	4
Process Completed	4 x per year	12x per year	30 x per day	2 x per year

3.5 Analyses of the Effects of the Experimental Workspace and Training on Business Process Efficiency

The effects of the treatment condition on business process efficiency (time to complete a process) was performed. A regression analysis was completed to examine the effects of the two aspects of the treatment. The results indicated that both aspects contributed to reductions in the time required to complete the business processes. Table 3 shows the treatment group and the overall process time saved. The sizes of

the effects of the two aspects of the treatment were roughly equivalent to each other. That is, the experimental group conditions (workspace only and workspace + training) each contributed equivalent amounts of effects in the improvements to process efficiency [Beta = 2.68, $p < .05$, (WS + T) and Beta = 2.49, $p < .05$, (WS only) $R^2 = .226$, $F = 4.68$, $p < .05$]. The two treatment conditions together accounted for roughly 23% of the total variance in the time-savings across the four processes. Reduction in process cycle time was calculated across all four processes that were measured. Percentage of reduction is pre-treatment process time versus post-treatment process time.

Table 3. Treatment Group and Process time

<i>Treatment Group</i>	<i>Reduction in Process Cycle Time</i>
Control	.46%
Experimental Workspace	5.62%
Experimental Workspace + Training	10.55%

4 Conclusions

The study results indicated that trained participants reported that the office ergonomics training was beneficial and that they could apply the information to their work environment. There was an observed increase for the WS+T participants in office ergonomics knowledge and skills in the categories of body postures, ergonomic design features and corporate resources from pre- to post-knowledge test after the training. Trainees exhibited a large, significant increase in knowledge in the categories of body postures, ergonomic design features and corporate resources. Through training, these employees were encouraged to use corporate resources to achieve an ergonomic fit with their new workstations. Participants also gained a high sense of knowledge and awareness of where to go and who to contact concerning the use of their company's corporate resources pertaining to ergonomic and facility adjustments and changes.

The finding that the WS+T group exhibited significant decreases in overall discomfort compared to the control group suggests that training provides employees with the knowledge necessary to use their workstations in a more ergonomic and healthy way. The observation that the WS-only group reported a greater decrease in overall body, upper and lower discomforts relative to the control group suggests that providing ergonomic furniture alone may be beneficial. These results are consistent with the earlier findings of Green and Briggs [21] and Verbeek [22]. The continued reduction of WMSDs over time for the WS+T group suggests that providing ergonomic skills, in the form of training, allows individuals to make appropriate workstation changes, thus reducing the musculoskeletal risks and discomfort associated with computer work.

Results of the business processes analyses revealed the impact that the workspace and training had on reducing the process cycle time. The group that received only the new workspace saw a moderate reduction (5.5%) in process cycle time. Those participants that received the ergonomic training and the new workspace experienced

a rather large reduction in their process cycle time of 10.5%. Interestingly, it appears that these effects are additive; that is, the effects of the training add on to process time reductions, on top of the positive effects of the work environment. Moreover, these study results suggest that the flexible workspace and training were significant predictors of process cycle time reductions. This finding supports the notion that workspace design and training can have positive effects on quantitative measures of organizational output.

Overall, it appears that due to the knowledge gained following the office ergonomics training and workplace design change, knowledge workers were able to appropriately change and adjust their workstation and chair setup as well as use the workplace facility more ergonomically and effectively. These results suggest that the provision of ergonomic skills, in the form of training, allows individuals to make appropriate workstation changes, thus reducing musculoskeletal risks and discomfort associated with computer work and improved organizational effectiveness.

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Splint Effect on the Range of Wrist Motion and Typing Performance

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Abstract. This study examined the splint effect on both maximal range of wrist motion (MROWM) and typing performance (typing speed and error rate). Three types of splints were evaluated, and bare-hand condition was included for comparison. The ANOVA results indicated that wearing splints reduced the MROWM in radial deviation, extension, and flexion, as well as the typing speed. Wearing splints did not change the MROWM in ulnar deviation or typing error rate. Additionally, participants reported subjectively that wearing splints increased the difficulty to type.

Keywords: Splint, Typing, Range of wrist motion.

1 Introduction

The awkward wrist and forearm postures with high repetitiveness and long duration during keyboard operations are recognized as the risk factors contributing to musculoskeletal disorders (MSDs). In order to alleviate incidence rate of forearm/hand MSDs, a number of alternative geometry keyboard designs have been proposed to reduce awkward wrist and forearm postures during typing [1,2,3,4]. On the other hand, splints have been marketed as personal protective equipment for the prevention of CTS in people who work in high-risk occupations, even though there is little evidence supporting the effectiveness of splints in preventing injury. The presumed therapeutic benefits of splinting are immobilization, pain relief, prevention of malalignment, prevention/ reduction of soft tissue shortening and contractures, prevention of soft tissue overstretch, counteracting hypertrophic scars, support of weak muscles, and improvement of function. Commercial wrist splints could lessen the wrist's deviation from the neutral position [5,6], and thus reduce the carpal tunnel pressure (CTP) caused by wrist extension/flexion [7]. Malone et al. [5] indicated that wearing splints could significantly reduce wrist extension during wheeling, but did not alter elbow motion or maximal wheeling speed. On the other hand, Rempel et al. [6] demonstrated that there was an augmentation in CTP while subjects were either wearing splints or performing repetitive tasks as compared with resting, and the influence of a splint on CTP was not significant during the performance of repetitive activities. The CTP was indicated to be higher in CTS patients than in normal people, and any situations causing higher CTP could make CTSs worse [7].

The splints are popular among people suffering from MSDs, such as those operating keyboard frequently. Could the splints affect the typing performance as the splints are worn? Therefore, this paper investigates the splint effect on typing speed and error rate, as well as the maximal rang of wrist motion in radial/ ulnar deviation, and extension/ flexion.

2 Experiment 1: Splint Effect on Maximal Range of Wrist Motion

2.1 Method

2.1.1 Participants

Twenty men and 20 women were recruited. All were right-handed, healthy and free from musculoskeletal disabilities of the upper extremities. Their anthropometric data are given in Table 1, in which the dominant hand was measured.

Table 1. The anthropometric data of the participants of this study

Item (unit)	Gender	Experiment 1 (20 men+ 20 women)		Experiment 2 (11 men+ 11 women)	
		Mean	SD	Mean	SD
Age (yr.)	Male	26.3	3.5	24.5	2.5
	Female	28.3	5.0	26.5	3.8
Height (cm)	Male	172.4	4.3	172.6	5.4
	Female	160.6	5.4	161.8	5.2
Weight (kg)	Male	68.5	10.4	70.7	12.7
	Female	54.8	6.1	55.1	6.0
Wrist circumference (cm)	Male	16.0	0.7	16.1	0.8
	Female	14.8	0.8	14.8	0.8
Hand length (cm)	Male	18.9	0.7	19.0	0.8
	Female	17.2	1.1	17.3	1.2
Palm breadth (cm)	Male	8.2	0.4	8.2	0.4
	Female	7.4	0.4	7.3	0.5
Palm length (cm)	Male	10.3	0.5	10.4	0.5
	Female	9.4	0.5	9.4	0.5
Forearm circumference, relax (cm)	Male	26.0	1.9	26.5	2.2
	Female	23.1	1.7	23.3	1.7

2.1.2 Materials and Apparatus

Three commercial types of flexible splints were selected. Two of them were flexible bands: one just could be wrapped on the wrist (denoted by 'W' splint), and the other could be wrapped not only on the wrist, but also on the palm (denoted by 'W+V-1'). The rest had a volar part, which can be worn on the palm and the band can wrap around the wrist (denoted by 'W+V-2'). Their appearance and characteristics are shown in Table 2. Additionally, a goniometer (manufactured by ISOMED) was employed.

2.1.3 Experimental Design

A balanced nested-factorial design was employed with the factors of gender, participant (nested within the gender), and the splinted condition (the bare-hand condition was included for comparison). The responses were the maximal ranges of wrist motion (MROWM) in extension/ flexion, and radial/ ulnar deviation. The level of significance is set at $\alpha=0.05$.

Table 2. The appearances and characteristics of splints used

Types of splints	W	W+V-1	W+V-2
Model	Special sp-2010	Special sp-2040	Oppo-1084
Size	One-size	One-size	S, M, L, XL
Manufacturer	SPECIAL PROTECTORS Co., LTD.	SPECIAL ROTECTORS Co., LTD.	OPPO MEDICAL INC.
Materials	80%Neoprene Rubber, 10%Coolmax(Polyester) 10%Nylon	80%Neoprene Rubber, 10% Coolmax(Polyester), 10% Nylon	70% Neoprene 15% Nylon 15% Cotton
Appearance			
			

2.1.4 Procedures

Before measurement, all participants were asked to warm up the wrist joint by smooth rotation. The upper arm was beside the trunk and vertical to the floor, whole forearm rested on a table and parallel to the floor. While measuring extension/ flexion, the palm faced down, and palm faced medial as radial/ ulnar deviation was measured. They moved their wrists to a specified direction as possible as they can.

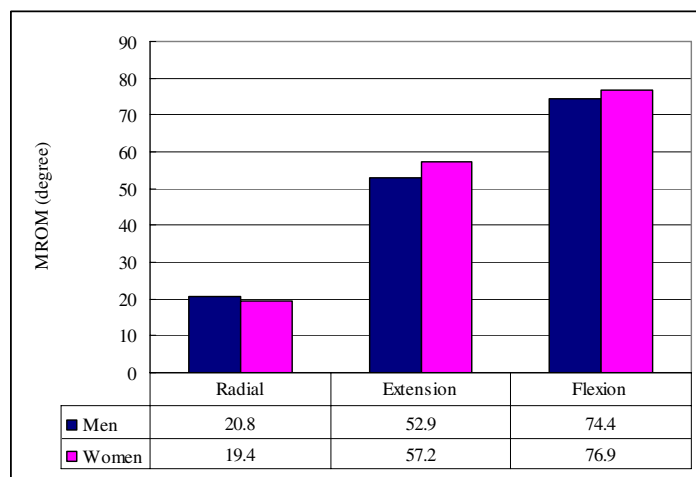
2.2 Results

The ANOVA results are as Table 3 shows. Except for ulnar deviation, gender effect is significant on MROWMs. As the Fig 1 shows, women MROWMs are greater except for the radial deviation. In addition, Fig. 2 displays the splinted effect on MROWMs. The Newman-Keuls method was additionally applied to discriminate the pairwise difference among splinted conditions. The results shown in Fig. 2, in which the same characters means mutually insignificant, demonstrates that all splints reduced the MROWMs significantly, especially those covered the palm.

Table 3. The ANOVA results for MROM

Sources of Variation	d.f.	F-value			
		Radial	Ulnar	Flexion	Extension
Participant (Gender)	38	14.00***	11.10***	16.56***	23.05***
Gender	1	7.27**	0.14	6.40*	25.89***
Splinted	3	51.54***	32.28***	66.46***	67.81***
Gender* Splinted	3	0.87	0.32	2.48	0.04

***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$

**Fig. 1.** The gender effect on MROM

3 Experiment 2: Splint Effect on Typing Performance

3.1 Method

3.1.1 Participants

Eleven male and 11 female participants took part in this experiment. Except two men and one woman, all were selected from the previous experiment. They were all qualified by a 10-min typing test documented by the Taiwan Computer Skills Foundation: typing speed was not less than 30 Chinese words/min and error rate was less than 10%. All were right-handed, healthy and free from musculoskeletal disabilities of the upper extremities. Anthropometric data are given in Table 1.

3.1.2 Apparatus and Materials

The workstation was in L shape, which equipped with a 17" LCD monitor, 73-cm height desk, adjustable chair, and conventional keyboard. The same splints applied in experiment 1 were used again. The software developed by Taiwan Computer Skills Foundation was used to examine the typing performance.

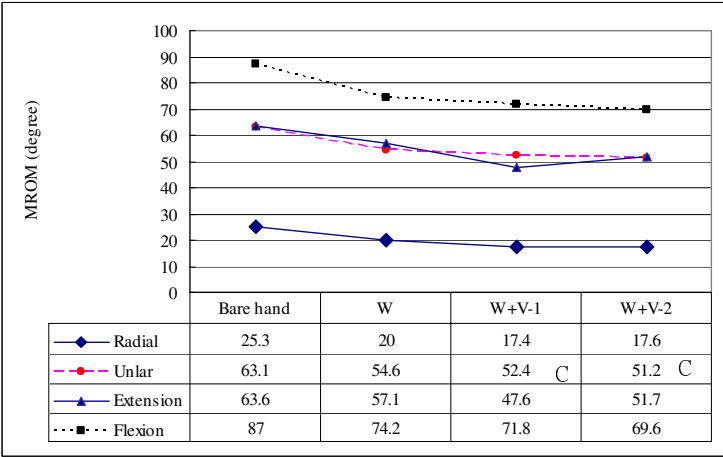


Fig. 2. The splinted effect on MROM (the same characters means mutually insignificant by Newman-Keuls method)

3.1.3 Experimental Design

The same experimental design in the previous was employed. The responses were typing speed and error rate.

3.1.4 Experimental Procedure

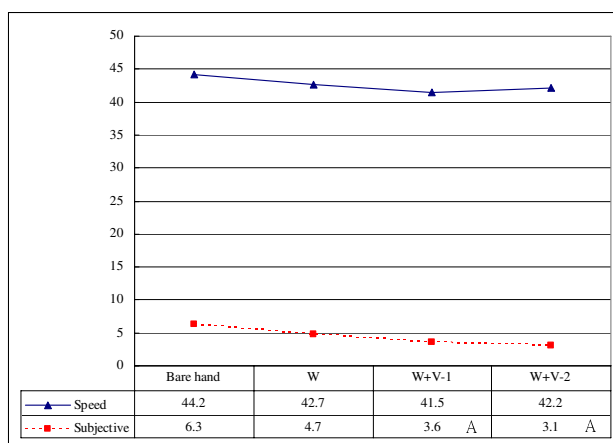
The goals and procedures were also first explained. Prior to type, participants adjusted the chair height to that they felt comfortable, and the document was put on the right side of the participant with a distance of 20 cm from away the edge of table. The distance from eyes to computer screen was 60~70 cm. The same article was used to familiarize participants with the procedure in a 10-min pretest. In order to minimize the learning effect, four different but equivalent difficulty articles documented by Taiwan Computer Skills Foundation were selected and randomly assigned to the four splinted conditions for all participants. During a 20-min formal typing task, all participants were asked to type as fast as they can. A 10-min break was scheduled between successive tasks, and a longer was allowed if participants requested. As soon as a given task was completed, a subjective assessment of how easily to type was conducted based on the Likert's 7-point scale, from 'very difficultly' (1) to 'very easily' (7).

3.2 Results

Table 4, the ANOVA result, shows that splint effect on both typing speed and subjective assessment was significant, but on error rate was not. The significant effects were tested by Newman-Keuls method to discriminate mutual difference. Fig 3 reveals that the bare-hand typing speed is the best (44.2 words/ min). Interestingly, wearing splints or not did not dramatically change the typing error rate. Furthermore, according to subjective assessment, bare-hand condition is considered to be the best situation to type (6.3), followed by wearing "W" splint (4.7), and the other rest two are the worst and not mutually different (3.6 and 3.1).

Table 4. The ANOVA results for typing task

Source of Variations	d.f.	F-value		
		Typing speed	Error rate	Subjective assessment
Participant(Gender)	20	40.77***	6.77***	3.53***
Gender	1	0.53	0.01	0.03
Splint	3	3.22*	0.59	30.76***
Gender * Splint	3	0.20	0.22	0.31

**Fig. 3.** The splinted effect on typing speed and subjective assessment (the same characters means mutually insignificant by Newman-Keuls method)

4 Discussions and Conclusions

Wearing splints constrained the range of wrist motion and constricted the wrist. Both led to a difficulty to operate the keyboard and reduced the typing speed. On the other hand, perhaps wearing splints did not affect the motor skill and/or the typing skill was screened at first, the typing error rate did not shift. Generally, wearing splints decrease the maximal range of wrist motion and increase the difficulty to operate the keyboard. They seem to contribute to lessen typing speed, but not to change typing error rate.

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The Impact of VDU Tasks and Continuous Feedback on Arousal and Well-Being: Preliminary Findings

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Abstract. In the present study the impact of VDU tasks differing in mental load and feedback were investigated in relation to physiological arousal and well-being. Healthy students ($N=37$, age 18-30 years) were included in the study. The subjects were divided in two groups starting with either a standard/feedback version of the Dual task (high task load), or a standard/feedback version of the Stroop task (moderate task load). Presently, we report the preliminary outcomes of this study. Overall, well-being gradually decreased and arousal increased while performing the consecutive VDU tasks. Furthermore, in HRA, mental effort, and subjective arousal a differentiation could be made between the two groups. When subjects commenced with a task with a high mental load (dual task), it had a higher impact on arousal and well-being as a function of time. Feedback did not appear to play an important role on a subjective and physical level.

1 Introduction

In a first step to integrate physiologic and subjective parameters into a 'smart surrounding', a validation study was performed to investigate whether differences in task load and feedback type invoke a differentiation in momentary physiologic arousal and well-being. It is well-documented that working under a high mental workload for a prolonged period of time could be detrimental for general health and may eventually lead to several (psycho)somatic complaints, e.g. arrhythmias, shoulder-pain, excessive fatigue, etc. (Insulander & Vallin, 2005; Leyman et al., 2004; Nooteboom et al., 2001). Little is known about the range of differentiation over time and the impact of performance feedback on physiologic and well-being parameters. In the present study we selected several physiologic assessments to determine their sensitivity on two widely used psychomotor tests. The physiologic measures were selected based on their relation with general physical arousal, repetitive strain injury, and mood. The outcomes of the present study will be used to integrate the most sensitive parameters in a smart or aware office surrounding.

2 Methods

2.1 Experimental Procedures

Healthy students from the TU Delft were measured (age 18-30 years; 16 males, 21 females). Upon entering the laboratory the subjects first engaged in a 5-minute baseline measurement. The first 10-min test bout was either one of two VDU-based psychomotor tests (with or without continuous feedback). The order of presentation of these four test-conditions was balanced over subjects and always included a 5-min resting period inbetween test bouts. In the 5-min resting period the subjects were allowed to do a Sudoku puzzle while remaining in front of the screen. The total duration of the experiment was app. 1 hour and 45 minutes (see Table 1).

Table 1. Overview of the procedures (example)

<i>Time</i>	<i>Procedure</i>
10:00-10:20	Adaptation
10:20-10:25	Baseline assessment
10:25-10:30	Questionnaires/Rest1
10:30-10:40	Dual task 1
10:40-10:50	Rest 2
10:50-11:00	Stroop 1
11:00-11:10	Questionnaires/Rest 3
11:10-11:20	Dual task 2
11:20-11:30	Questionnaires/Rest 4
11:30-11:40	Stroop 2
11:40-11:45	Questionnaires/Rest 5

2.2 Physiology

By means of the Mobi8 polygraph (TMSi, Oldenzaal, The Netherlands) electrocardiography (ECG), electromyography (EMG), Skin Conductance Reponse (SCR), and oxygen saturation in the blood (SaO₂) were assessed. The Mobi8 is equipped with independent 24 bit A-D converters per channel with DC coupled amplifiers allowing DC to 512 Hz (0dB). The sampling rate was 1024 Hz. The following physiologic output indexes were calculated: HRA, HRV (rMSSD), EMG (RMS; representing the strength of contraction of the muscles) of the upper trapezius muscles, SCR level, and SaO₂ (%), of which HRA, rMSSD, and EMG will be reported in this paper. For each parameter 30-s blocks were calculated and averaged over 5 min. blocks.

2.3 VDU Tasks

Two VDU-based psychomotor tests, i.e. Dual Task (DT) and Stroop Colour Word Task (SCWT), were used to assess different aspects of performance. The DT (memory search and unstable tracking) is considered to be a highly challenging test, requiring simultaneous motoric and mental effort (AGARD, 1989). The SCWT is more monotonous in nature as compared with the dual task, but requires sustained attention and high-rate responses (Insulander et al., 2005). In both tests, correct trials were

rewarded, whereas incorrect trials resulted in penalties (monetary gain or loss). In the standard version of the tests the punishment or reward, based on their final score, was shown on the screen immediately after the test bout. In the versions with continuous feedback, subjects were constantly updated on their score and remaining time of the task (see Fig. 1). The Dual and Stroop tasks were presented alternately (Table 1). The subjects were divided in two groups: one group started with the dual-task (DSDS group), whereas the other group started with the Stroop task (SDSD group).



Fig. 1. The dark grey bar represents both the progression of time as the nominal pace of the test. The white bar indicates whether the subjects were either behind or ahead of schedule.

2.4 Questionnaires

Several health aspects were measured prior to the experiment (not reported here). Momentary assessment of well-being included several individual items (e.g. fatigue, frustration) which were assessed on a five-point scale. Additionally, arousal and valence were measured with the self-assessment maniken (SAM) and experienced mental effort was measured with the Rating scale for Subjective Mental Effort (RSME scale).

3 Results

3.1 Physiology

Repeated measures ANOVA showed no significant effects for continuous feedback tasks as compared with the standard version of the tasks, nor was there an effect for sexe. No statistically significant effects were observed for within-task differences (5 min blocks, e.g. T1a vs. T1b, Fig.1). Overall, the physiologic parameters showed the highest arousal scores in the first test bout. A significant Task Order $\times$ Event interaction was observed for HRA ($F_{df13,377} = 3.20$; $p < 0.05$), indicating that if the subjects started with the dual task, it elicited higher HRA values in the first and third test bout as compared with the subjects who first started with the Stroop task (Fig.1a). Irrespective of the task, a gradual decline was observed for HRV ($F_{df13,377} = 9.81$), with clear differences between tasks and intermittent resting periods. A similar pattern was shown for EMG, with relatively lower values during test bouts compared to the resting period, which was confirmed by a significant effect of Event ($F_{df13,390} = 9.92$).

3.2 Well-Being

Most subjective measures showed a significant decrease in well-being during the experiment, albeit that most decreases were relatively small. Figure 2 shows the experienced mental effort. A gradual increase can be observed for the level of effort during the experimental period. Also, a difference between the two groups (task order) was

shown, with higher values after the Stroop task in the DSDS group. Both groups showed higher values on mental effort after performing the Dual task. This was supported by a repeated measures ANOVA, showing a significant effect for Event x Task Order ($F_{df3,105}= 17.712$; $p<0.001$). A similar interaction was observed for subjective arousal ($F_{df3,105}= 5.76$; $p<0.001$). Overall, correlations between well-being and HRA

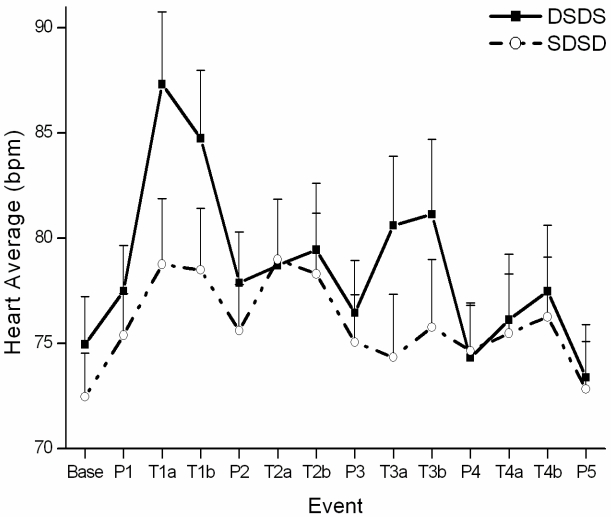


Fig. 2a. HRA of the two groups. DSDS (N=14) denotes Dual, Stroop, Dual, Stroop, SDSD (N=17) denotes Stroop, Dual, Stroop, Dual. Base denotes baseline, P denotes Puzzle, and T denotes test bout.

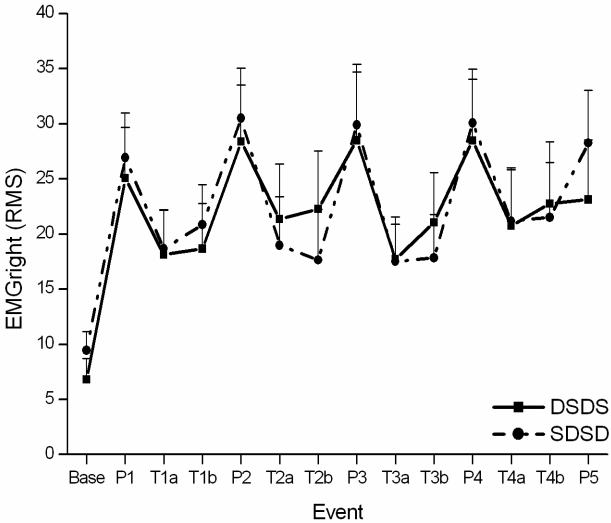


Fig. 2b. EMG (RMS) of the right upper trapezius muscles

parameters on each testing event were moderate (<0.60) and inconsistent. The experienced mental effort, motivation, and boredom seemed to have the most consistent correlations with HRA across the experiment.

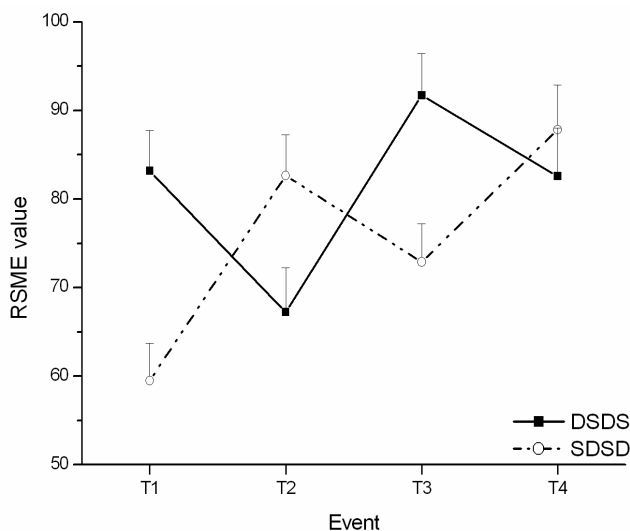


Fig. 3. Rating scale for Subjective Mental Effort: >3 very little effort, >22 little, >38 more than a little, >58 moderate, >71 above moderate, >87 much, >102 very much, >114 extreme. T denotes test bout.

4 Discussion

The preliminary findings of the current study showed a consistent tendency in heart activity parameters, with a sharp increase in physiologic arousal in the first test bout and a gradual decrease during the remainder of the experiment. The order of task presentation appeared to differentiate the two groups with respect to physical and subjective arousal, and exertion of mental effort. Earlier studies have also indicated that a higher task load elicits higher arousal (Gaillard, 1996; Sosnowski et al., 2004). No evidence was found for a difference in reactivity when subjects were or were not exposed to continuous feedback. Also, no apparent variation within the tasks was found for either task, i.e. first 5 minutes vs. last 5 minutes. Overall, a decrease in momentary well-being was found compared with baseline, but this effect was not very pronounced. Contrary to other studies, the present results showed a relatively lower level of muscle activation when subjects were performing a test than when at rest, irrespective of task load (Roe & Knardahl, 2002; Waersted et al., 1991). A possible explanation might be the difference in activity during the testing and resting periods. It is known that a tracking task, for instance, elicits a rather small elevation in trapezius muscle tension (Roe & Knardahl, 2002), whereas during the resting periods, subjects were allowed to do a Sudoku puzzle, possibly bringing forth more movement than the

Dual task or Stroop task. Note that muscle activation was nonetheless higher during the testing periods than during the baseline period.

From these data it could be hypothesized that in individuals who initially have to exert a high level of mental effort (high task load) a higher level of subjective and objective arousal might be expected, accompanied by a decrease in heart rate variability. This will probably have a spill-over effect on subsequent tasks. In parallel, a relative decrease of trapezius muscle tension might be expected when performing tasks wherein a high level of attention and concentration are required. The intermittent resting periods showed a distinctly lower heart rate as compared with the testing periods, accompanied by higher heart rate variability. Thus, intermittent short breaks could already be immediately restorative on a physical level. For prolonged periods of testing a general decrease in arousal and well-being might be expected.

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Effects of the Office Environment on Health and Productivity 1: Effects of Coffee Corner Position

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Abstract. New technology will make it possible to have access to information everywhere. As a result “face to face” communication with colleagues could reduce and creativity and health could be influenced negatively. In this paper a coffee corner is changed and the effect on communication is tested by measuring the number of conversations at the coffee corner. A coffee corner with screens, tables and a possibility to sit, resulted in more conversation than a coffee corner that is open and had no seats. In both coffee corners more than 4 out of 5, were conversations about work. These informal discussions could contribute to productivity as many informal conversations increase creativity. It could also contribute to a better health as social support could reduce stress.

Keywords: health, productivity, creativity, office interior, coffee corner.

1 Introduction

The majority of the working population in the EU and the USA work in offices [13]. A recent study in the Netherlands among 7,022 workers showed that 63,4% use a computer [14] and have an office work station. This means that two third of the working population in the Netherlands now works with computers in a certain kind of office environment. It is expected that in future also in other European countries and the USA the majority of workers will work with computers. There will be an increase of white collar work as most of the employment growth will occur in service-producing industries [14]. The type of work will also change. The work will become more knowledge intensive [14]. Simple work will be done by technology. This means that offices should facilitate these new work processes.

In a knowledge based and innovation driven competitive business environment, a company that needs to compete on innovation needs its organizational members not only for reaching productivity goals, but also for developing novel and useful ideas for solving problems and developing new products, services, processes, systems, and work methods. The creative potential of the workforce needs to be stimulated and work environments need to be designed to support worker creativity [4].

Apart from the change in the character of work, technology will change as well. According to Brauer et al. [2] there will be rapid technological developments. “Electronic paper, flexible transparence displays, nanocomputers, tiny sensors, wireless networking with completely new types of equipment will tie the individual person into an information network which is constantly present”. One of the consequences of this information network that is available everywhere, is that the work does not have to be done at a fixed location in the office.

These developments have the risk that employees loose their connection to colleagues and their companies as they can do their work everywhere individually. For companies it is important to keep their personnel connected to the company and the colleagues.

Both demands for future office work (creativity and connection) have consequences for the design of the office interior. Effects of the office interior on creativity have been described before in the literature (see table 1). Hypothesis have been described on the effects of plants, colors, multidisciplinary groups, coffee lounges, space for informal meetings, breaks, desk sharing, software and hardware characteristics and food supply on creativity. However, no clear evidence has been found. The same counts for connectivity. Showing the effect of office environments is difficult as the office environment is complex and difficult to model. Even for effects of office workstations on visual and musculoskeletal symptoms no clear conclusions can be drawn [9].

Table 1. Some relationships between office environment characteristics and creativity described in the literature

some factors in the office environment stimulating creative ideas	source	reference
plants in the office inspire employees	Shibata & Suzuki, 2004	[10]
variation in colors stimulates variation in creativity	Lloyd, 2001	[6]
multidiscipline groups are needed for creativity	Mensink, 2005	[7]
80% of the creative ideas come from informal meetings	Lloyd, 2001	[6]
coffee lounges are needed to stimulate informal meetings	Creelman, 2006	[3]
spaces for formal and informal meetings and interaction support creativity	Haner, 2005	[5]
create breaks with toys to stimulate creativity	Snead & Wykoff, 1999	[11]
desk sharing stimulates new ideas	Pullen et al., 2001	[8]
using the right software and hardware stimulates creativity	Andripoulos, 2003	[1]
the right food supports creativity	Lloyd, 2001	[6]

Assuming that some relationships described in the literature are true, we tested a hypothesis based on these relationships. If 80% of the creative ideas come from informal meetings and if coffee lounges are needed to stimulate informal meetings it would be good to have a coffee lounge facility that is often used and where often informal conversations are found. It is also assumed that more conversations with colleagues lead to more connection to the company. We also assume that the type and location of the coffee corner influences these effects. Therefore, our hypothesis is:

The type and location of coffee corners have effects on the number of meetings between employees and on the informal conversations.

2 Methods

To test the hypothesis a pilot study was done in an office, where the coffee corner was located and designed in two different ways. In the first situation the coffee corner was located in the office garden. Everyone could see who was drinking coffee, because there was no protection. There was no possibility to sit. In the new situation the coffee corner was located more central in the office environment and screens were positioned that could increase the privacy feeling. Also, seats were added and a table with magazines enabling conversations and rest breaks.

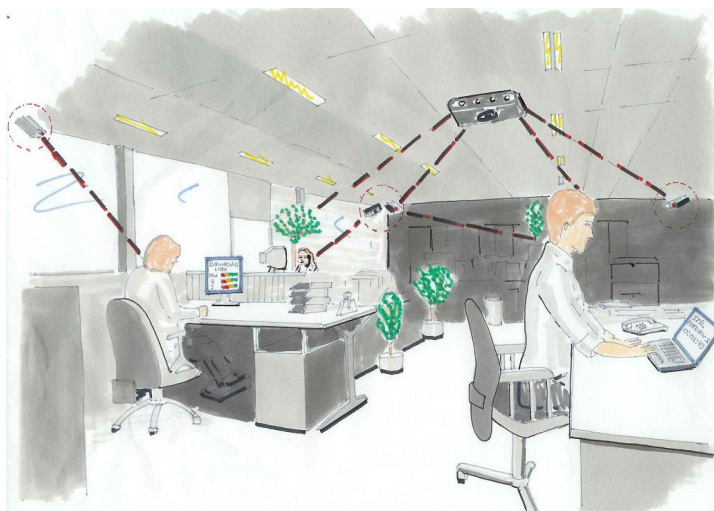


Fig. 1. Schematic overview of the recording system showing an office environment and cameras and microphones recording a whole day work

A new system of measuring was developed. It consisted of cameras and microphones recording movements and sound (see fig. 1). The cameras and microphones were positioned in such a way that every part of the office environment could be recorded visually and sound synchronously. Software was developed to analyze the data afterwards. To establish whether two or more persons were around the coffee corner, a line was defined afterwards on the recorded video files around the

coffee corner for. A special software package was able to detect if two or more people were within the area. At that moment the sound was switched on (by the programmed software) and recorded whether or not subjects were discussing. These talks were analyzed. Topics of one subject were clustered. Like a short conversation on the weather was seen as one “talk” and typified as private. When this conversation was followed by a discussion on how to answer a certain phone call of a client this work this was defined as another “talk” typified as work. All “talks” were recorded in the old and new situation during a day work at an office were about 50 employees work. All subjects were informed about this procedure and before publishing the results were shown to the participants and permission to use the data was asked. The t-test was used to measure significant differences ($p<0,05$).

Additionally, in interviews with 7 employees the usefulness, of the new coffee corner was evaluated.

3 Results

The position and design of the coffee corner had no significant effect on the number of movements to and from the coffee corner. There was a significant difference in number of “talks” (see table 2). The new situation resulted in more conversation. The percentage of conversations on work and on non-work issues did not differ significantly. About 84-90% of the conversations concern work issues and about two third is about strategic issues.

The interviews showed that the employees liked the new coffee corner as they now also have the possibility to talk with colleagues planned and unplanned. The impression was that is was nice to have more possibilities share operational and strategic issues with colleagues in a more closed environment. They experienced more social support.

Table 2. Differences in number and character of conversations between two different types of coffee corners

	old	new
Number of movements to coffee corner	239	170
number of “talks” recorded by the system*	338	514
Percentage of “talks” about work	90%	84%
Percentage of “talks” about strategic aspects of work	51%	63%
Percentage of “talks” about operational work aspects	39%	21%
Percentage of non-work “talks”	10%	16%

* significant difference (t-test, $p<0.05$)

4 Discussion

The hypotheses that the type and location of coffee corners have effects on the number of meetings between employees and on the conversations is not falsified.

Coffee corner location and design have influence on the number of talks. Even in a situation where less people meet each other around the coffee corner more “talks” were recorded. In one visit more “talks” were recorded as the subject changed frequently. Probably the privacy and the possibility to have a seat did stimulate the participants to have more “talks”.

Interesting is the fact that between 84 and 90% of the conversations is about work. Especially, as Lloyd [6] describes that 80% of the creative ideas come from informal meetings and Creelman [3] states that coffee lounges are needed to stimulate informal meetings. In this study it is clear that a coffee corner with seats and tables and screens that increase the privacy feeling stimulate the number of conversations. Most of the work conversations increase and it seems that more strategic questions are discussed in the situation with more privacy. However, the number of non-work conversations increases as well. This could be seen as non-efficient, but it could be possible that these contribute to a better communication as well.

The number of movements was higher around the coffee corner in the old situation although not significant. This means that the office workers picked up more coffee collected or additional products like sugar and milk in the old situation than in the new situation. There is no clear explanation for this difference, except perhaps that there were more visitors.

Generalization of these pilot test results to other office situations is difficult. This was only one day in the old and new situation. Differences could be caused also by differences in work content. These results can be different for other types of work and another population. However, the indication found in this paper, that coffee corners that invite to discuss and have privacy lead to more informal conversations about work, is not illogical.

There could be a relationship with health and productivity of the position of the coffee corner. One of the important aspects of productivity in the future is creativity (see introduction), 80% of the ideas come from informal meetings and coffee corners could support that. Regarding health it might be interesting that social support did increase in the new situation in the perception of employees. Svard et al. [12] described that social support reduces stress. Therefore, the coffee corner could even contribute to health improvement.

5 Conclusion

Coffee corner design could have effects of the office environment on health and productivity. A coffee corner with screens, tables and a possibility to sit resulted in more conversation than a coffee corner which is open and had no seats. In both coffee corners more than 4 out of 5 conversations were about work. These informal discussions could contribute to productivity as many informal conversations increase creativity. It could also contribute to a better health as social support could reduce stress.

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Guerilla Ergonomics: Perceiving the Affordances for Workplace Design

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Abstract. A successful ergonomic intervention involves creating affordances that support safe, effective, productive and comfortable working conditions. Guerilla ergonomics entails creating the requisite affordances using objects that are readily available in the workplace. This often means using objects in ways not intended in their original design. As such this has the advantage of creating viable working conditions quickly and cheaply. Workers learn how to adapt quickly to new problems or changes in the work environment. Our research has shown that the perception of the affordance for an object's intended use can interfere with a person's ability to see other uses for the object. Practice in perceiving new uses for objects as well as compiling a directory of possible solutions may help overcome these limitations.

Keywords: Affordance; workplace ergonomics; ergonomic intervention.

1 Introduction

The need for ergonomic interventions has increased over the course of the past century as a consequence of the mechanization of work in factories and in the modern office as a result of the introduction of computers. Merlie and Paoli [1] reported that the workers in the EU have back pain nearly one-third of the working time and neck/shoulder pain almost one fourth of the working time based on 1000 workers studied in each country of the EU [also 2]. Dainoff [3], Spilling, Eirtheim, and Aaras [4] and Westgaard and Aaras [5] have documented the positive effects of improved workplace design on worker productivity, health and safety. Together, these studies and many others point not only to the need for ergonomic interventions, but also their cost effectiveness, especially when the costs associated with job turnover, missed work and health costs are taken into account.

1.1 Ergonomic Interventions Create Affordances

How do ergonomic interventions improve work environments? Ergonomic interventions create what James Gibson [6] referred to as *affordances*, properties of the work environment that support the ongoing work activities. In creating affordances, ergonomic interventions produce safe, effective, healthy and comfortable

working conditions. One design challenge is to make the affordances visible to prospective workers so that they will take advantage of these possibilities for safe and effective work.

There are two properties of affordances with which we are concerned: First, according to Gibson [6], affordances entail a relationship between a worker and relevant properties of the environment needed to support the action for that worker. Gibson [6] states that, “the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or for ill,” and further notes that affordances “have to be measured relative to the animal.” Affordances constitute opportunities for action and depend on the actor’s body scale and action capabilities. As such, affordances describe the *fit* between a particular aspect of the environment and the actor’s capabilities. For example, a chair that is designed for an adult will not afford the same sitting action for a year old child; on the other hand, an infant car seat will not afford sitting for an adult.

Second, affordances exist independently of whether they are actually perceived [6] [7]. Whether an affordance is perceived depends on whether there is information about the affordance for the prospective actor, whether the prospective actor detects that information or has need for the affordance in the course of carrying out a goal-directed activity. That need and the intention to act on that need should, *ideally*, increase the likelihood the user will actually perceive the affordance. To reiterate the point of this section, the goal of an ergonomic intervention is to construct affordances for safe, comfortable and productive work. .

1.2 What Affordances Are Needed to Perform the Work to Be Done?

The requirements for a given workplace are determined by the work to be done [8]. It is here that ergonomists rely on task analysis [9] or work analysis [10] in order to establish the types of activities that the workplace must afford. Toward this aim, ergonomic standards, such as BRS/HFES 100: *Human Factors Engineering of Computer Workstations*; *Department of Defense Handbook for Human Engineering Design Guidelines*, offer statements of current *best practices*—postures, actions and work conditions that must be afforded by the workplace. The end result of the ergonomist’s analysis may be conceptualized as a set of affordances that must be created in the workplace to support the work to be done. In the modern office, these include affordances for sitting, reaching, seeing, interacting with computers; factory work adds a variety of affordances related to lifting, and other actions being performed on objects. A further challenge is for ergonomists to integrate the various affordances into a coherent design so that the requirements of individual affordances do not conflict with one another.

Toward these aims, ergonomists and facility managers frequently recommend purchase of expensive ergonomic furniture, chairs, workstations, computer peripherals and other accessories that can be quite expensive, costing several thousand dollars per workstation. Weeks and months may pass while the equipment is being ordered, delivered and installed. But what does an ergonomist do when faced with an immediate problem of workers suffering from musculoskeletal disorders? Waiting several weeks or months may be necessary to obtain the best equipment, but what happens to the worker until the equipment arrives? More importantly, many

organizations cannot afford expensive ergonomic chairs and workstations. Dainoff and Dainoff [11] provide an answer in the form of an ergonomic intervention they refer to as *guerilla ergonomics*.

2 Guerilla Ergonomics: Creating Affordances in the Workplace

2.1 A Case Study

Recently, one of us consulted with a local family resource center, where the director had symptoms of musculoskeletal problems, including neck, wrist, shoulder and back pain. She was working in a makeshift office, sitting for long periods of time in an old nonadjustable chair, while talking on the phone, working on a computer placed on a file cabinet, or interviewing visitors needing assistance. The agency operated with a very limited budget for non-family assistance items and thus state-of-the art ergonomic workstations and chairs were simply not an option. The challenge was to improve her working conditions so that she could continue her work comfortably, in the absence of pain and without spending a large sum of money.

The concept of an affordance provided a useful direction. The goal of the intervention was to create a workplace layout that afforded the work activities that had to be performed. Ultimately, the agency was able to purchase a relatively inexpensive ergonomic chair with adjustable seat pan height and angle and backrest angle. However, this chair did not have all of the affordances needed. For this reason the consultant and director worked together in order to find available (no cost) objects that could create those missing affordances. For instance, a small pillow was tied to the chair's backrest to create an adjustable lumbar support. A footrest was created using a large telephone directory, taped together for stability and appropriately angled by placing it on a wedge. A place for her legs to fit underneath the worksurface was created by placing the monitor on a sheet of plywood the extended beyond the edge of the file cabinet on which the monitor rested; this also created a keyboard shelf and mousing area.

2.2 Guerilla Ergonomics

The above intervention was modeled after the work of Dainoff and Dainoff [11] that focused on creating the requisite affordances using whatever means are available. They coined the term “guerilla ergonomics,” which “means making ergonomic improvements with materials which are free, cheap, or readily available—even though your Standard Image-Conscious Corporation would not consider your improvements aesthetically correct.” [11] Usually, this means that human artifacts have to be used to create functions for which they were not originally designed.

For this approach to succeed, the creation of affordances has to be based on an understanding of the principles (based on ergonomic research and statements of best practices, including workplace standards) that are entailed in creating a fit between the environment and the worker so that the work activities are supported. Ergonomists have the responsibility for providing workers with information, such that they understand the activities to be afforded and why those affordances are needed. This includes learning about where the body is most vulnerable to injury as well as

principles for safe working postures and movements. A successful intervention may also include training teams of workers to solve problems as they arise, using both their knowledge of ergonomic principles and ability to find available objects to create desired affordances. In the above case study, by providing the agency director with basic information about the human body and how the environment had to support her work activities to avoid the problems she was experiencing, the agency director was able to work with the consultant to create those affordances. Moreover, after the consultant left, she was able to continue to improvise in order to find better solutions and adapt to changing conditions.

Guerilla ergonomics challenges ergonomists, facility managers and workers to identify novel uses for common objects. This is not a simple skill because research has shown that people have difficulty in finding new uses for common objects.

3 Finding New Affordances for Old Objects

People have difficulty finding nontypical uses for objects. In problem solving this is often referred to as *functional fixedness* [12], which can be understood in terms of affordances: When faced with an object that was originally designed to create a specific affordance, people often find it more difficult to notice other affordances for that object that might support other activities. Even 6-7 year old children tend to focus on an object's typical function, though children younger than 5 years do not [13]. People may have difficulty noticing non-typical affordances of an object when the task entails functions that are different from those related to the use for which the object was designed. There is evidence that functional fixedness is a universal phenomenon, even among people from technologically-sparse cultures [14]. Thus, the strong association between the physical properties of an object and its typical use may inhibit the actor from discovering novel uses for the object, especially when the novel use entails different affordances. In the research discussed below, we find evidence that even when the initial affordance perceived for an object is not its primary affordance, people may still have difficulty noticing other uses for the object.

3.1 Perceiving Multiple Uses for an Object

The current investigation examines whether the perception of one of an object's non-primary affordances will interfere with the perceiver's ability to detect a second non-primary affordance for the same object. Does perception of one of an object's affordances interfere with detecting another affordance for that object?

Method. In Experiment 1 participants were presented with a collection of nine objects that could be divided into three classes defined with respect to a pair of affordances. Some of the objects ($O_{\text{AFF } 1}$) had only the first affordance (e.g., pour-in-able), but not the second affordance (e.g., stretchable). Other objects ($O_{\text{AFF } 2}$) had only the second affordance, but not the first. The third class of objects ($O_{\text{AFF } 12}$) had both affordances. (Neither of these affordances was the primary affordance for which the objects had been designed.) Participants performed two tasks: For Task 1, participants identified all of the objects with the first affordance. (The instructors told participants to identify objects with the first "use" because the term affordance would not be familiar to

them.) This would include objects with both affordances ($O_{\text{AFF } 12}$) as well as objects with only the first affordance ($O_{\text{AFF } 1}$). Immediately after completing the first task, participants performed Task 2 in which they identified objects with the second affordance, which again included objects with both affordances ($O_{\text{AFF } 12}$) as well as objects with only that second affordance ($O_{\text{AFF } 2}$). If the perception of one of an object's affordances affected whether a person notices another of its affordances, on Task 2 participants should be more likely to identify objects with only the second affordance ($O_{\text{AFF } 2}$) than objects with both affordances ($O_{\text{AFF } 12}$).

Results and Discussion. Figure 1 shows that for Task 2 participants were far more likely to identify objects that had only the second affordance than objects with both affordances. When people recognized one non-primary affordance of an object, they were less likely to notice another affordance for that same object. Figure 1 shows the mean percentages of second affordance-only objects ($O_{\text{AFF } 2}$) and both-affordance objects ($O_{\text{AFF } 12}$) identified for each of the four pairs of affordances in Task 2. Overall, the second affordance-only percentage ($M=88.52\%$) was considerably higher than the both-affordance percentage ($M=57.92\%$). The results of a second experiment demonstrated that the objects with only the second affordance ($O_{\text{AFF } 2}$) are not better exemplars of that affordance than the objects with both affordances ($O_{\text{AFF } 12}$). Together these findings show that the perception of one affordance can interfere with the perception of other affordances for that object.

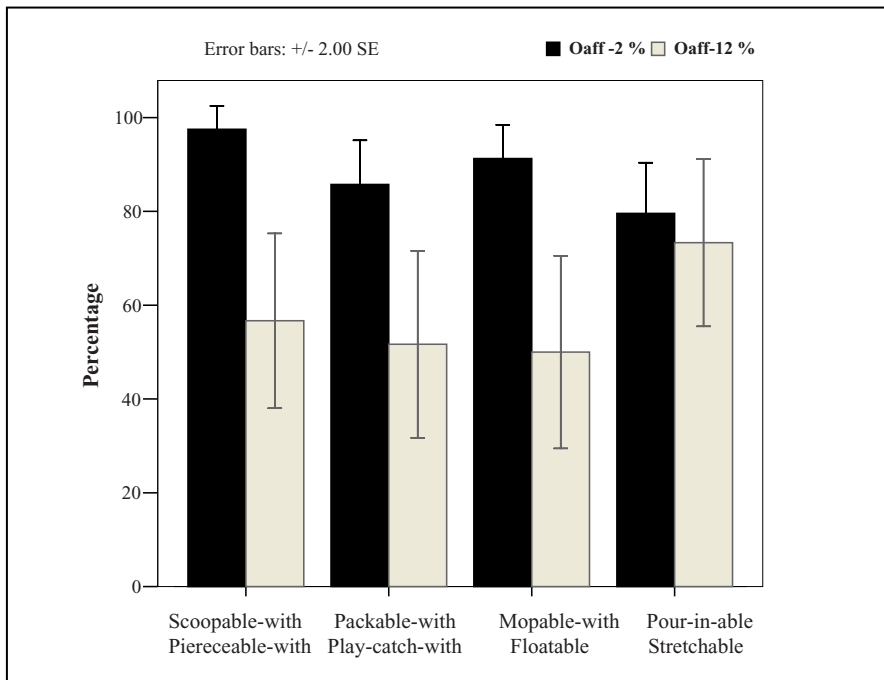


Fig. 1. The mean percentage of identified objects with *only the second affordance* ($O_{\text{AFF } 2}$) and objects with *both affordances* ($O_{\text{AFF } 12}$) for each pair of affordances in Task 2

3.2 Implications for Guerilla Ergonomics

Guerilla ergonomics involves perceiving new uses for objects that were originally designed for other purposes. Our research has shown that the perception of one of an object's affordances can interfere with the perception of another of its affordances. Although ergonomists and workers can successfully overcome this *functional fixedness*, we believe that practice may well prove useful [15]. In addition, it may also be important to establish a directory of objects that can be used to create a particular function and thus create a necessary affordance for safe, effective, productive and comfortable work. Such a directory, however, should be organized around the fundamental ergonomic constraints that have been identified in ergonomic research and constitute the foundation for current best practices. Dainoff and Dainoff [11] offer a model for how to organize this information.

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Constraints on Demarcating Left and Right Areas in Designing of a Performance-Based Workstation

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Abstract. The purpose of this study was to show the constraints that demarcate right and left areas in designing a performance-based workstation. As a part of the larger project, the current experiment was designed to determine the directional location at which people change from using their right hand to using their left hand when reaching for a pen to write their name. The results from 21 right-handed participants showed that their left hand was not used significantly in any azimuth lines. Although right-handed participants used their left hand more often as the target location approached their contralateral side of their body, the frequencies of left hand use were not significantly dominant even beyond the left shoulder plane used in this experiment. Along with findings from previous work, we conclude that for this particular task the hand-use transition occurs beyond 20 degrees left of left shoulder plane. The location of this boundary is markedly farther to the left than identified in other research, thereby demonstrating the importance of task constraint in describing work area.

Keywords: Lab study; constraints, reach, handedness, performance-based approach; workstation design.

1 Introduction

On what basis should the work area be demarcated right and left side when designing a workspace? Geometric models of normal work area [1] have typically been based on limb size and a typical body posture or movement, i.e. upright torso with rotating forearm. The obtained model is then reflected to the left side of the body assuming that the work area is symmetrical around the body median.

In contrast, a performance-based approach demarcates the boundary of a reach envelope as the distance or direction at which the worker changes from one type of reach movement to another. When observing the movements used in performing a reach task, we find that as reach distance increases, people introduce more parts of the body (i.e. from arm movement to arm and torso movement). Mark et al. [2] pointed out that this transition from arm movement to arm and torso movement occurs at shorter distances than the absolute maximum distance for their arm movement. This is because people rarely seem to commit to an extreme movement or potentially

awkward posture, such as extending their arm or leaning forward as far as possible. Rather, people prefer to rotate their shoulder or lean their torso instead of extending their arm to its maximum reach distance. Also, they would rather stand up to avoid an extreme forward lean. A number of studies have found that people preferred to change their posture in order to avoid such extreme movements that might place them at increased risk for injury [2, 3, 4]. When these findings are applied to delineating work area, the final area actually reached by the same type of movement is smaller than its absolute maximum area of that movement, and is considered the “performance-based normal work area” where “work is handled most efficiently and workers can reach with comfortable arm movement”[4]. There is also evidence that the location of the transition between different reach movements may be related to the reacher’s attempt to minimize discomfort [5].

This preference-driven movement selection is also true for limb (arm) selection. Given that almost all people have a dominant hand, it was observed that the actual area of right and left hands used in uni-manual tasks was not symmetrical around the body median [6,7]. In general, people used their dominant hand more often when they were allowed to use their preferred hand [8]. This trend is more distinctive when the required skill level of the task is increased. People tend to use their dominant hand more often when the task requires fine motor skills than when the task is simple. For example, people are more likely to use their dominant hand when moving a cup fully filled with water than when they pick up a small, nonbreakable object. Also, it was reported that when people were instructed to perform the same task with their non-dominant hand in their dominant area (i.e., asking strongly right-handed individuals to use their left hands when reaching for an object located in his right side), both accuracy and speed were impaired [7].

Choi et al. [9] varied object locations and observed participants’ hand selection during a simple reaching task. They found that the location of transition between the right and left hands depended on the reach distance as well as direction. In another experiment, Choi et al. [10] found that strongly right-handed people used their right hand up to their left shoulder plane for simple reaching tasks. Beyond left shoulder plane, people used their left hand significantly more often than their right hand. Choi et al. [10] also brought up a question to ask whether different types of actions would affect the selection of hand use. A reaching action to pick up a small, nondelicate object is a simple and fundamental action and does not require a particularly skillful action. That is, it doesn’t matter which hand you choose to pick up a baseball or an apple because both hands will complete the task, “pick-up”, equally well. This indicates that it is the location of the object that may affect hand selection when performing these types of neutral tasks. But suppose that after picking up the object an additional task had to be performed that required the use of the dominant hand. Would this additional task affect limb used to reach for and grasp the object? In other words, if a right-handed individual is asked to pick up a baseball and throw it to a target, would limb selection for picking up a baseball differ from when he is asked just to pick up a baseball? The purpose of this research reported here is to determine whether a task requiring right hand use for right-handed people affects the selection of hand used to grasp the object. The results have implications for our efforts to demarcate left and right hand using area.

To investigate this question, “reaching for and picking up a pen and writing words with it” was selected as the task. “Reaching for a pen” is one of the common actions in

an office environment and “writing words” is a task which involves using the dominant hand. In this investigation, a writing task which involves absolute usage of dominant (right) hand will be performed to see how often people use their non dominant hand to pick up an object (pen) at different locations. The resulting critical boundaries will delineate the work area based on the interaction of physical, environmental and task constraints as such. This performance-based boundary provides a basis for the design of ergonomic work areas.

1.1 Pilot Study

One man and two women participated in a pilot experiment that was intended to identify two settings for the experiment: azimuth lines for the object (pen) location and the spatial orientation of the object (pen). From the previous study [10], the boundary delineating left and right hand using area for reaching task was suggested as the left shoulder plane when the task doesn't require higher or skillful performance. In addition, the skill level of the task was expected to affect the location of the directional boundary (i.e. the more skillful task being performed, the more often right hand will be selected to perform the task when reaching toward the left side of body part). Therefore, various azimuth lines for target location were examined for these three participants and a final set of azimuth lines were selected based on the frequencies that our pilot participants used their left hand to pick up the pen presented. Since no one used their left hand on the azimuth lines located on the right side of their body median, the azimuth lines for the experiments were decided to be located at body median and left of body median.

The pilot experiment also enabled us to establish an orientation for the pen. There was one assumption that we consider. If asked to pick up a tool that has a handle, which would indicate the place to grab on with hand, would participants reach for the indicated part, handle, spontaneously [11]? In this study, rubber grip was assumed as the handle of target. Thus, the center of the rubber grip was located at the target location. From this pilot test, it was confirmed that all the participants reached for the pen by the rubber grip, but there were some exceptional cases. When the grip part of the pen is far enough to introduce other parts of body severely to pick it up, but the other end of pen is closer (i.e. when required to stand up to reach for the rubber grip, otherwise possible to pull the pen by leaning forward), participants easily reached for the closer part of the pen. Thus, to make the rubber grip as the closer part to the participants, the pen was presented directing toward the participants [Figure 1].



Fig. 1. Center of the rubber grip is placed at the target location

2 Method

2.1 Participants

11 men and 10 women participated for course credit. Each participant was tested individually. All participants were strongly right handed as determined using the Handedness Questionnaire [12] that describes 12 common actions. Participants were counted as strongly right-handed if they indicated they used their right hand to perform at least 10 out of 12 actions.

2.2 Apparatus

A Roc-n-Soc (Ashville, NC) chair was used. The chair was height-adjustable with a small backrest, and no armrests. The table was part of motorized, height-adjustable workstation (220cm * 122cm). A video camera recorded the actions from the participant's right side. The target was a 14-cm long pen that could be grasped by the rubber grip. A piece of white paper containing a blank table was placed in front of each participant.

2.3 Procedure

This experiment consisted of two parts whose order was counterbalanced. There were 23 object locations in each part so that there were total of 46 different object (pen) locations [Figure 2]. There was a total of five azimuth lines which included body median (0 degree) and 5-degrees left of the body median, left-shoulder plane and 10-degrees, 20-degrees to the left of the left shoulder plane. Along each azimuth line, there was total of five locations (reach distances), except for the 20-degree to the left from the left shoulder plane on which only 3 locations. All the reach locations were scaled based on each participant's maximum reach capability. Each participant's maximum reach distance (100% capability location) was measured. The maximum arm-only reach was used in the first part of the study and the maximum arm-and-torso

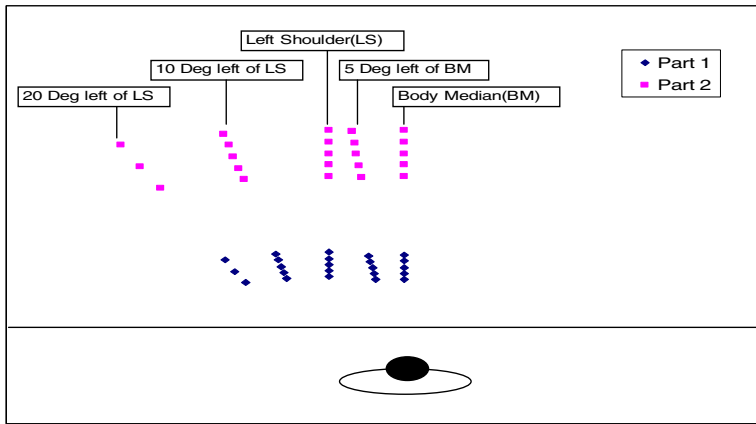


Fig. 2. Direction and distance of 46 target locations

reach was used in the second part of the study. In part 1 of the study, five locations that participants reached for the target object were calculated based on their maximum arm-only reach distance from 80% to 100% of their maximum arm-only reach in 5% increments. In the 20 degrees left of left shoulder direction, participants reached for the target object at three distances ranging from 80% to 100% of their maximum arm-only reach in 10% increments. In the second part of the study, the maximum arm-and-torso reach distance was used to calculate the ranges from 85% to 105% of their maximum arm-and-torso reach.

In each part, participants sat in front of a table and were asked to close their eyes while the experimenters place the object at the proper location on the table. Participants were then instructed to reach for and pick up a pen by whatever reach action and hand that they felt would be the most natural or comfortable. After picking up the pen, they wrote their initial in one location on the table drawn on the white paper placed in front of them.

The order of the 23 locations in each part was randomized such that participants could not anticipate the target location in advance. Participants were videotaped as they performed three sets of (randomized) trials at each reach location. Three experimenters reviewed the videotapes of all trials. For each trial, the hands used to pick up the object and to write their initials were recorded separately. The most frequently used hand (twice or more) out of three trials at each location was encoded as the data point for analysis. If an individual grasped the pen with right hand (1st trial), left hand (2nd trial) and right hand (3rd trial) at 95% location on left shoulder plane, that person's final data was encoded as "right hand" for grasping action at that location.

3 Results

The data for the 21 participants were analyzed using chi-square tests to determine which hand used at each location was significantly predominant.

Table 1. χ^2 Statistics with frequency and percentage of hand use for part 1

Azimuth	% of ACB1	Left hand		Right hand		χ^2 (1, $N = 21$)
		Freq.	%	Freq.	%	
Body Median	100	0	0.00	21	100.00	21.00*
	95	0	0.00	21	100.00	21.00*
	90	0	0.00	21	100.00	21.00*
	85	0	0.00	21	100.00	21.00*
	80	0	0.00	21	100.00	21.00*
5 degrees to left of Body Median	100	1	4.76	20	95.24	17.19*
	95	0	0.00	21	100.00	21.00*
	90	1	4.76	20	95.24	17.19*
	85	0	0.00	21	100.0	21.00*
	80	1	4.76	20	95.24	17.19*
Left Shoulder	100	4	19.05	17	80.95	8.05*
	95	1	4.76	20	95.24	17.19*

Table 1. (continued)

	90	7	33.33	14	66.67	2.33
	85	3	14.29	18	85.71	10.71*
	80	3	14.29	18	85.71	10.71*
10 degrees to left of Left shoulder	100	7	33.33	14	66.67	2.33
	95	8	38.09	13	61.91	1.19
	90	7	33.33	14	66.67	2.33
	85	7	33.33	14	66.67	2.33
	80	7	33.33	14	66.67	2.33
	100	7	33.33	14	66.67	2.33
20 degrees to left of Left shoulder	90	8	38.09	13	61.91	1.19
	80	7	33.33	14	66.67	2.33

ACB1: Maximum Arm-only Reach, * Sig, Right hand use

Table 2. χ^2 Statistics with frequency and percentage of hand use for part 2

Azimuth	% of ACB2	Left hand		Right hand		χ^2 (1, $N = 21$)
		Freq.	%	Freq.	%	
Body Median	105	0	0.00	21	100.00	21.00*
	100	0	0.00	21	100.00	21.00*
	95	0	0.00	21	100.00	21.00*
	90	1	4.76	20	95.24	17.19*
	85	0	0.00	21	100.00	21.00*
5 degrees to left of Body Median	105	4	19.05	17	80.95	8.05*
	100	0	0.00	21	100.00	21.00*
	95	2	9.52	19	90.48	13.76*
	90	2	9.52	19	90.48	13.76*
	85	3	14.29	18	85.71	10.71*
Left Shoulder	105	3	14.29	18	85.71	10.71*
	100	5	23.81	16	76.19	5.76*
	95	4	19.05	17	80.95	8.05*
	90	3	14.29	18	85.71	10.71*
	85	2	9.52	19	90.48	13.76*
10 degrees to left of Left shoulder	105	10	47.62	11	52.38	0.05
	100	8	38.10	13	61.90	1.19
	95	9	42.86	12	57.14	0.43
	90	6	28.57	15	71.43	3.86*
	85	6	28.57	15	71.43	3.86*
20 degrees to left of Left shoulder	105	10	47.62	11	52.38	0.05
	95	9	42.86	12	57.14	0.43
	85	9	42.86	12	57.14	0.43

ACB2: Maximum Arm-and-Torso Reach, * Sig, Right hand use

All participants used their right hand to write down their initials on the paper. Thus, the chi-square tests were done on the frequencies of hand use for grasping the pen at each location. Since the hand selection at each location was independent of one another, and all participants had two choices in hand selection at each location, the expected frequency at each location was calculated as half of the total participants, 10.5 (Expected frequency = total number of participants/total number of categories = $21/2 = 10.5$). Observed frequencies at each location along with the chi-square statistics are presented in Table 1 for part 1 and Table 2 for part 2.

The chi-square test was significant if more than 15 people (about 70%) used their right hand for grasping the object (pen) at each location. Tables 1 and 2 show that as the reach direction approached the left side of the body, participants used their left hand more frequently, but the frequency of left hand use was not significant at any location even on 20 degrees to left of the left shoulder plane. Figure 3 summarizes these results: Red markers (to the right on the scale) indicate predominant right-hand use. Color changes from red to blue (left) reflect an increasing percentage of left-hand use. Based on the color in the figure, it is clear that left hand (blue) was not used very often in any azimuth line.

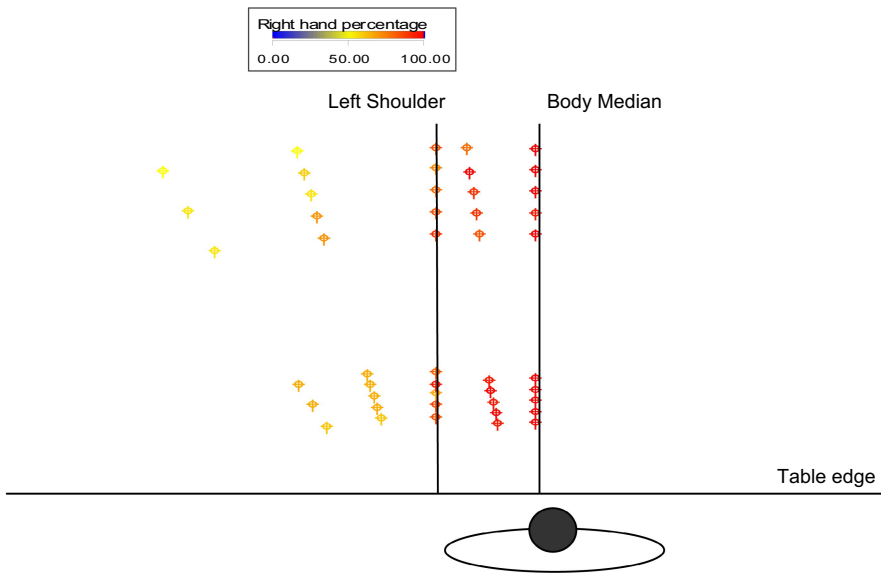


Fig. 3. Envelope of significant hand use

4 Discussion

In summary, right-handed people used their left hand more often as the target location approached their contralateral side of their body but the frequencies of left hand use were not significant even beyond the left shoulder plane. From these results we conclude that right-handed people will use their dominant hand predominately up to 20 degrees to the left of their left shoulder plane when the task that they perform

requires them to use their right hand. The transition between the right and left hand use is expected to occur beyond 20 degrees to the left of their left shoulder plane. This transition is markedly to the left of the boundary identified in previous research [9, 10] for tasks that did not involve the use of the actors' dominant hand. Thus, task constraints affected the location of the directional boundary at which people change from reaching with their right hand to left hand.

There have been a few other experiments to explain why people use their dominant or preferred hand more often than their non-dominant hand. Recently, Farina et al. (2003) pointed out that muscles in the non-dominant side are more easily fatigued than those in the dominant side. They argued that this could be due to "long preferential use of the specific side." People use their dominant hand for longer periods of time, which causes gradual changes in the muscle fiber membranes of that side. This will eventually cause different performance levels between sides. Although their research still could not explain young children's hand preference which they might have born with, it can explain why people use their dominant hand so often willingly and why the area reached by their dominant hand is relatively wider than the area reached by their non dominant hand. Thus, when designing the workstation layout, handedness of the target population should be considered such that tasks with heavy loads or requiring fine motor skill could be easily accessed by the operators' dominant hand side without causing awkward postures.

Finally, one limitation of this study is chair function. The chair used in this study was fixed so that participants were not allowed to rotate it. Had participants been allowed to rotate chair, the frequency of left hand would likely have decreased because by rotating the chair participants could relocate the target relative to their right hand. Under those conditions, it is questionable whether strongly right-handed people would actually use their left hand.

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Design of an Adaptive Feedback Based Steering Wheel

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Abstract. This paper aims at describing the architectural model of an adaptive force-feedback for a By Wire steering wheel system. This solution uses a steering wheel to replicate the reactive torque law which allows the driver to complete a precise driving scenario or a task with the higher performances. Then, the steering wheel adapts the reactive torque to the driving scenario. Since the design of this system considers the driver performances, it is called Ergonomic Steer-By-Wire. Now a prototype version of the ESBW is connected on a professional driving simulator and several tests are going to be conducted in order to tune the system components. Adapting the force feedback to the driving scenario could be a solution for improving driver's safety and vehicle control.

Keywords: HMI, steer-by-wire, driver performances.

1 Introduction: Human Factors Studies in Steering Systems

The aim of the study is to create a reconfigurable force-feedback system for a by-wire steering wheel (Zheng, 2005) which allows the driver to complete a precise driving scenario with the higher performances. The force feedback manager which takes care of the human performance is called Ergonomic Steer-By-Wire (ESBW). The field of "X-by-wire" systems have been investigated and used in other fields, such as the avionic and is now being largely explored within the automotive area. This study selected a SBW control due to a technical reason: in a SBW no mechanical junctions between the front wheels and the steering control are necessary, and hence the steering dynamic can be completely reconfigurable. It is in fact electronically commanded and can be completely controlled by a software.

In literature each force feedback law reproduced by the steering wheel can be classified into two categories:

1. proportional to the steering angle;
2. based on vehicle dynamics.

The force feedbacks from the first group are also called “spring-based” since the reactive torque increases with the steering angle. These are the most common laws replicated on driving simulators since they emulate the transmission on the steering of the auto-alignment of the front tires (Gillespie, 1992). The cons of this group is that they represent an approximation of the control of the vehicle and thus the driver is not able to feel the real dynamic of the car.

The force feedbacks of the second group are based on the vehicle dynamic. That is, the reactive torque is replicated as a function of several vehicle parameters, like the speed, the yaw rate, yaw angle, lateral acceleration, sideslip. The pros of this solution is that the driver can feel how the vehicle moves on the steering; however, this force feedback based solution is more difficult to implement.

The idea of a reconfigurable force feedback for a steering wheel comes from an analysis of the literature on human factors studies in driving control. This analysis focused on the relationship between the driving performance of the driver, his or her interaction with the steering wheel and the driving environment.

For instance, previous works stated that in certain road paths a specific force feedback law loaded on the steering wheel gives higher performances than with other force feedback. It was found that drivers driving on a curvy road or rural path feel that they have an especially high vehicle stability control when a reactive torque based on lateral acceleration or yaw rate is loaded on the steering wheel (Kimura, 2005). The same results were not confirmed in the highway where drivers were seen to prefer a spring-based reactive torque (Mourant, 2002).

In these works, the driver performances were assessed using several driver behavior indexes, in particular self reporting measures (Nasa Tlx, RSME, etc. - Aide, 2004; Östlund, 2004) driving performance measures (standard deviation of lateral position, steering entropy, speed variation, etc. - Östlund, 2004) and physiological measures (heart rate, eye movements, etc. - Aide, 2004). Then, it was possible to state that a certain force feedback is better than another one in a specific context of use: for example, a comparison between a spring-loaded and a force feedback based on vehicle dynamics in a rural road driving scenario (including curves of 100, 200 and 300 radii) was presented in (Mourant, 2002). The aim of the study was to understand which was force feedback that gave the driver the better maneuverability and control of the vehicle. The preference for a vehicle's dynamic force feedback was confirmed by analyzing a) the drivers' performance through several measures like the mean lane position of the vehicle on the road and b) self-reporting measures, that is, a questionnaire on the feeling of the two force feedbacks.

A list of the best force feedback solutions for each driving scenario was created; the list represents a basis for the development of a preliminary work on the so-called ESBW. Starting from this list, the ESBW aims at reproducing the best force feedback for a specific scenario.

In order to test whether the ESBW is comfortable and safe for the end user, several tests on a driving simulator will be completed.

2 Selection of the Best Force-Feedback Solutions

The Ergonomic Steer By Wire aims at improving the driver performances during driving in specific scenarios. The study of the ESBW is conducted on a driving simulator in a laboratory on Mechatronics named MECTRON and placed in Reggio Emilia (North of Italy)¹ and it is currently developed and tested on a driving simulator.

The first step for the development of the ESBW was a study conducted in 2006 by the MECTRON laboratory regarding the literature on human factors studies in vehicle steering control. The study focused on identifying the best force feedback solutions reproduced by different driving control systems (e.g. standard steering wheel, steer-by-wire, joysticks and so on) in specific driving conditions. The driver performances were analyzed by monitoring specific physiological, performance-based or self reporting measures as described above. The result of the research was presented in *tables of correspondence* between the most common driving environments and the best force feedback law sourced by the literature. An example of the table applied to the case of a rural road scenario is depicted below.

Table 1. Correspondence between driving scenarios and best force-feedback solution

<i>Scenario</i>	<i>Study</i>	<i>Best Force Feedback solution</i>	<i>Measures of performance</i>
<i>Rural road</i>	Pei-shih, 2004	1) at low speeds the feedback force is dependent on yaw-rate. 2) at intermediate to high speeds the feedback-force is obtained from lateral acceleration	Available in Huang, 2004
<i>Rural road</i>	Toffin, 2003	Force feedback proportional to steering angle: 1) Linear with an angular coefficient of 1,5 [N x m/rad] 2) Linear with an angular coefficient of 2,5 [N x m/rad] 3) Parabolic with saturation at 4 [N x m/rad].	Standard Deviation (SD) of lateral acceleration, steering angle and lateral deviation.

The information filled in the table was used to select the best performing force feedback solution which has to be implemented on the ESBW in a specific driving environment. Since for each driving scenario more than one force feedback law are available (e.g. for rural road, 5 laws are listed – see Table 1), it was decided to limit the number of force feedback laws to one for each scenario.

To do that, a further selection of the force feedbacks listed in the *tables of correspondence* like Table 1 has to be carried out. Then, several tests are going to be completed on a fixed driving simulator; the aim of the tests is to assess what force feedback law allows the driver to increase his/her performance in a specific driving

¹ Mectron (www.mectron.org) is a research Laboratory of the Hi-Mech technological district placed in the north of Italy (<http://www.hi-mech.it>).

scenario. A description of the test is provided at the end of the document. In order to test each force feedback solution the architectural model of the ESBW was developed. In the next paragraph, the design concept of the system is described.

3 Architectural Model of the ESBW

The design concept of the ESBW can be summarized in the figure below. In this figure, the high level functionalities of the system are depicted.

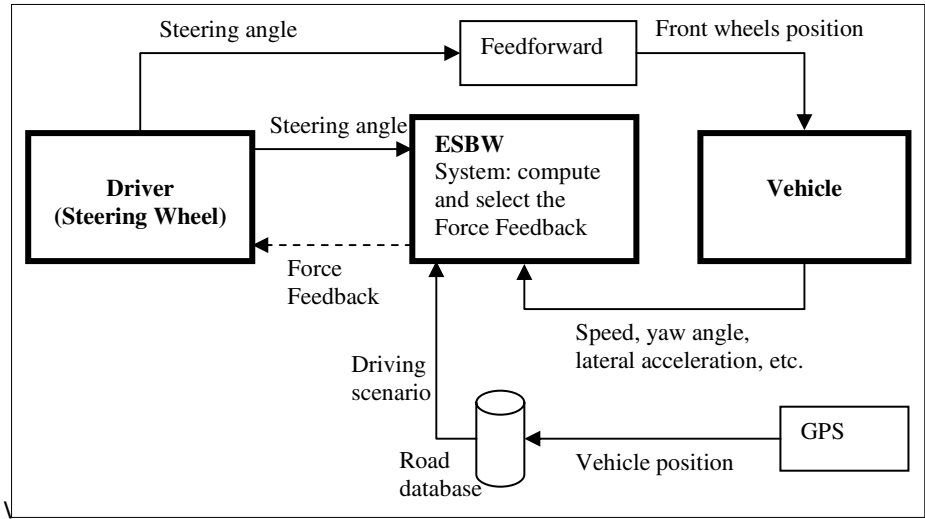


Fig. 1. Design concept of the ESBW system

Fig. 1 shows the main components of the ESBW. The solid lines entering the ESBW subsystem represent the input of the systems, while the dotted lines are the output. To compute the reactive torque for giving feedback to the driver, the ESBW needs three main components: the driver, the vehicle and a vehicle's position system (e.g. a GPS).

As mentioned before, the force feedback laws may be classified into two categories: steering angle based and vehicle's dynamic based. Since the position of the steering wheel is required for the first group, the ESBW has to source this parameter from the driver steering; after that it may compute the required force feedback and replicate it on the steering wheel.

As for the second category, several vehicle dynamic's parameters (e.g. speed, yaw angle, lateral acceleration, etc.) are required to compute the force feedback; the ESBW has to source them from the vehicle.

The signals corresponding to the steering angle and the vehicle's dynamic can be directly sourced from the vehicle's CAN (Controller Area Network).

Finally, the ESBW has to select the force feedback solution to be replicated on the steering wheel in a specific scenario. In order to do that, it is necessary to know the

position of the vehicle and to identify the current type of scenario. Since a the GPS system is able to track the position of the vehicle, a road database connected to the GPS would be able to identify the driving scenario (e.g. city road, highway, rural road, mountain road, etc.) and communicate it to the ESBW. This kind of information is now available in modern car navigation system.

Focusing on the internal logic of the ESBW, a schema of the system is depicted in the following figure.

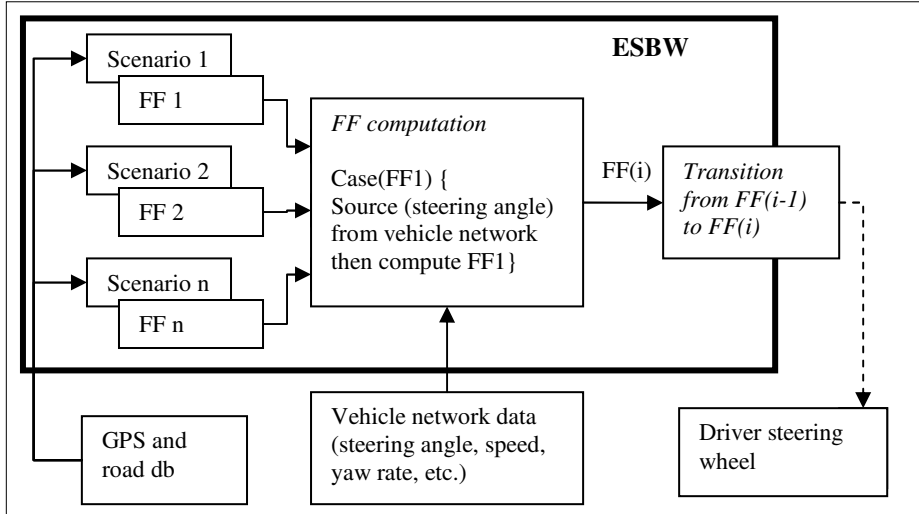


Fig. 2. Internal logic of the ESBW

As shown in Fig. 2, the internal logic of the ESBW is composed by three main components:

1. the scenario and force feedback laws database (database subsystem);
2. the computation of the force feedback laws (computation subsystem);
3. the communication of the force feedback to the driver (communication subsystem).

Point 1 of the list represents the result of the collection of the best force feedback laws for each driving scenario sourced by the literature. This information is filled into a database which links the best force feedback to the related scenario. Point 2 is the subsystem related to the calculation of the force feedback which has to be replicated on the steering wheel: data related to what force feedback the systems has to compute is sourced by the database (point 1) and the parameters needed for the computation (e.g. steering angle, yaw rate, etc.) are sourced by the vehicle CAN network. Finally, point 3 describes the subsystem related to the transmission of the force feedback to the driver (i.e. steering wheel); since the ESBW aims at loading a different force feedback law for each driving scenario, it is necessary to transmit the new force feedback which has to be reproduced in the most driver-comfortable way. In fact, an abrupt modification of the vehicle handling behavior may lead to risks for the driver's

safety. Moreover, a bad design of the transition from a force feedback law to the next one, may cause an out-of-the-loop syndrome (Endsley, 1995; Billings, 1991; Wickens, 1992), compromising the effectiveness of the automation introduced by the ESBW as the drivers have the impression to be excluded from the controlling task. An example of how the ESBW works is shown in the following use case (Table 2).

Table 2. Example of a Use Case for the ESBW

<i>Pre-condition</i>
GPS and road database communicate to the ESBW the road the vehicle is moving: at time $t(i-1)$ the vehicle is moving in an highway road. A certain force feedback (FF(i-1)) is reproduced on the steering wheel .
<i>Use case story</i>
1. At time $t(i)$ the vehicle is moving on a Rural road. 2. The new scenario is revealed by the GPS, then it is communicated to the database subsystem of the ESBW. 3. The database selects the new force feedback to be reproduced on the steering wheel (i.e. FF(i)) and communicates it to the computation subsystem. 4. The subsystem sources the data needed to compute the FF(i) from the vehicle network, then FF(i) is executed. The values (output) of the FF(i) are transmitted to the communication subsystem. 5. The subsystem generates the transition from the previous force feedback loaded on the steering wheel, FF(i-1), to the new one, FF(i), in a specific time interval and following a precise transition rule (e.g. a smooth transition can be provided).
<i>Post-conditions</i>
After the time interval of the transition phase, the correct force feedback is reproduced on the steering wheel.

4 Interface of the ESBW with a Driving Simulator

The logic of the ESBW is now under development and tuning in a simulated environment. Using Matlab Simulink/Stateflow² a prototype of the final system was created and it is going to be tested on a driving simulator. The design of the prototype's high-level logic is described in Fig. 1 and Fig. 2.

The simulator used for HMI studies on the ESBW is composed by:

- a car cabin of a real vehicle (i.e. the vehicle driven by the subjects of a test) equipped with pedals (brake, clutch and accelerator), gear box, hand-brake and a steering wheel;
- a projection system which shows the driver the driving scenario, the vehicle interaction with the driving environment and traffic into a front screen;
- an Ethernet network which allows the communication among the car cabin, the simulated scenario and the data recording system.

The most interesting component is the steering wheel; it is an Active Steering Wheel System (ASWS)³ which emulates the behavior of a Steer-by-Wire (SBW)

² www.mathworks.com

³ <http://www.conekt.net>

system. Like an electronic SBW, the dynamic of the ASWS can be completely software controlled.

Since the simulator can be connected to Matlab Simulink/Stateflow by using specific APIs (Application Program Interface), a connection between the ESBW prototype system and the simulator was created. According to Fig. 1, GPS data and Road database data are completely sourced from the simulator environment by connecting the database subsystem of the ESBW to a simulated GPS receiver; thus, the vehicle position and the type of the road are available. Moreover, the set of data needed for the computation subsystem of the ESBW (i.e. vehicle dynamic and steering wheel data) are sourced from a simulated electronic unit able to source CAN messages from the vehicle's network which is simulated by the simulator's Ethernet. Finally, the ESBW is able to transmit to the driver the specific force feedback computed in the Matlab workspace by modifying the dynamic of the force feedback actuator installed on the ASWS; thus, the driver will feel the reactive torque reproduced by the ESBW.

Now all the components of the ESBW prototype have to be tuned in order to create a system which is comfortable and safe for the driver. In particular, the following step are going to be completed:

- *Tuning of the database subsystem*: for each driving scenario it was decided to reproduce only one force feedback on the steering wheel in order to reduce the complexity of the system and the number of transitions from a force feedback law to another one.
- *Tuning of the computation subsystem*: after the tuning of the database subsystem, the computation of all the selected force feedback has to be reproduced in a single subsystem.
- *Tuning of the communication subsystem*: in order avoid possible risk situations due to the transition from a force feedback law to the next one replicated on the steering wheel, different transition solutions have to be assessed on the drivers during several tests on the simulator.

Now the prototype of the ESBW developed for the test on the simulator is configured for the tuning of the database subsystem. Then, it is able to:

- receive from the simulated GPS and Road database the scenario where the vehicle is moving;
- associate the scenario to a specific force feedback law;
- compute the selected force feedback law;
- replicate the force feedback on the steering wheel without transitions.

The selection of the best force feedback solution for the tuning of the database subsystem is made through the assessment of the driver behavior and performances during driving. A description of the test is depicted in the next paragraph.

5 Experimental Test: Tuning of the ESBW

A test aiming at tuning the database subsystem of the ESBW was prepared; the results of the test will be the selection of only one force feedback law for a specific driving scenario. The results will be available in the middle of 2007.

Six different force feedback laws were selected from the *table of correspondences* before mentioned. These force feedbacks have been tested and reported in literature both in highway road and rural road environment. Three force feedbacks are classified as proportional to steering angle and they are sourced by Toffin, 2003 and Godthelp, 1985; the others are based on vehicle dynamics and they are sourced by Segawa, 2001, Pei –shih 2004 and Kimura, 2005.

In order to compare the force feedbacks and select the best one for a specific scenario, the same environment as in literature were created, that is, a highway road and a rural road. Furthermore, a city road was created in order to test each force feedback solution and verify whether one of them gives better performance in this scenario.

The test will be carried out on 54 young subjects, aged between 20 and 30. Each driver will be asked to drive for 40 minutes in the three mentioned scenarios. During driving, the drivers are asked to perform a primary task, that is, to drive in the lane, make several lane changes in precise coordinates of the road and to drive in traffic. For each driving task, the ESBW transmits only a force feedback law to the steering wheel, then it is configured to work like a traditional steering system. While driving, a set of behavioral measures of the drivers will be collected. A part of the selected measures was the same of those used in the literature works from where the force feedbacks laws were sourced, in particular:

- driver performance measures: Standard Deviation (SD) of steering angle, SD of lateral acceleration, SD of yaw angle, deviation from the lateral lane;
- self reporting measures: RSME (Rating Scale Mental Effort - Zijlstra & Van Doorn, 1985), four level sensory evaluation scale (Nakano 2005).

In this way, it will be possible to compare the results of this test with the literature. Furthermore, other driver behavioral data are planned to be recorded in particular:

- driver performance measures: HFC (High Frequency component of steering angle), SE (Steering Entropy), TLC (Time to Lane Crossing);
- self reporting measures: Nasa – TLX, DQS (Driving Quality Scale);
- Physiological measures: heart rate inter-bit-intervals, heart rate variability, skin conductance variation.

All the mentioned measures are listed and described in (Östlund, 2004) and (Aide, 2004). Other tests on the tuning of the ESBW subsystem database are going to be completed on the driving simulator: in the end, one force feedback law for each driving scenario will be provided. As for the tuning of the computation subsystem, several functionality tests will be provided on the ESBW's prototype in the Matlab Simulink/Stateflow workspace. Finally, the tuning of the communication subsystem will be carried out on the drivers by testing several transition solutions.

6 Conclusions and Future Steps

The main aim of the ESBW is to allow the driver to improve his or her performance during driving by providing a different force feedback law for each driving scenario.

One of the further steps of the activity carried out on ESBW aims at exploring how it can be used to provide warnings and information to the user for ADAS (Advanced

Driver Assistance Systems) functions (e.g. Lane Departure Warning, Curve Warning, Lane Keeping Systems – Aide, 2004), putting the level of driver support, the optimal feedbacks and the driving scenario in close relationship. For example, an appropriate torque to suggest the driver the right maneuvers (aborting the overtaking, or keeping the vehicle inside the lane) could be provided. Important results can be achieved in this area, as a practical example of use of the ESBW system as informative channel.

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Virtual Reality in the Study of Warnings Effectiveness

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Abstract. Warnings are a very important method to control hazards and to promote safety. Despite its importance, warnings have important gaps that limit their validity and make its design so difficult. In this sense, warnings effectiveness evaluation is crucial to guarantee effective people safety. However, warnings traditional evaluation methodologies have several limitations. To this extent, the main purpose of this work is to determine Virtual Reality (VR) ecological validity as a warnings evaluation technique. We describe a methodology that uses VR as a technique to evaluate safety signs. The main advantages of VR use, associated with the interaction level, are discussed.

Keywords: Warnings, Behaviour, Effectiveness, Virtual Reality, Interaction.

1 Introduction

Warnings research basic goal is to develop an effective method for designing good warnings and to assess their effectiveness. This is an important matter because information transmitted by warnings is critical to avoid accidents, injuries and material losses. Especially when we know that, despite its importance, warnings have serious limitations. However, despite knowing that warnings could fail their purpose of promoting safe behaviours, they are used in a great number of situations. Among the most popular types of warnings are signs, labels, instructions and many others. Generally warnings are static and visual, and most of them containing text, pictograms and colour-form code components. Visual warnings are very popular but they require user to direct its attention towards them, otherwise they will be undetected. This does not happen with auditory warnings, because they are omnidirectional. Research has shown greater levels of compliance for multimodal warnings [1-3]. Besides the warning displaying method [4], warnings effectiveness is affected by several other variables such as warning design characteristics [5] and warnings content [6].

Warnings effectiveness can be assessed through the evaluation of several factors, such as the ability to switch and maintain the attention, the understanding easiness, the memorized/evoked intensity, its adjustment to users beliefs and attitudes, the

motivation strengths and, the ability to change the receivers behaviour. These factors are organized in stages, as described in "Communication-Human Information Processing" (C-HIP) model [7]. According to this model, the information processing sequence begins with the source and goes through several stages, specifically related to receiver, as attention, comprehension / memory, attitudes / beliefs, motivation and behaviour. The literature reveals that, each stage is influenced by different variables and works as a bottleneck to warnings success. Despite the processing appearing like a linear sequence, actually, feedbacks exist between stages and it does not exist a fixed sequence processing. We can summarize this process in 3 major moments that can also be used as warnings criteria of quality: 1) noticing the warning; 2) comprehending the information and 3) complying with the warning.

We can use several methodologies to evaluate warnings but, the main problem is the ecological validity that such methodologies possess. The literature reveals that the success scores are affected by methodological variables such as the used test technique and the exhibition context method. This influence was also verified in the comprehension test, previously accomplished by us, with the intent of evaluate ISO type signs [8]. It was possible to confirm the pictures great influence, when used to supply context information. We concluded that people try to acquire cues, from the images, that may help them to understand the signs [9].

Comprehension test is frequently used because message understanding is a very important indicator of its quality and also because this is also a much simpler procedure than the one that is necessary to evaluate the user's real behaviour. However, with the comprehension test is only possible to check the declared behavioural intentions, but not the real behaviour. These findings motivated us to look for a methodology that could avoid this problem but, at same time, with good ecological validity. Consequently, with this study we intend to propose the VR use as context displaying technique. We start from the assumption that VR, as technique for warnings evaluation, possesses high ecological validity and that it is a valid alternative to other traditional techniques. With VR the exhibited context can be dynamic, realistic, rich in details and it can allow great interactivity with users, resembling the real world. An advantage of this technique is the possibility to evaluate the warnings effectiveness in a complete way. We could, for instance, know if the signal was detected, if it was understood and if the adopted behaviour was the correct one.

2 Assessing Warning Effectiveness Methodologies

Behaviour evaluation: Behavioural consonance is considered the gold standard measure of warnings effectiveness. In practice, what really interest is if the instructions, contained in the warning message, are followed. However, from the research point of view, the behaviour analysis is the most difficult evaluation of all. This is due to several reasons: a) we cannot expose people to dangerous or potential traumatic situations, because of ethical and safety reasons; b) during the extent of the observation period, the probability of occurring dangerous situations is very low; c) for a simulated situation be credible, it should look realistically dangerous but, at the same time, be safe for the participants; d) this kind of research is time consuming,

expensive and difficult to carry out. The behaviour evaluation has been investigated, most of the time, in laboratory because it is difficult to observe real users dealing with warnings in a real context. To be more effective, this evaluation should be incidental exposure type, in which participants ignore experiment true purpose. Due to the above mentioned difficulties, when a field study is carried out, it is almost always performed using questionnaires to collect data about risk level perception, message understanding, warnings evocation and behavioural declared intentions assessment.

Comprehension evaluation: The comprehension is, next to the behaviour evaluation, the best indicator used to check signs success, being also relatively easy to implement. The most recommended method for evaluation comprehension is the structured interview with open-end and oral answers accompanied with the context, exhibited through pictures. Although this method is not the most frequent, it is what presents larger ecological validity. The most frequent method is the multiple choices questionnaire, which is faster to apply and easier to deal with data. In ANSI Z 535.1.5 [10], both tests are accepted, regardless of preference given to open-end oral tests. The multiple choice procedures should be avoided also because the inappropriate inflation of comprehension scores that result of the comprehension influence imposed by the distractive answers [11]. A multiple choice procedure does not reflect usual signs processing. In the real world there are no similar situations, where individuals have to choose an answer from a group of juxtaposed alternatives. Wogalter, Brantley, Laughery, & Lovvoll [12] suggest that the open-end answer method is the most suitable for comprehension tests accomplished, accordingly to ISO 9186 [13]. The open-end answer procedure can be filled writing or verbalizing the answers. However, the obtained results in both procedures are not the same. According to Brantley & Wogalter [14] the written answers can supply such brief answers, that they can fail in the transmission of the participants true knowledge. The incomplete answers can contribute to lower comprehension scores. Further more, the oral answers will allow the interaction of the investigator with the respondents, through the accomplishment of follow-up questions. This could help to gather more information from participants increasing the success without biasing the answers [14].

Context supply: About context supply Wolff and Wogalter [15] state that, in the real world the signs exist inserted in a context that necessarily affects its understanding. Without the existence of contextual cues the obtained results can be false. Therefore, independently of the adopted method, to guarantee the ecological validity of the evaluation, the warnings should always be inserted in a context. This context should be the real, with all the associated problems that were mentioned before, or it can be simulated at laboratory. The simulated context, that it is the most viable option, can be supplied through several processes: realistic physical sceneries built in a studio; virtual reality; video; picture and text. All these context supplying types have important differences among them: at the realism level; at the amount of information transmitted; at the immersion level and at the level of allowed interaction. The use of pictures is a good method to supply context indications. However, accordingly to the literature we need to take some precautions with the pictures we present because, it can affect interpretations, once images can emphasize certain objects or behaviours. Thus, an elucidating picture of the context should show the environment, instead of

people. If, eventually, the picture illustrates people, then it should not show those people involved in a forbidden or undesirable behaviour, because that could distort the answer.

3 Some Considerations About VR in Warnings Research

Nowadays, thanks to technological evolution, VR is used in different areas such as medicine, aviation, military training, education and ergonomics. In warnings issues VR is becoming an alternative research technique. Glover and Wogalter [16] have developed a virtual coal mine to evaluate warnings effectiveness. They compared the workers exit behaviour during an emergency situation, with the behaviour during a normal lunch exit. The obtained results, although limited, have revealed that this is a promising technique.

Some of the advantages associated to the use of VR are high level of variables control; the rigor of behaviour observation during tasks implementation; the richness of the contexts; the easiness of variables manipulation; the possibility to evaluate behaviour during dangerous simulated situations. VR difficulty of construction and implementation is related with the fact that it is an interactive system. Interactivity implies hardware and software combination in order to trade inputs/outputs between them so that human operator can carry out certain task. This interaction can happen with several immersion levels, precision and efficiency.

Considering that a VR application should contain a wide variety of objects, behaviours, interactions and communications, with different complexity degrees, its project is complex and requests robust methodologies. We think that the methodology to conceive VR application should be based in a user centred design process, as proposed in ISO:13407 [17]. This approach will complement the chosen methodology. To ensure that VR usability is guaranteed, the conception procedure should also be multidisciplinary, incorporating human factors and ergonomics knowledge and techniques.

4 Related Work

Just as mentioned, the present study was motivated by the methodological difficulties felt during the accomplishment of a previous comprehension test. Such test was accomplished to evaluate the effectiveness of 17 safety signs, ISO type, in use in Portugal. To carry out that evaluation we have performed a comprehension test with potentials users. The purpose was to obtain comprehension scores, for the selected signs, using the methodologies recommended in the literature. The whole procedure is concisely described below.

- *Procedure*

Signs selection: given the great diversity of available safety signs, it was necessary to find a process to reduce the variety. The selection was accomplished in two stages. The first stage consisted of a Heuristics Based Preliminary Evaluation, performed with a sample of 6 individuals, both genders, whose ages ranged from 24 to 57 years old. These individuals did not participate in other subsequent tests. The

accomplishment of preliminary tests helps to save time and money by rejecting inadequate signs, in an early stage of the design process, and promoting more detailed tests only with signs that are potentially effective. Researches refer that 80% of problems can be identified with only 5 respondents [18]. The purpose of this preliminary test was to choose those signs that were considered the most difficult to comprehend by the users population. This procedure allowed the selection of 30 signs from dozens available in specialty catalogs. Some signs, considered easy to understand, were also chose in order to have a comparison term in the obtained data. In a second step, the 30 selected signs were tested a second turn with a procedure designated as Judged Comprehensibility. This procedure, proposed by ISO 9186 (2001) [13] standard allows to identify the signs variants that reach higher understanding values and that are worth more study. The purpose of this procedure is to esteem the understanding value, in a fast and cheap way, before the use of other costlier methods. The judged comprehensibility could also be useful to compare comprehension levels of same referent variations [19]. According to Zwaga [20], the results from this estimation test could help to preview the final comprehension test scores, with a 20% of margin error. To carry out this test a table was built, in Excel[®] software, where the selected signs from the preliminary test were inserted together with referent description, intended meaning and context of use. At the bottom, it was included a small demographic questionnaire: age, gender, education level, studies subject and occupation. The file containing the test was sent by e-mail with brief explanations about test purpose and filling instructions. The sample consisted of 90 individuals, with ages ranging between 18 and 62 years-old, with an average age of 28 year-old and 10,32 standard deviation, males and females. These individuals did not participate in any other test. The participants filled out the table and they returned the file also by e-mail. The selection of the 17 final signs, which will follow to next phase, was supported by the achieved mean values.

Comprehension evaluation: the comprehension was evaluated using a method designated by Comprehension Test. This method consists of a structured interview, accomplished individually. The answers are open-end and supplied vocally. The whole procedure is videotaped. The studied signs were printed in an A4 sheet of paper, on their real colour together with a picture (context). The approach to the participants began with a generic explanation of the present study purposes complemented with instructions, together with an example about the requested task. The individuals answered the following questions: What does mean this sign? Which is the certainty degree on the attributed meaning? Did you already know the sign? Where do you usually find it? What should be done when sighting this sign? Along the whole procedure, some follow-up questions were putted: What else can you say about this sign? What do you identify from the drawing of the pictogram? There was no time restriction. The sample consisted of 90 participants, both gender, 30 working adults with active life, 30 young graduation students and 30 people with cerebral palsy.

Obtained results: The comprehension of the sign meaning was divided in two aspects: the comprehension of the pictogram meaning and the comprehension of sign colour-shape code meaning. The answers were classified in 5 categories accordingly to the recommendations of ISO 9186: (1) Correct or almost correct answer; (2) Much

probable correct answer; (3) Probable correct answer; (4) The given answer is wrong or is "I don't know"; (5) The given answer is opposite to the intended one (critical). To reduce the level of subjectivity the answers were evaluated by a jury of 3 elements. To obtain the signs final score, designated by rate of successes (of comprehension and of behavioural adequacy), it was attributed a value to each one of the answer categories. Like this, the frequency values, relative to each answer categories, was multiplied by the following values and after transformed in to percentage: a) answers belonging to category one: $x \ 1$; b) answers belonging to category two: $x \ 0,75$; c) answers belonging to category 3: $x \ 0,5$; d) answers belonging to category four: $= 0$; e) answers belonging to category five: $x \ -1$. The value obtained by the addition of all values is the final score of the sign.

The accomplishment of statistical inference (test of Mann-Whitney and Kruskal-Wallis) allowed the determination of the existence of eventual statistically relevant relationships among the independent variables (e.g. gender, age, education, specialization area, occupation, usual mean of transportation; ATM'S use; Internet use; sample; etc.) and the dependent variables (meaning comprehension; behavioural intentions adequacy).

This test allowed checking hypotheses as: a) are the studied signs understood, in a satisfactory way, by the users? Do users know the correct behaviour they should adopt in face of the signs? Where the signs already known by the users? Are signs comprehension success and behavioural adequacy related to the independent, intrinsic and extrinsic signs variables?

5 Methodology with VR

The present study will be laboratorial and incidental exposure type. The main purpose is to observe the participants' real behaviour during the interaction with signs. The context method of exhibition will be VR. The participants will interact with VR using a head-mounted display, with sound stereo and a joystick. During that interaction participants will be confronted with different sceneries, containing signs, where they must accomplish predefined tasks. The signs will transmit the necessary information for adopting the adequate behaviour. The behaviour quality, speed reaching goals and accuracy of the decisions will be important indicators to register. The adopted methodology is divided in 4 major phases: (1) Definition; (2) Modelling; (3) Data collect; (4) Results and conclusions.

Definition: To begin with VR application design process it is necessary a previous definition of the work context (physical and organizational environment; products and machineries; displayed environmental signs; types existing dangers) that will be simulated. To achieve it, a brainstorming meeting will be accomplished among the research team members. Following, will be defined the activity/task to carry out (type task(s); danger level; mental work load; duration; sequences; etc), based on heuristics and field analyses. The signs type to include will also be chosen. One of the most important stages, in this phase, is the definition of the variables to study (independent and dependent), as well as, the values types to be monitored, the measurement and registration processes. This moment ends with the VR system verbal/graphic (tree

diagram) description and its decomposition in sub-components to design those which are conceptually distinct and easier to achieve. Each one of these components is a VR interface component.

Modelling: The modelling process will be iterative, top-down type and turning around a cycle composed by high-level and low-level design phases. High-level design means a moment where the VR application design and architecture are specified with high level of abstraction. To obtain that interface generic description we just need to have its functional description. Low-level design phase means a phase with high detailed and concrete definition of the interface. The high-level design phase will consist in a storyboard followed by a paper prototyping. The storyboard, where the activity to be simulated will be illustrated, is based upon the data collected in the previous phase. This document will be created using the drawing cartoons techniques and will be useful as a visual and written guidebook for modelling procedures. As soon as the storyboard is finished and considered appropriate, we could begin to elaborate the paper prototype with the sceneries development. The paper prototype will consist of boards, A3 format, that will illustrate two-dimensional sceneries views (floor plans and cross section drawings), with rigorous proportions. The purpose of this prototype will be the rigorous definition of all the variables to model indicating, for instance, entrance places, routes, equipments, signs location, among other modelling relevant aspects. With paper prototype we can accomplished a prior test with specialists, to analyse the proposal adequacy to the defined purposes. This analysis will involve 5 specialists. After dealing with all data, it will be possible to initiate the VR digital modeling at a low-level design phase. Consequently, low-level design begins with the elaboration of a digital prototype that should respect all previous obtained conclusions and it finishes with the VR application final design. The digital prototype will be elaborated using a software considered appropriate, like 3DStudio Max®, or similar, that will allow the visualization of the VR sceneries that already should resemble, as most as possible, in detail and quality, to the final proposal. This digital prototype will be subject the prior tests also with 5 potentials users. This design process is characterized by a great interactivity, being accomplished in design-evaluation cycles until reaching a refined solution. This will allow to evaluate VR usability and to correct all detected deficiencies. After having concluded the process of prior tests, having all emends and modelling optimized, the elaboration of the VR final version will begin using *Unreal* platform and chosen hardware. This moment will finish with the final design of VR application, which should be ready to collect data. It will be still accomplished the synchronization between the simulation and the chosen peripherals (glasses, headphones, joystick). The great advantage of this methodology is to allow an easy understanding and the systematic analysis of what is inherent to the interface design, in other words, the several human-computer interaction types, the objects, the behaviours and the communications, needed to interact.

Data collection: A sample of 50 signs potentials users will be recruited to participate in this phase. The interaction with VR begins with the accomplishment of a trial test, to determine the participant ability to interact with VR (to detect the presence of simulators sickness, phobias, etc). This moment serves also to familiarize the participant with the simulator commands, navigation procedures and to understand the

kind of task she/he is asked to carry out. Following, the participant will fill out a small demographic inquiry and sign a declaration as she/he has consciousness about the test type in which she/he will be involved and their purposes, as well as giving consent to use data and collected images during the test. After this, the participant is randomly distributed for 2 test conditions: 1) sceneries containing static signs; 2) sceneries containing dynamic signs. Next, the participant receives the equipment that she/he should put with investigator's help. Specific instructions about the following tasks purposes and progress process are given. The interaction begins. The participant will have to fulfil a task, established at the beginning of the interaction, in which, the reading of the signs is fundamental. Completing the task presupposes reaching stipulated parallel goals as, for instance, to perform a calculation task, to press a certain command, to read a written message, to hear auditory instructions, to memorize environmental characteristics, etc. During the displaying sequence of sceneries the mental workload and the risk level will increase, until it reaches an emergency (a fire) situation. To reach interaction success, or in other words, to reach the established goals, the information transmitted by the signs is fundamental. The whole procedure will be digitally videotaped. During the interaction it will be collected data related to: a) ocular movements (visual sceneries exploration; signs detection); b) stimulus response time; c) adopted behaviour. At the end, after exposure, other subjective and objective data will be gathered through questionnaires, similar to those described in related works item of this paper. Other aspects related to communication human-information processing will be assessed in this questionnaire: 1) *Attention*: did the participants see the signs? Are the signs sufficiently conspicuous? Are the signs readable? 2) *Comprehension*: What message does the sign transmit? Do the signs transmit useful messages to avoid danger? Do the signs transmit information about the potentials consequences associated to a non consonant behaviour? Do the participants have knowledge about the potential danger associated to the sign, and about the severity of the potentials consequences related to an inadequate behaviour? 3) *Knowledge*: Which was your previous experience with the situation, the activities and/or tasks? Which was the subjective notion of danger level associated to the signs? Which was the participant's familiarity with the situation and the signs? 4) *Motivation*: Which is the cost-benefit rate associated to the signs? Was there any social influence? Which was the work load influence? The questionnaire will also evaluate the participant's opinion about sceneries, about the tasks, about the signs and about immersion level. The adopted behaviour will be analyzed through the analysis of the monitored performance. It will be accomplished a subsequent statistical analysis to find out the existence of eventual statically significant relationships among independent and dependent variables.

6 Conclusions

During the accomplishment of previous safety signs comprehension test, using pictures as a technique to display context, was possible to observe that pictures have huge influence on participant's answers. The weight of the context increases in function of the sign pictograms abstraction degree. This behaviour was expectable as we know that human perception is characterized by a simultaneously direct and

indirect processing. The quality and the perception speed will be larger and better, when the available information is also larger. Therefore, the choice of the context displaying method can not be made by chance. In our opinion, a way to run away from the potential bias, provoked by the context displayed by pictures, will be the use of dynamic contexts with larger ecological validity. The video is a possibility but, that technique implicates the access to a real context to gather the images. This would create an extreme difficulty to the research because, except if there was sceneries constructed in a studio, which would be very costly, it would be very difficult to have the absolute control of those variables. In this sense, VR is figured as an alternative, with ecological validity. This technique allows, not only, a realistic and dynamic context but, also, the possibility to manipulate and to control countless variables in a simpler way than in other procedures. The VR related difficulties do not overcome the associated advantages once, not all analyses will request high realism, detail, immersion and interactivity levels. The behaviour can be directly observed in VR, in different mental load and risk level situations. VR allows observing the signs displayed in very unfavourable situations to the user. The signs design should be focused for extreme situations, which are those when the users belong to lower abilities and capabilities group, where the environmental and physics variables are the most extreme and unfavourable to the accomplishment of the task, where the work load is high and where the risk is very high. If a sign reaches acceptable effectiveness levels in these conditions, then it will have a very high probability of success in most situations.

Unfortunately, the actual reality tells us that many signs are badly designed and are being used without any validation process. This reality can reflect the absence of design and validation methodologies easy to implement, or, methodologies with significant functional limitations that capture biased data. Therefore, the Virtual Reality comes as a technique with potential to allow the interaction investigation as an open system and in constant movement, but, without losing the demanded realism. Through the simulation with virtual environments, it can be easier to understand which fault has led to sign failure and in which process step it occurred.

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An Interactive System to Measure the Human Behaviour: An Analysis Model for the Human-Product-Environment Interaction

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Abstract. The analysis of Mans' interaction with the elements of a system has a fundamental purpose in the ergonomic analysis of work situations, as well as, in the design of new tasks and products. This analysis involves the collection of Human activities' information, in specific conditions, in a usable format to be used in the following stages, particularly in ergonomic intervention. In this work a systematic method is presented for observation of the behavior of workers' interaction in a real work situation.

Keywords: Ergonomic analysis, Video analysis, Behavior.

1 Introduction

The complexity of nowadays productive systems demands to workers a high performance level, in particular, where the work situations involve risk with negative impacts for workers' safety and health, or for work risk involvements. For that reason, the evaluation or conception of work situations imposes a detailed knowledge of its operation and vulnerabilities for the several types of human interaction. To this extent, the video permits a detailed analysis of human behavior during interaction, improving the study and understanding the inherent mechanisms of workers' occurrence problems and to productive system. The video is a powerful tool to interaction behavior investigation, being used in many studies, in particular, sociology has a rich tradition of observation theories techniques (for example, [9]; [25]), however, challenges continue to exist for investigators, concerning connection of empiric data, specific of certain context, and for theories and general paradigms [28].

Recently, the technological advances of digital video equipments associated to its low cost have generalized the video as a routine tool in human behavior investigation. The use of video makes possible multiple revisions, thus allowing the retraction of detailed information that would be impossible in field collection, appealing only to visual memory. In this in case, the use of a single source of observation may cause

losses due to memory lapses and potential interpretation difficulties. It is, however, important to point out that for the ergonomist, the exclusive use of video alone, does not substitute the collection of field data. The work situation knowledge is necessary, in particular, of the performed tasks, the workers complaints, its interpersonal relations, the technician tools, and in general, of work conditions.

In Ergonomics, the observations methods are frequently used to estimate the work postures and to conduct studies in human movement, identifying muscle-skeletal problems. In comparison with the direct measure techniques, they have lower cost and show great versatility, generalization and acceptable precision ([26]; [27]). We can distinguish two important methodologies in this scope:

- Data recovery in pre-defined moments, for example, through samples such as Posturegram [16], OWAS [10], PWSI [3] e
- Real time data register; in this case the events are collected at the moment where they occur, for example 'Posture and activity classification system [8], Postural analysis of the trunk and shoulders [13]. Unfortunately these tools precision is low [1], [11].

Although these techniques are currently generalized in ergonomics analysis of work situations, they present problems, due the fact that they are dependent of users capacities; it does not approach the work situation entirely, considering only one point of view of the work situation (normally related with muscle-skeletal problems). As alternative, video constitutes a technique that gives better guarantees, prevents distortions related to subjective view of the information collected for the analyst eyes and ears, allowing a systemic vision of work situation.

2 Situations Where Studies with Video Were Applied

The video allows putting in evidence aspects of the work, such as: performance task and workers' strategies, letting the analyst analyze the following work aspects [15]; [17]:

- Where and when the problems related with security and workers health's occur.
- How the individual differences lead the resolution of problems related with work activity;
- How workers solve an emergency situation, putting in evidence the strategies and fragilities of one equip;
- Identify the conditions in which mistakes and errors happen;
- Understand how the workers react under stress.

The video has been also used for the auto-confrontation, or goal-functionary activity, and it consists in one individual reflection or group on the activity through the observation of a video register [6]. This procedure appears as a complement of video analysis and allows justifying the analysis results, becoming explicit the aspects that cannot be explained by another form.

3 Analysis of the Information Registered in Video

The main problem in the information analysis of the registered in video, is to collect useful information from film. This difficulty is, above all, related with the acted behaviors visual conversion, in numeric greatness that can be useful to understand the interaction behaviors, and in the elaboration of appropriate measures to a new design of the work situation.

Some programs have been developed to help the filming analysis (for example, [13]; [24]). These programs are based on structures definition under model forms that are used to verify a definite occurrence in the filming. The main problem of these approaches is based on the difficulty to define these analysis structures that allow codifying and selecting the filming events and on these programs usability.

The strategy that is being developed in the Laboratory of Ergonomics of the Technical University of Lisbon, aims to solve some of these problems and to validate analysis structures that allow codifying and analyzing the filming of specific contexts. In particular, for Ergonomics, it consists in definition categories with interaction behavior that normally occurs in one specific context, for example, office work.

This method involves filming the worker activity and an ergonomic analysis of the work situation, involving a task analysis and the collection of workers opinion about the effect of their working conditions and productive system. For each task, the activity observed in some workers is specified. This specification incorporates an exhausting description of the strategies like postures and actions, to identify tasks. This information will be codified after in a database with an expert system that allows the selection of behavior categories with the characteristics of the analysis context.

4 Propose of a Methodology for Behavior Analysis in Work Situation

Considering the aspects of the previous item, a methodology was developed, with a computer system basis, for work behavior analysis of a real work situation, using a video support. This system was conceived to be integrated in the analysis methodologies and ergonomics interventions, thus, the effectiveness of its use is deeply related with the abilities of the ergonomist.

4.1 Ergonomic Analysis

The first phase consists on the execution of a task analysis, through workers interview, with the aim to identify the real tasks. In simultaneous, for each described task, the worker reports the main problems to physic, cognitive and organizational levels.

These data are complemented with the activity observation in the work place, with the aim to identify the main problems.

4.2 Definition of Analysis Objectives

The definition of analysis objectives is a fundamental step in applying this methodology. These are defined in agreement with the results of ergonomic analysis

and the ergonomic study, practice or investigation. For example, if the identified problems concerned on muscle-skeletal system, the analysis will report on the organizational and physics aspects.

4.3 To Make a Video

The video recording should occur after the phase 4.2 and should focus on workers interaction with other system elements.

In industrial situations of work or services, the workers do not like to be filmed, therefore, a time for its familiarization is necessary. Our experience has shown that these situations can be avoided if:

- the filming starts after the ergonomic analysis, describes before;
- the filming objectives are explained to workers, preferentially in a meeting;
- it is guaranteed the consistency of the images and collected data;
- it is guaranteed that the presented results will be of the group and never personalized to one person.

4.4 Number of Video Cameras

The number of video camera depends on the objectives of the study and the complexity of the movements that result from workers interaction with the work station. Normally one video camera is recommended in the analyses that do not involve complex movements, and located, preferentially, in the left or right sagittal plan.

Also in the cases where is necessary to collect information of differentiated nature, as it was in this case, eye direction and reach of inferior members to the commands in a panel, it is recommended the use of two video cameras, one to collect the movements of the head and eye direction and another one for the movements of the superior members.

4.5 Sample

The sample is dependent of the study objectives, of seasons or financial problems, related to the study, Ergonomics practical or inquiry. Samplings must be at least of 30 individuals, compatible with a statistical study. In the case where studies are related with the ergonomic practical, the conditions of seasons and financial problems are not compatible with big samples. In these cases, it is recommended, as rule, to record 10% of workers that execute the same task type.

4.6 Recording Time

The time of recording depends on the number and number of task cycles, the objectives and the nature of the study.

For the ergonomic practical, it was used as a rule, filming during one day of work. However, when the task cycle is short, or is only intended to analyze the task, the period of filming can be shortened.

4.7 Definition of the Behavior Categories

We understand that a behavior category is a pre-defined section of interaction actions associates to the tasks. The definition of these categories includes:

- Main tasks characterization, it corresponds to the more frequent ones. For example, answer the telephone. It can be defined up to 6 main tasks simultaneous.
- Sub-tasks characterization, second level tasks. For example, to answer the telephone and, at same time, write a note. For each basic task, it can be find up to 6 sub-tasks.
- Characterization of the behaviors associates to each sub-task. For example, for sub-task “to answer the telephone and write a note”, the following behaviors can be registered: to keep the telephone between the right shoulder and the ear and look at the monitor of the computer; to keep the telephone between the right shoulder and the ear and look at the horizon; to keep the telephone between the right shoulder and the ear added to another postural behavior, as well as elements of psychosomatic nature such as the humor changes: happiness, sadness, euphoria, among others (figure 1).



Fig. 1. Principal screen off Behavior Video software with the followings items: 1 – Selection of task 1 with propagation of its position in sub-tasks area. 2 – Selection of sub-task A with propagation of its coloration for all activities area. 3 – Certain activities for task 1 and sub-task A, related to analysis of the humor alterations. 4 – Bar of control with control information with information of analysis and the video control at right.

4.8 Category Register

The register of the categories is done beyond a computer application specially developed to this effect. The use of the program is developed in the following phases

- Annalist identification, date and place of data collection;
- Identification of the worker that will be analyzed and work station characterization;
- Program Formatting through the fulfilling of the main tasks, sub-tasks and behavior categories.

After the formatting the screen appears for data register (figure 1).

4.9 Presentation of the Results

In any moment of data recovery, the Behavior Vídeo software can present several types of reports. These are composed through the combination of total times attributed to each one of the defined study categories:

- Occurrence frequency of each main task;
- Total occurrence frequency of each sub-task from a main task;
- Each activity occurrence frequencies for each sub-task and main tasks; and
- Mixed reports, described to proceed.

Presentation of the Results. Theses reports represent a frequency of occurrence of each category (main task, sub-task or activity) related to the total time of analysis. It is possible too see the number of time each category occurs, as well as, the moment of its temporal occurrence along with total time analysis. Together, these data allows the ergonomist to have a systematic notion of the relationships between tasks and sub-tasks and the real work activity, allowing a better understanding of the human behavior, as well as, of factors that influence it, in a certain work situation.

The reports are presented either in line graphs or form of tables, or in bars adapted to each type of collected variable.

Presentation of the Results. With the intention to turn this tool more flexible, it was tried to incorporate the possibility of analyst accomplishing reports through the crossing of variables, between tasks, sub-tasks and activities. In this case, the analyst selects the relationships that he would like to cross, following the relationship criterion between Tasks X Tasks. Sub-tasks X Sub-tasks and Activities X Activities.

5 Conclusions

The video presents many advantages related to direct observation, in particular: a video sequence can be observed several times in order to be observed items separately; the reduction of images projection speed allows to observe in detail aspects that would be very difficult to identify for direct observation. However, the video presents some disadvantages, such as: the increase of time to analysis of data; the impossibility of the analyst to look for other vision angles, process that is very

simple in direct observation in the work station; the rank of a video camera can also create ethnic problems in some situations.

In this article we present a methodology for analysis of the worker behavior in real work situation, supported for a computer program that allows collecting at the same time of frequencies and occurrence the main tasks, of sub-tasks associate to each main task and of the activity associated with each sub-task. This platform appears in the sequence of previous systems, PASEA "Postural Analysis system for Ergonomics Applications" [3]; [18]; [20]; [21]; [23]; and of its evolution to the Behavior Video System [4]; [5]; [7]; [22].

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Computer, Television and Playstation Use in Developmental Age: Friends or Enemies of Growth and Health? Study on a Northern Italy Sample 6-14 Year Old

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Abstract. The indiscriminate use of new technologies can compromise a correct and harmonic physical development of children because of inadequate workstations and maintenance of wrong postures, and moreover because of the immoderate time dedicated to sedentary activities instead of physical ones. The paper examines the children's excessive use of computer, TV and playstation at home, and the physical problems they feel after their use. Furthermore it analyses the ergonomic suitability of students' workplaces and environment. It emphasizes also the importance of knowledge dissemination of ergonomic principles among teachers and families, in order to reduce children's risk of musculoskeletal disorders and damages to their visual system.

Keywords: computer, television, playstation, children's health.

1 Introduction

In the computer science world the hierarchies between generations and knowledge sectors have been levelled and new culture diffusion media have been born. In the last years technological applications in games and study activities expanded so fast in the young people everyday life, that in many countries they even extended to the first infancy.

Moreover, the indiscriminate use of new technologies can compromise a correct and harmonic physical development of children because of the use of inadequate workstations and the maintenance of wrong postures, and moreover because of the immoderate time dedicated to sedentary activities instead of physical ones, that are very important during the period of body development and growth. Repetitive movements typical of some video games and poor postures, often induced by furniture of incorrect size, can expose particularly the youngsters to harmful problems in different body segments that can increase their risk to develop later in life repetitive stress injuries and back strain [1][2]. Other possible risks can involve vision, as asthenopic phenomena due to incorrect lighting systems and glare on the screen.

The aim of our work is to analyse the use-misuse of the technology by the new generations, trying to point out the main risks to their health and correct psychophysical development.

2 Materials and Methods

Within a wider study on the physical and behavioural characteristics of scholar age subjects in the Piedmont territory (Northern Italy) we surveyed the modalities of PC, TV and playstation use, on a sample of 585 students of both sexes 7-14 year old. The sample (Table 1) consists of 278 subject from a primary school (6.6-11.5 years old) and 307 from a middle school (11.6-14.5 years old).

Table 1. Age classes of the surveyed sample

	6.6-7.5	7.6-8.5	8.6-9.5	9.6-10.5	10.6-11.5	11.6-12.5	12.6-13.5	13.6-14.5	TOT
MALES	17	34	26	28	28	48	52	51	284
FEMALES	17	27	33	31	37	49	51	56	301
TOT	34	61	59	59	65	97	103	107	585

The first age class is less represented as, asking a wrote consensus to the families to measure the children and to submit the questionnaires, their parents' agreement to the research was low; anyway we decided to use even the data of this age class to individuate the trend of the different analysed parameters.

On every subject we measured 37 anthropometric and biomechanical variables and we submitted a questionnaire on VDT, TV and playstation use at home, with particular attention to postural aspects, workstation and furniture dimensions and environment characteristics. Through specific questions and graphical representations of the most relevant body segments we evaluated the presence of discomfort and pain after the extended use of the technological devices, analysing the different anatomical districts affected and the symptoms severity. Aiming to understand the causes of those problems, we tried to collect information on the time spent every day on the different technological tools and on the dimensions of workplaces and furniture. For the latter part of the questionnaire we suggested the children to ask their parents' help to fill it at home.

3 Results

A first result is a methodological consideration deriving from the quantity and quality of the answers: for subjects of the first ages classes it would be necessary to use a simpler questionnaire or a short interview, as the youngest sometimes are unable to answer or they do it in an unsatisfactory way.

Nevertheless it was possible to point out for all the ages classes problematic health aspects, that can represent a serious risk for the psycho-physical development of growing subjects, and critical elements referred to behavioural habits, postures and furniture inadequate to children's characteristics and needs.

First of all, we analysed the time spent in front of a monitor at home. Considering TV as unquestionably present in all the families, we asked how many young people have a personal computer (Fig. 1) and/or a playstation at home (Fig. 2).

It is possible to remark that in average PC possession at home is quite high for both genders (more than 80%): in the highest age classes the percentage are similar for both males and females, while within the youngest there is a slight prevalence of possession by males. For playstations ownership the gender difference is evident: in average 84 % of males has a playstation, vs. 50% of females; boys seem to be very interested to new entertainment technologies in all ages classes, while girls show an increased interest in middle school (11.6-14.5 years).

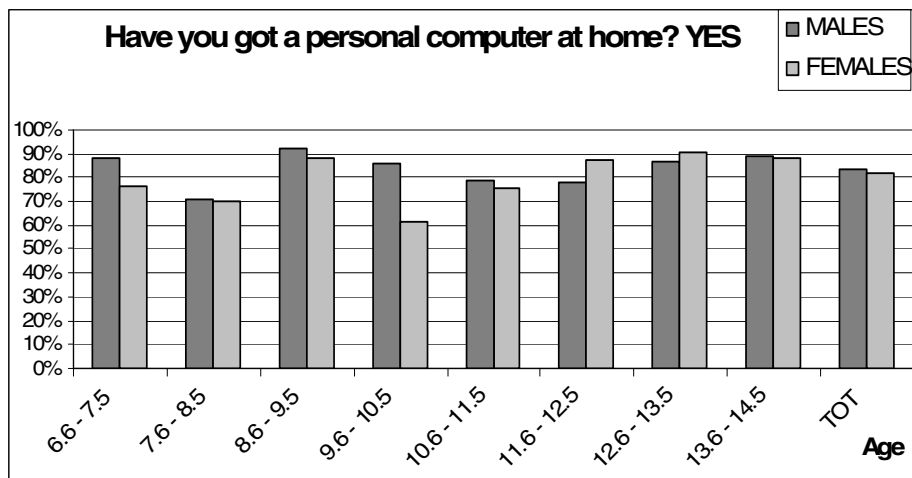


Fig. 1. Percentages of males/females that have a PC at home

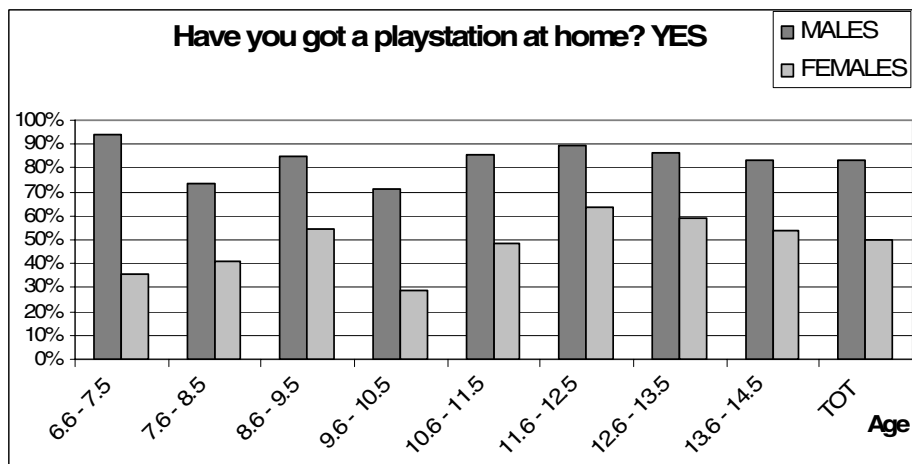


Fig. 2. Percentages of males/females that have a playstation at home

In Table 2 is shown the average time per day spent by the students at home in front of a computer monitor, TV screen or playstation: the total time is definitely high and

increases with age, especially for males (that spend more time using playstations) reaching more than 5 hours/day in the two last ages classes; in the meanwhile we assist to a progressive reduction of motor abilities of children in developmental age [3]: this two phenomena negatively affect the children's lifestyle and can influence the correct growth of their different body segments during their developmental phase.

Table 2. Hours per day spent in front of a monitor by age classes and gender

	age classes							
MALES	6.6-7.5	7.6-8.5	8.6-9.5	9.6-10.5	10.6-11.5	11.6-12.5	12.6-13.5	13.6-14.5
TV	2,21	1,93	1,90	2,04	1,93	2,97	3,79	3,45
VDT	0,43	0,34	0,25	0,29	0,33	0,46	0,63	0,89
Plays	0,39	0,66	0,38	0,52	0,64	1,32	1,78	1,38
TOT	3,03	2,93	2,53	2,85	2,90	4,75	6,19	5,72
FEMALES	6.6-7.5	7.6-8.5	8.6-9.5	9.6-10.5	10.6-11.5	11.6-12.5	12.6-13.5	13.6-14.5
TV	1,77	1,73	1,93	2,06	1,88	3,26	3,67	3,49
VDT	0,22	0,20	0,25	0,18	0,43	0,41	0,58	0,63
Plays	0,21	0,22	0,34	0,29	0,40	0,77	0,95	0,67
TOT	2,20	2,15	2,52	2,53	2,71	4,44	5,20	4,80
AVERAGE M+F	2,62	2,54	2,53	2,69	2,81	4,60	5,70	5,26

Probably the precision of the answers of children of the first ages classes wasn't very high, but anyway data reliability can be considered acceptable, as the gender differences in time of playstation use correspond to the expectations. It is important to point out that data of Table 2 are average values and that 3% of boys of middle school use playstation every day for more than 4 hours!

Quite high is the time spent to watch TV programs, that shows limited differences between males and females; the time is considerably higher for children in the middle school, that seem to watch TV about the double of the time of children of primary school, but probably this latter time could be underestimated, for the considerations done before.

Time per day spent in front of a VDT is not very high but seems to increase for both sexes with age.

We also analysed the presence of poor postural and behavioural habits in VDT, TV and playstation and the consequent occurrences of physical discomfort and pain.

In Fig.3 we can see the percentage of subjects feeling pain in at least one body segment after VDT use: it is impressive that in average 31% of females and 25% of males feel some pain, even if the time spent in front of VDT, as shown in Table 2, wasn't very high. Females are more sensitive and show higher values, that tend to increase with age. It is possible that girls denounce more frequently troubles and discomfort as they usually give more attention to their body than boys. This gender difference is confirmed also later, in adult age: women seem to complain more than men for a high incidence of musculoskeletal disorders in clerical activities [4].

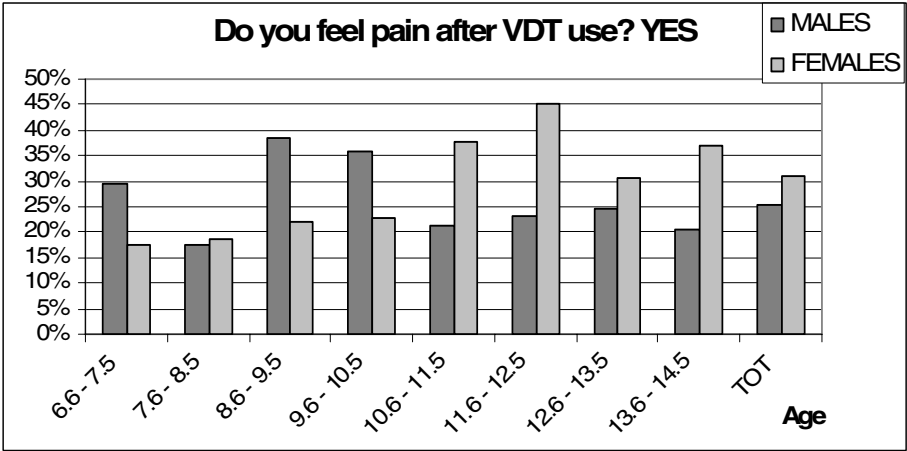


Fig. 3. Percentage of subjects feeling pain in at least one body segment after VDT use

The investigation of painful body regions was obtained asking children to point on a human body silhouette where they felt pain after VDT use. They often indicated more than one area.

Table 3. Percentage of subjects declaring to feel pain after VDT use in the different body parts in primary school (6.6-11.5 years) and middle school (11.6-14.5 years)

BODY PARTS	VDT			
	MALES		FEMALES	
	6.6 - 11.5	11.6 - 14.5	6.6 - 11.5	11.6 - 14.5
EYES	21%	6%	17%	10%
NECK-HEAD	5%	11%	3%	14%
BACK	11%	9%	6%	19%
INFERIOR LIMBS	4%	3%	1%	8%
WRISTS, HANDS	10%	3%	12%	7%
SUPERIOR LIMBS	1%	1%	0%	1%

In Table 3 we can see the percentage of subjects (males and females) declaring to feel pain after VDT use in the different body parts, with data gathered for the two school levels considered. Youngest subjects (both males and females) declared to have more problems to eyes, while, growing up, the prevalent pains are the musculoskeletal ones (particularly on back and neck/head) for both genders.

Pain presence is confirmed also after playstation use: 22% of females and 31% of males in primary school, 30% of females and 21% of males in middle school declared to feel pain in at least one body segment. In Table 4 are shown the percentages of subjects (males and females) declaring to feel pain in their different body parts. Eyes are the more affected body parts for all the subjects categories, followed by neck/head

and wrists/hands districts. Generally males show higher percentages vs. females: this is consistent with their higher use of playstations.

Table 4. Percentage of subjects declaring to feel pain after playstation use in the different body parts in primary school (6.6-11.5 years) and middle school (11.6-14.5 years)

BODY PARTS	PLAYSTATION			
	MALES		FEMALES	
	6.6 - 11.5	11.6 - 14.5	6.6 - 11.5	11.6 - 14.5
EYES	13%	8%	5%	8%
NECK-HEAD	6%	4%	0%	3%
BACK	3%	2%	2%	2%
INFERIOR LIMBS	2%	1%	0%	2%
WRISTS, HANDS	4%	2%	3%	6%
SUPERIOR LIMBS	1%	0%	2%	1%

Comparing the disturbs caused by computer use vs. those by playstation use, VDT seems to induce much more problems, even if the average time spent in their use is shorter: this fact could depend on the greater postural constraints of VDT use.

Visual fatigue in PC use is particularly evident in primary school, for both sexes, while in playstation it is noticeable especially among boys.

Musculoskeletal discomfort and pain after PC use is mainly localized in the back, that isn't particularly affected by playstation use; pain in neck/head and wrists/hands is quite high after PC use, but is also evident after playstation use.

One of the possible causes of visual disturbs and fatigue is the inadequate position of monitor in relation with natural and artificial lighting: in Table 5 are reported the percentages of subjects of primary and middle school that declare to have noticed reflections on the screen in the different situations examined: the very high percentages evidenced by middle school students for all the media can be due to their greater consciousness about glare problem.

Table 5. Percentage of subjects in primary school (6.6-11.5 years) and middle school (11.6-14.5 years) that notice reflections on VDT, TV and playstation monitor

REFLECTIONS	MALES		FEMALES	
	6.6 - 11.5	11.6 - 14.5	6.6 - 11.5	11.6 - 14.5
VDT	22%	46%	24%	48%
TV	11%	56%	31%	62%
PLAYSTATION	22%	46%	19%	44%

The origin of musculoskeletal disturbs can depend by the fact that the analysis of the working environment features shows few aspects compatible with ergonomic principles: critical situations are prevailing, mainly regarding workplaces dimensions,

wrong postural attitudes and improper use of the structures. In particular, 46% of males and 52% of females maintain the screen in a too high position, with the highest point of the monitor above the eye level (Fig. 4). Only 6% of males and 8% of females has the monitor correctly positioned lower than the eye level.

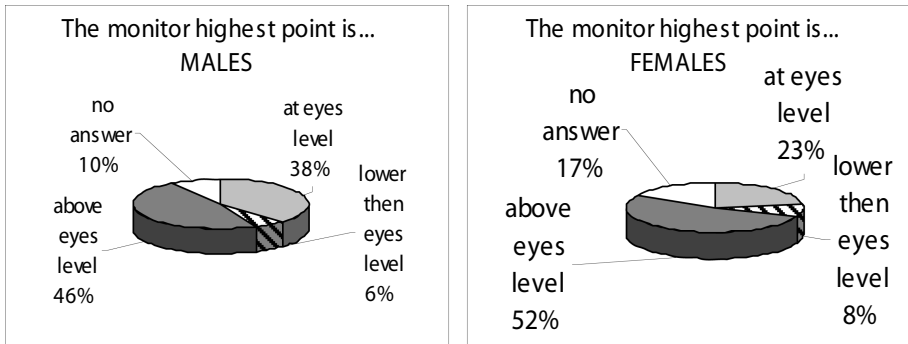


Fig. 4. Position of the highest point of the monitor and the eye level

Contrary to the expectation that youngest subjects could have the monitor too high, because of their smaller stature, this wrong position is common in all age classes and in both genders (Fig. 5). A possible cause for this scattered distribution of incorrect monitor position could be the high percentage of children that use unadjustable seats: 44% of males and 37% of females of primary school children and 47% of males and 38% of females of middle school.

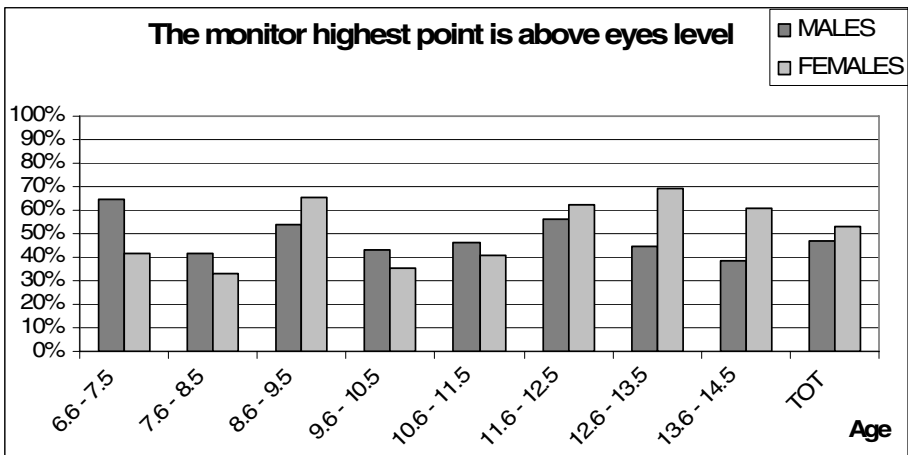


Fig. 5. Percentages of subjects that have the highest point of the monitor above the eye level

In addition poor habits and incorrect postural behaviours are quite frequent during VDT, playstation and TV use: the most common are shown in Tab 6: the total

percentages can be over 100%, as some subjects had contemporarily more than one poor habit. In VDT use there aren't particular differences by gender and age, but poor habits are frequent and could explain the high referred incidence of the musculoskeletal pains. Using playstation most of the children don't support their arms and values increase with age; often they stay on the floor or lay on the bed or sofa. The latter bad habit is evident also watching TV and increases with age. The total of percentages of poor postural habits using playstation and watching TV increases with age, particularly in females.

Table 6. Percentage of subjects in primary school (6.6-11.5 years) and middle school (11.6-14.5 years) with poor postural habits in VDT and playstation use and TV watching

POOR POSTURAL HABITS	MALES		FEMALES	
IN VDT USE	6.6 - 11.5	11.6 - 14.5	6.6 - 11.5	11.6 - 14.5
don't support their forearms during keyboard use	59%	52%	54%	52%
don't support their wrists during keyboard use	62%	51%	62%	47%
don't support their back (often or always)	19%	17%	19%	22%
hasn't the monitor centred with the sagittal plane	27%	30%	20%	31%
TOTAL	167%	150%	155%	152%
IN PLAYSTATION USE				
laying on the bed/sofa	10%	15%	7%	14%
staying on the floor	18%	8%	20%	19%
don't support their arms during console use	58%	74%	54%	83%
TOTAL	86%	97%	81%	116%
WATCHING TV				
laying on the bed/sofa	27%	39%	26%	39%
staying on the floor	15%	5%	10%	9%
TOTAL	42%	44%	36%	48%

4 Conclusions

It is quite alarming that a considerable percentage of children complains of symptoms of visual fatigue and musculoskeletal problems after the use of new technological devices, that evidently create additional eyestrain and stress in their developing muscles, bones, tendons, and nerves, with possible cumulative effects. As younger children begin using new technologies intensively, they may be at greater risk than older ones, since their body structure is still growing.

Although it is recognised that videogames, TV and computer can have a formative value, it is necessary to enforce hazard prevention teaching educators and families [5]:

- to limit the time spent by children in front of a monitor
- to instruct them to maintain correct postures

- to choose workstations and furniture compatible with the ergonomic requirements of children, possibly adjustable, to take into account that they are in a growing phase: equipment and furniture designed for adults should not be shared by children, because usually they do not fit their needs.

It seems even important to emphasize their role of technology intermediaries to make children aware about the importance to devote a sufficient time to physical activities, to social relations and to the interaction with the natural and real world. Such attentions can help to prevent the risk of serious physical and psychological effects on young people, that can have dangerous long-term consequences, sometimes irreversible and lifetime lasting. As it is difficult to unlearn deep-rooted poor habits, it is necessary to instruct children to work in neutral, supported postures and to take frequent breaks, during which they move and stretch.

In Italy we notice a recent increasing awareness about children's back pain and the need to adequate school furniture to users' dimensions according to Mandal [6] suggestions. An educational program on school ergonomics for children 8-11 years old is now supported by ISPELS (Istituto Superiore per la Prevenzione e la Sicurezza del Lavoro – Superior Institute of Work Prevention and Safety) and includes also a module on the correct use of a computer workstation [7]. We hope that it could find a large application in schools, in order to promote changes in current behaviours.

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Ergonomic Requirements for Input Devices

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Abstract. The aim of this literature research was to gather information on ergonomic requirements for input devices that are provided by investigations applying biomechanical criteria. Firstly, international and national standards, guidelines as well as checklist of this topic had been looked for and their propositions were summarised. Secondly, a query on Internet search engines and databases had been conducted. A ranking system for the selected articles had been installed in order to comprehensibly rate the information obtained from each study. For every regarded input device, i.e. keyboard, mouse, trackball, graphic tablet/stylus and additionally forearm/wrist support, biomechanically based assessment parameters were deducted and outlined. Finally, these findings were discussed with respect to the recommendations of the standards and an overall ergonomic design of office workplaces with VDTs. In conclusion, this will lead to the development of a checklist for keyboards and mice that should be evaluated by occupational health practitioner.

Keywords: office ergonomics - input devices - musculoskeletal disorders-biomechanical criteria.

1 Introduction

Nowadays, the use of a computer and consequently of input devices is hardly indispensable at most workplaces and therefore widespread. Even though computer work and operating input devices do not seem to be a physically demanding work, a link between work-related risk factors and musculoskeletal disorders especially of the upper limb is described in the literature [1]. In this context, national and international standards concerning ergonomics at office work with visual display terminals (VDTs) do not provide precise, physiologically/biomechanically based criteria to support practitioners in Occupational Safety and Health in evaluating the ergonomic suitability of input devices. Nevertheless, the standard EN ISO 9241-9 gives information on instruments and methods that could only be employed by experts and allow for objective analysis of the exposure to biomechanical stress. By this, researchers in the field of office ergonomics should be encouraged to use these methods during studying the ergonomics of input devices and to give scientifically based further recommendations. In order to gather and summarise the results of such studies, the VBG, the Institution of statutory accident insurance in the field of administration, initiated a literature review on this issue that was conducted by the BGIA.

2 Methods

At first, national and international standards as well as guidelines and existing checklists that treat “ergonomic” design of input devices had been found out.

Secondly, in search for international articles of the last twenty years a query on Internet search engines and databases, e.g. those of the Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (German Federal Institute of Occupational Safety and Health) and of the Berufsgenossenschaften as well as CiteSeer, Compendex, Forschungsportal.net, GoogleScholar, Inspec, and Pubmed, had been executed. English and German search terms had been the following nouns: keyboard, mouse, trackball, graphic tablet and pen and/or mouse, joystick and touch screen in various combinations with computer, office workplace, data input devices, input devices, ergonomics, peripheral equipment, and so on. If the query results exceeded the number of 1000 papers, the query would have been refined. As few papers that deal with the use of joysticks or touch screens at office workplaces could be found, these subjects were excluded from further investigation. The amount of query results necessary to carry out a sound appraisal of studies was only reached for the search terms keyboard, mouse and trackball. During the literature research, forearm and/or wrist supports emerged as an important influencing factor on assessment of input device ergonomics, so that the search terms arm rest, arm support and similar expressions had been added.

First selecting criterion for papers had been the relevance of the topic in the underlying study. Papers had been sorted out, if the underlying studies did not deliver information on ergonomic requirements for input devices and if no biomechanical criteria had been applied for the assessment. Then the study design and the applied methodology of each remaining article had been assessed and ranked in order of relative quality. For this procedure, six criteria (number of test subjects, collection of data, investigation schedule, kind of work/task, control group/comparison group, statistical analysis) and the conditions under which they were met or not had been defined. If all criteria were fulfilled the quality of the study was estimated as very good (3); studies that achieve the conditions of at least three criteria were marked as good (2); otherwise (less than three criteria met) the score was fair (1). This ranking was installed to comprehensibly rate the information obtained from a study.

3 Results

The results will be outlined once as a summary extracted from existing standards, guidelines or checklists and once as findings drawn from the appraisal of the literature.

3.1 Review of Standards, Guidelines and Checklists

Table 1 gives an overview of the relevant standards, guidelines or checklists that define parameters of input devices’ design and propose certain metrics.

Table 1. Relevant standards, guidelines or checklists and their topics

Standard/Guideline/Checklist	Topic
EN ISO 9241-400 [3]	Input devices in general
EN ISO 9241-4 [4]	Keyboard
EN ISO 9241-5 [5]	Forearm/wrist support
EN ISO 9241-9 [2]	Various input devices, excepting keyboard
ISO/CD 9241-410 [6]	Various input devices
Arbeit mit dem Bildschirm aus dem Handbuch der Arbeitsmedizin [7]	Keyboard, mouse
Bildschirm- und Büroarbeitsplätze. Berufsgenossenschaftliche Information (BGI) Verwaltungs-Berufsgenossenschaft (VBG) [8]	Keyboard, mouse
Guidelines to the selection and purchase of workstation furniture and equipment. Human Resource Management Division (HRM), New Zealand [9]	Keyboard
Health and safety regulations. Workstation risk assessment questionnaire. Health and Safety Executive (HSE), England [10]	Keyboard
Ergonomics for the Prevention of Musculoskeletal Disorders. Swedish National Board of Occupational Safety and Health, Sweden [11]	Various input devices
Guidelines on office ergonomics, CSA-Z412. Canadian Standards Association (CSA) International, Canada [12]	

Summary for keyboard. Regarding the tilt of a keyboard a front-to-back inclination is generally recommended and mostly in the range from 0° to 15° [4], [6], [8], [9], [11]; only one guideline prefers a smaller tilt of 10° at maximum [7].

Although 30 mm are frequently defined as the limit for the height [7], [8], [9], [11], two standards find 35 mm also acceptable as maximum, but would advise 30 mm [4], [6].

The width is not specified in the mentioned references, the single allusion concerning this measure is the vague expression “not further extended than required by mechanical considerations” [6].

If the depth of the desktop - that means the space between the computer display and keyboard is restricted, the keyboard should be as small as possible [6].

The appropriate key switch design is described in terms of key displacement (acceptable 1,5mm - 6 mm and optimum 2 mm - 4 mm) [4], [6], [8], key switch make force (tolerable 0,25 N- 1,5 N, ideal 0,5 N - 0,8 N) [4], [6], [7], and key switch force-displacement characteristics like snap action, ramp action, and initial resistance (25 % - 75 % of the force at the character generation point for ramp action or at the snap point for snap action) [4, 6].

Summary for mouse. With regard to the ergonomically relevant properties of the mouse the following more or less detailed propositions from the standards and checklists could be condensed.

The mechanical design of the housing and the buttons should allow for a relaxed, comfortable posture of the hand and fingers [9]. Buttons should have a displacement force within the range of 0,5 N - 1,5 N until actuation and a displacement from a minimum of 0,5 mm to a maximum of 6 mm [6], [12] The fingers should be able to make contact and actuate buttons without excessive deviation from a neutral posture [2]. Input devices should be operable by either hand; or right and left-handed devices should be available [6], [8], [11]. Mouse should be placed at the same level as the keyboard [9] and in such way, that it could be handled without arm abduction or wrist extension [12].

Summary for trackball. In addition to the recommendations for general design aspects of input devices like housing, button design, handedness and so on (see Summary for mouse) the special design requirements for trackballs are mentioned below.

The chord length of the exposed area of the trackball should be at least 25 mm [2], [6]. The exposed arc, measured from the centre of the trackball should be not less than 100° and not greater than 140°. The recommended exposed arc is 120° [2], [6], [12].

The permitted range of actuation rolling force goes from 0,2 to 1,5 N; the starting resistance should be 0,2 to 0,4 N [2], [6], [12].

Comparing mouse and trackball user compatibility the trackball use achieves a lower level of effectiveness and efficiency. Unintended loss of control may occur more often as well. Trackballs may prove more appropriate for most applications with a graphical interface or in any environment with limited space. As trackballs are susceptible to environmental influences, i. e. vibration, instable work surface, and especially dust, the ball shall be easily removable for cleaning [6].

Summary for graphic tablet/stylus. The peculiar design requirements on graphic tablet/stylus are outlined herewith.

The design (height depth and slope) of the tablet that is incorporated into the workstation should allow the user to adopt the design reference posture [6].

Cylindrical styli should have a length between 120 mm and 180 mm and a diameter from 7 mm to 20 mm. The mass should be between 10 g and 25 g [2], [6], [12]. Buttons surfaces should be perpendicular to the displacement direction and to the motion of the finger during flexion [6], [12]. A selector button should feature a contact surface with a circular area not smaller than 5 mm in diameter [2], [6], [12]. The displacement force of buttons may range from 0,3 N to 1,5 N until actuation and the displacement may vary from 0,5 mm to 6 mm [2], [6].

For intermittent input against the tablet, the maximum force required for input should not exceed 1,0 N and for continuous input using styli, the activation force for the stylus on the tablet should not be greater than 1, 5 N [2], [6]. However, the Canadian Guidelines on office ergonomics prefer an activation force limit for styli on he tablet during continuous input of 0,5 N[12].

Summary for forearm/wrist support. Instructions how to realise sufficient support for the forearm and/or wrist are given in very different ways. The most tentative statement was to provide enough place for the hands and arms [10]. Other standards and guidelines specify the interspace needed in front of a keyboard from over 50 mm [7] up to 100 mm at minimum [4], [5], [6], or in front of a wrist support from 100 mm to 150 mm [8].

3.2 Review of the Literature

Table 2 shows the number of papers found for several input devices and forearm/wrist supports in order of quality score.

Table 2. Number of papers categorized by type of input device in order of quality score

Number of papers for (total number)					
Score	Keyboard (30)	Mouse (34)	Trackball (14)	Graphic tablet/stylus (5)	Forearm/wrist support (21)
1	2	3	4	1	0
2	19	20	7	6	14
3	6	6	2	0	6

Remark 1. This literature could be asked for at the author.

The risk factors of the work with input devices that are accused to cause musculoskeletal disorders of the upper extremity had been identified as awkward respectively static postures, exerted force and repetitiveness. While in most cases an improvement of repetitiveness could be achieved by organisational restructuring of the office work and tasks, an “ergonomic” design of input devices could help to tackle both first mentioned problems. In the reviewed literature such design solutions had been investigated and evaluated by means of measurements of postures, electrical muscle activity (EMG), and performance, as well as of subjective ratings of perceived exerted force or comfort/discomfort and disorder questionnaires.

Summary for keyboard. The observed postures of the upper extremity during keyboard use had been described as extension of 8° - 20° and ulnar deviation of 10° - 20° for the wrist and a nearly wholly pronation (80°) of the forearm [13], [14], [15]. New designs of keyboards that enable the user to adopt a more neutral posture had been launched: keyboards with a negative slope target the extension, angling or separating two halves of the keyboard and for example synclinal shaped keypads should reduce the ulnar deviation, lateral tilted or vertical orientated keyboard sections should promote the neutral forearm posture. The analysis of the study results on these keyboard designs suggests an ergonomic benefit by using keyboards with a slightly changed design, i. e. negative slope of ca. 7°, angling of halves of about 25° and a slight lateral tilt. This recommendation is especially valid for VDU workers who know ten-key typing.

For keyboard users who already report health complaints like paraesthesia of the hand, changes of the key switch displacement-force characteristics might to be useful

[16]. Furthermore, a decrease of exerted force seemed to be achieved more efficiently by reducing the typing speed [17].

Summary for mouse. The deviations from the neutral posture during mouse use could be characterised as the following: wrist extension in the range from 15° - 30°, ulnar deviation between 5° and 18°, shoulder flexion up to 30° and arm abduction of 30° to over 40°, outer rotation in the range from 5° to 45° [18], [19], [20], [21], [22], [23], [24], [25]. Hand-contoured mouse design - sometimes adapted to individual hands - and ideas to shape the mouse like a joystick or a pencil in order to avoid the pronation of the forearm had been realised. Several investigations approve the positive effects on disorders and muscle activity brought about by such new designs. [21], [26], [27] [28], [29], [30], [31].

Other factors sustainably influencing the ergonomics of mouse use are the position of the mouse on the desk top, the combined use with other input devices and the operation methods.

Summary for trackball. Often, the examinations of trackballs were comparisons between trackball and mouse. The results of these studies were somewhat contradictory in dependence of particular designs of the used trackball, individual differences in test persons and the tasks carried out during the tests. Overall, it seems that the trackball requires more finger movements than a mouse [32], the ulnar deviation is smaller but the dorsal flexion of the hand is greater. An easier change from the dominant hand to the other in operating a trackball [33] and the option of stationary use are estimated advantageous.

Summary for graphic tablet/stylus. Study results support the opinion that graphic tablets handled with a stylus represent a real alternative to the mouse.

Summary for forearm/wrist support. The possibility to perform data input using any devices with supported forearm are released favourable. Forearm supports could be implemented in the workstation by providing a desktop of sufficient depth, arm rests of the office chair or separated arm rests. In every case the overall workplace ergonomics must be taken into account.

4 Discussion

Physiologically/biomechanically based criteria to assess the design of input devices from the ergonomic perspective could be extracted from the reviewed literature. Nevertheless, some criteria were ambiguous, when the whole workplace setting is regarded and seemed to be contradictory to the aforementioned standards. For example, the recommended negative slope of the keyboard conflicts with the propositions of the standards and guidelines. This contradiction derives from the necessity of valid standards in general for all (or at minimum most) workplaces and the whole workplace setup. In fact, the reverse slope provokes a lower adjustment of the desktop surface or a higher sitting position and consequently, additional adjustments like foot rests are necessary. Additional to this, during the conduction of

other tasks, e.g. operating the mouse, writing, reading or anything else without computer use, the higher sitting position hinders to adopt the reference posture and might be uncomfortable. One solution for this dilemma might be to produce desks where only a segment of the desktop where the keyboard is placed could be inclined, so that the level of the remaining desk top is suitable for all tasks. However, the fixed position of the keyboard and consequently of the user could be estimated as disadvantage.

This discussion reveals that the recommendations for the ergonomics of input devices found and evaluated in the literature only works under specified conditions taking into account the tasks, method of operating, individual health problems and so on and have to be given in a very sophisticated way.

5 Conclusion

The approach to give complicated advice concerning ergonomics of input devices in a comprehensible and practicable way had been made by compiling a checklist introduced by a code of practice. At first, occupational health practitioners are requested to specify occurring health problems and the underlying reasons in terms of risk factors (awkward posture and so on) and to investigate the workplace. When the most relevant risk factor is identified, based on the results of the literature review - proposals how and under which condition the problem could be resolved are listed in the checklist with respect to the overall workplace ergonomics. The checklist had been worked out for every single risk factor in relation to the use of keyboards and/or mouse as well. The information on other input devices regarded in the literature review was also implemented in the checklist because they were mentioned as alternatives to the both aforementioned input devices most in use. The checklist will be subject of an evaluation in collaboration with occupational health practitioners who will experimentally apply it.

Aside from this, the literature review highlights a field of interest for further research on this issue of wrist/forearm support. It had been shown that even the standards and guidelines deliver inconsistent information how a wrist/forearm should be realized. From the studies that deal with this topic it could be deducted that somewhat larger space to support the forearm should be provided at the workplace but no measure could be quantified.

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Factors Relating to Computer Use for People with Mental Illness

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Abstract. People with mental illness, especially schizophrenia, usually experience obstacles in computer and internet access. The purpose of this study is to investigate factors relating to computer use among Taiwanese adults with mental illness. Individual and semi-structured interviews were used during data collection. Grounded theory data analysis method was used in data analysis. There were one male and six females who live in the community that participated in this research. Results showed that information access, information literacy, information application, family information agency, and personal clinical characteristics were related to computer use. The results of this study may assist computer, education and health professionals in their work with people with mental illness to reduce the digital divide and to experience a better life by expanding their choice of activities through computer and internet access.

Keywords: Computer Access, Digital Divide, Occupational Therapy, Rehabilitation, Schizophrenia, Special Education.

1 Introduction

1.1 Background

Computer technology has developed rapidly and has become an essential part of peoples' daily lives. It is an important tool for learning, social participation, and recreation and has been integrated into everyday activities. Computers can seem very daunting, especially to people who are easily intimidated or confused. They may struggle to understand the concepts and the jargon. People with mental illness, especially schizophrenia, usually experience obstacles in computer and internet access because of their cognitive deficiency. They may encounter difficulties with the computer environment, data entry, information output, and computer learning. These difficulties limit their opportunities to engage in work, learning and leisure activities. If we are able to discover the factors relating to computer use, we are able to expand their choice of activities through computer and internet access.

1.2 Purpose and Significance

The purpose of this study is to investigate factors relating to computer use among Taiwanese adults with mental illness. This study seeks to increase our understanding of the digital divide in an understudied population. It is also the purpose of study to help computer, education and health professionals assist people who have mental illness to reduce their digital divide and to experience a better life.

2 Literature Review

Schizophrenia is a major psychiatric disorder and one that can be long-term disabling. The onset of schizophrenia frequently occurs in early adult life and may pre-empt the development of the daily living and occupational skills of the mature adult, thus making the rehabilitation process difficult [1].

Schizophrenia is a mental disorder characterized by positive symptoms and negative symptoms [2]. Positive symptoms including delusions, hallucinations, and disorganized thinking have generally been assumed to be important determinations of outcome in schizophrenia [2,3]. Negative symptoms include affective flattening, poverty of speech and avolition (inability to initiate and persist in goal directed activities) [2]. Schizophrenia is currently not curable, but through the use of anti-psychotic medication and psychotherapy, the positive symptoms of schizophrenia can usually be controlled. The side-effects of medication include tremor and muscular rigidity [2] which may affect the hand and finger dexterity.

Cognitive deficits associated with schizophrenia commonly consist of impairment in attention, reaction time and memory. Impairment of individuals with schizophrenia had been noted to include: the inability to selectively attend to relevant information while ignoring unnecessary information, the inability to sustain focus over a period of time, and reduced speed in cognitive processing. This results in slowed reaction time and the inability to pay attention to multiple stimuli, which negatively impairs computer use [4].

Based on the positive symptoms, negative symptoms and cognitive deficits, people with mental illness often have problems with computer use and computer learning. Additionally, many professionals find it difficult to advise people who have problems with computer use [5]. Individuals with severe mental illness may benefit from staff that consistently reward small successes and from programs that build positive reinforcements into the program structure [6]. Professionals who know about these factors relating to computer use are therefore extremely important for people with schizophrenia. In response to these needs, we conducted this research to evaluate the factors effecting computer use for people with schizophrenia.

3 Methods

Convenient sampling was used in this study. The participants in this study were seven people with schizophrenia. The location of the interviews was in a day care unit in a

hospital in northern Taiwan. Individual and semi-structured interviews were used during data collection. Data collection was conducted from July to October 2006.

All interviews were audiotaped. Field notes from observations and memos from the researcher's thoughts were also recorded as soon as each interview finished. The length of the interviews ranged approximately 15 minutes to 30 minutes per person. The time depended on the flow of the conversation of that particular interview. Each interviewee was interviewed twice. The total interview time was four hours, producing 137 double spaced pages of transcription in Mandarin Chinese. Grounded theory data analysis method was used in data analysis. The data analysis began with coding the transcripts. The codes for similar concepts were put together as subcategories. Finally, themes related to research questions were identified. Data were analyzed by illustrating subjects' descriptions about computer use in terms of how it relates to their daily living.

4 Results and Discussions

There were one male and six females who live in the community that participated in this research. The age of the participants ranged from 17 to 34 years with a mean age of 25 years. Demographic characteristics for the participants were presented in Table 1. The level of education ranged from junior high school to college. Five of the seven participants are computer literate.

Table 1. Demographic characteristics of participants

<i>Names</i>	<i>Age</i>	<i>Gender</i>	<i>Education</i>	<i>Computer level</i>
Liu	17	Female	Junior high school	Word, Excel
Jiang	19	Female	Senior high school	----
Zheng	23	Female	Vocational senior high school	Word(a little)
Huang	26	Female	Senior high school	Word, Excel, PowerPoint, Outlook, FrontPage /with certificates
You	29	Male	Senior high school (did not graduate)	Delete and copy files
Hu	30	Female	College	Word, Excel, PowerPoint
Wu	34	Female	Senior high school (did not graduate)	----

Results showed that information access, information literacy, information application, family information agency, and personal clinical characteristics all affect the quality and quantity of computer use in the daily lives of the participants.

4.1 Information Access

None of the participants in this study have a personal computer of their own. Also, they do not have computer access in the day care center because the computer room is now occupied by a workshop. The households of most of the participants contain a computer that they can share with family members. One participant's family members do not allow him to have internet access in order to restrict him from surfing on the internet or talking to friends on the internet. So within a household, the level of computer use and internet access of a person's family members can affect his own level of computer use and internet access.

4.2 Information Literacy

Participants who currently use computers already knew how to use computers before they developed mental illness. Some of these participants still have an interest to continue developing their computer skills. One participant has gone to community college for continuing education and has earned a few computer skill certifications. Some participants continually improve their computer literacy on their own by either reading computer related books or surfing on the internet for information. One participant mentioned that English websites or websites with English words were difficult for her to read, even though most websites in the world contains at least some English words or terms. One participant mentioned that she had difficulty in typing Chinese words by using phonetic symbols. A few mentioned that they were afraid of computer viruses because they do not have the computer problem solving skills necessary to handle viruses.

4.3 Information Application

Most of the participants use computers to search for information on the internet related to job, leisure, and health issues. Some mentioned that they search on the internet for medical information, such as checking the side-effect of the medicine they were taking from the on-line pharmacy or comparing different day care centers through their websites. The design of websites does matter to them. One participant mentioned that the day care center she attended had an easy to read website design and contained information that was useful to her.

4.4 Family Information Agency

Family members can help people with mental illness get the information they want when they are not able to acquire the information by themselves. Even though people with mental illness are not good at using computers, they are able to enjoy the convenience of digital technology by family members' assistance. However, family member can be one of the factors that limited the opportunity for computer use and further engaging in computer related activities in people with mental illness.

4.5 Personal Clinical Characteristics

People who have schizophrenia may have personal clinical characteristics which including negative symptoms of illness, side effects of medicine, and impaired cognitive ability. Negative symptoms such as avolition may affect leaning and developing computer skills. Some participants give up easily when confronted with difficulties. Side effects of medicines such as tremor negatively affect the hand and finger dexterity in manipulation of the computer mouse and in keyboard typing. Double clicking of the mouse is difficult for a few participants. Some participants experience difficulty with website surfing or e-mailing because they cannot understand computer file structures due to their lack of abstract thinking ability, memory, and attention span.

In conclusion, findings suggest that it is not only important for people with mental illness to have access to computers, but it is also important to increase their computer information literacy and computer information application in daily living. Family members or caregivers can provide or limit the opportunity of computer use in people with mental illness. Because people with schizophrenia may have negative symptoms and impaired cognitive ability, user friendly computer and website designs are very important. They will benefit from websites designed with a user-friendly interface, particularly in websites related to mental illness, such as hospital affiliated day care center, on-line pharmacy, job search, and on-line support websites.

5 Limitations

The limited number of sessions and length of time of the interview could be considered as limitation of this study. People with mental illness may have poor ability to express their ideas due to their positive and negative symptoms.

Only participants in one day care center in Northern Taiwan were recruited in this study. The level of urbanization and the difference between town and country may influence the results of this study. Although all the participants live in the counties outside of the Taipei city in northern Taiwan, people who live in northern Taiwan may have more experience in computer and internet use compared to other regions in Taiwan. The experiences of these participants may not represent all people with mental illness in Taiwan.

6 Application

The results of this study may assist health professionals, such as occupational therapists, in their work with people with mental illness and further to help them to use computers in their daily lives. First, people with mental illness who have limited problem solving ability and short attention span should be provided a stable, fast and virus free computer. Second, a computer rehabilitation program that is focused on enhancing computer literacy, information application, and personal motivation will promote computer use in this population. The computer rehabilitation program should be designed according to the subject's cognitive level. The computer rehabilitation program can also redesign the computer or mouse, such as changing the mouse double click to a single click or prolonging the time of double clicks in order to compensate for

the tremor of hand movement. The professional should pay attention to the subject's needs for daily computer use and provide suitable problem solving strategies regularly. Third, a website that is created specifically for use by people with mental illness is important to increase their motivation and efficacy in using computers and the internet. The website design should contain an easy interface with clear icons and not too many main points in one webpage. Important areas of content should be accessible within 1 or 2 clicks of the mouse. The website design should make it easy to navigate from webpage to webpage. Our findings may provide website designers with ideas about how to design a user friendly website that people with mental illness will be motivated to visit and browse.

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A Biomechanical Analysis System to Evaluate Physical Usability of Kimchi Refrigerator

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Abstract. A biomechanical analysis system, consisting of measurement and analysis subsystems, were developed and applied in evaluating the physical usability of a kimchi refrigerator. In the system, 3D motion measurement system and force platform system were used in measuring joint positions, ground reaction forces and moments. The systems also includes 3 analysis modules: kinematic, kinetic, and 3DSSPP analyses. Kimchi refrigerator, which is very popular as a specific refrigerator for kimchi, a Korean traditional dish, was evaluated using the system. The refrigerator is designed as a top-cover that makes the users feel uncomfortable in using it, though most people think it is a very useful product. The result showed it is possible to evaluate the physical usability of the refrigerator using the system effectively and reliably.

Keywords: biomechanical analysis, 3D motion analysis, physical usability, kimchi refrigerator.

1 Introduction

In applied ergonomics area, biomechanical approaches have been mainly used in evaluating physical tasks like manual materials handlings [1]. In the process of product design, it seems that ergonomics is emphasized as the principle to improve the usability of a product, which is thought to be less related to biomechanical approaches. Although usability is often thought to be cognitive measures rather than physical aspects in using a product, there should be no barriers in describing and measuring how a product is easy to use. Physical usability is used in this study to specify the usability related to the physical ways of using a product.

Biomechanics is a multidisciplinary activity to investigate and describe the motions and forces of body parts during several activities [1]. When a user uses a product like a refrigerator, his/her motions and related forces on the body could be measured and analyzed through biomechanical approaches. The analysis can be connected to the physical usability of the product.

To carry out those studies, there should be some equipment to measure positions of body parts and forces related to the motion. In addition, it needs properly designed biomechanical analysis modules in which some measures, such as position, force,

moment, velocity and acceleration, should be calculated. The system including measurement system and analysis modules can be used in evaluating physical usability of products.

The objective of this study is to develop a biomechanical analysis system using measurement systems in order to evaluate physical usability of consumer products. The main scope is to develop biomechanical analysis modules using the data obtained from the measurement system. A case study was carried out to investigate how the system works by evaluating the physical usability of a kimchi refrigerator.

2 Biomechanical Analysis System

The biomechanical analysis system consists of a measurement system and analysis modules. Fig. 1 shows the structure of the system and the outputs to be obtained through the analysis modules.

2.1 Measurement System

The system consists of 3 subsystems: a 3D motion measurement system, a ground reaction force and moment measurement system, and a digital recorder. The 3D motion measurement system is an optoelectronic motion measurement system with 5 infrared cameras (ProReflex, Qualisys, Sweden). Reflective markers are used in measuring 3D positions. A force platform is installed to the system to measure the ground reaction forces and moments in three directions (AMTI, USA). Finally, a digital video recorder is used to record the motions. The three subsystems are all connected together so that the measurement could be synchronized automatically.

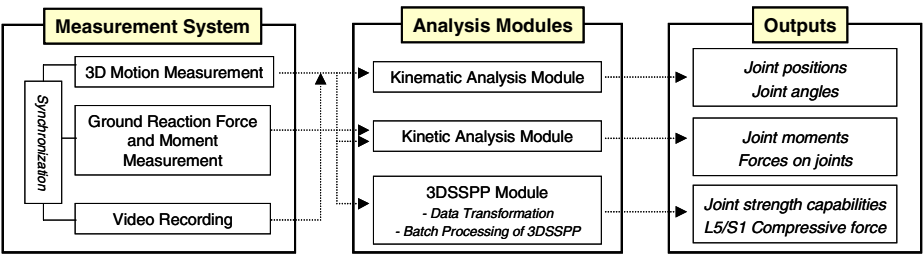


Fig. 1. Structure of the biomechanical analysis system

2.2 Analysis Modules

There are 3 analysis modules in the system: kinematic analysis, kinetic analysis, and 3DSSPP analysis modules. In the kinematic analysis module, the body motion can be analyzed by calculating joint positions, joint angles, body parts' velocities and accelerations. In this module, joint position data measured through the 3D motion measurement system are mainly used and the video recording is used in visually comparing the analyzed data.

In the kinetic analysis module, the physical load on joints can be analyzed by calculating joint reaction forces and moments. In this module, the data from the 3D motion measurement system and the ground reaction force and moment system are mainly used. The module, developed using Microsoft Excel, includes an algorithm to find out the motion with high moments on each joint.

In the 3DSSPP analysis module, 3DSSPP (3D Static Strength Prediction Program) is used in analyzing biomechanical load on the body [2]. The program was designed to evaluate manual materials handling tasks through biomechanical analyses. In this module, an algorithm to transform the joint position data measured by the 3D motion measurement system into an input format of 3DSSPP. The transformed data is used in making a batch file to be processed by 3DSSPP for analyzing the physical load of the tasks. It is possible to analyze many motions using 3DSSPP at a time in this module. The results include the strength capabilities and compressive force at L5/S1. The module was developed using SAS and Microsoft Excel.

3 Case Study: Evaluation of Kimchi Refrigerator

3.1 Kimchi Refrigerator

Kimchi refrigerator is a specific refrigerator for kimchi, which is a traditional Korean dish of fermented vegetables seasoned with chili peppers and salt. The kimchi is so popular in Korea that most Koreans eat it everyday and keep some quantity of kimchi at their home. Because kimchi is a fermented dish, the length of keeping its proper taste is strongly affected by the temperature and the storing way. In tradition, Koreans have stored lots of kimchi in ceramic jars buried under the ground to secure its optimal taste during winter season. However, the Korean modern housing circumstances have made it difficult for the people to take the traditional way of storing. As the society developed economically much, the people began to feel that the general refrigerator has a limit in storing lots of kimchi for a long time. The kimchi refrigerator was developed based on the social necessities about 10 years ago, and now it came to be a popular consumer product like the general refrigerator, washing machine or TV set. It is presumed that more than 80% of Korean families have their own separate refrigerator that is designed to keep kimchi at an optimal temperature for proper fermentation [3].

In a survey to investigate the customer satisfaction of kimchi refrigerator, it was shown that the most users are satisfied with the use of the refrigerator [4]. However, they also reported high discomfort related to the way of using the refrigerator, in particular, bending his/her torso very much to put kimchi cases into the refrigerator, take them out of it, or clean its inside. Seventy-five percent of the respondents reported the experience of body-part pains and 58.4% of them reported pain experience in the back. It is presumed that these results are highly correlated to the top-cover design of the refrigerator, which is the popular style to improve its performance of maintaining the temperature properly (Fig. 2).



Fig. 2. An example of a popular top-cover kimchi refrigerator

3.2 Experiment

Subjects. Three female volunteers participated in the laboratory experiment. They have no history of any musculoskeletal diseases. They all have the experience of using kimchi refrigerator.

Measurement of Joint Positions. An optoelectronic motion measurement system with 5 infrared cameras (ProReflex, Qualisys, Sweden) was used to measure the position of joints. Reflective markers were put on 22 landmark positions: right and left sides of the head, the 7th cervical vertebra, sternum, right and left acromions, right and left elbows, right and left wrists, right and left hands, right and left pelvises, right and left hip joints, right and left knee, right and left ankle joint (Fig. 3).



Fig. 3. The positions of markers for 3D motion analysis

Kimchi refrigerator. A kimchi refrigerator commercially manufactured was selected in the experiment (Fig 2). It has three bays to put kimchi cases or vegetables. Usually, the upper bays with top-cover are used in storing kimchi, which is kept in the specific cases. The refrigerator was designed to put 6 cases into the upper bays, which are stacked in 3 layers and 2 columns: case 1: an upper layer and forward column (close to the user); case 2: the upper layer and backward column (far from the user); case 3:

a middle layer and forward column; case 4: the middle and backward column; case 5: a lower layer and forward column; and case 6: the lower layer and backward column.

Experimental task. The subject was asked to stand on the force platform, which is located in front of the refrigerator (Fig. 3). The subject then took out the kimchi cases, which were filled with sand and weighed 10 kg, from the refrigerator in the order of the case numbers (1 to 6). She took out the kimchi case and stacked them on the floor by the refrigerator.



Fig. 4. The postures adopted for putting a case into the refrigerator

3.3 3DSSPP Analysis

Using the 3DSSP analysis module, the 3D position data were transformed automatically and the batch processes of 3DSSPP were carried out. It was possible to calculate L5/S1 compressive forces at all motions of lifting the kimchi cases out of the refrigerator. As expected, the compressive forces were highest when the subject lifts up the case from the stack. The compressive forces at that moment were extracted and Fig. 5 shows the mean values. The graph shows that the compressive force increase as the layer of case is lower and the case is far away from the user. The

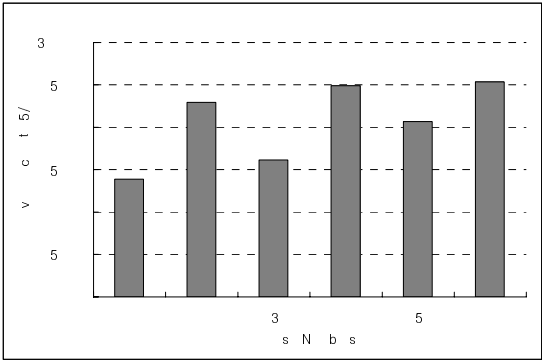


Fig. 5. Mean compressive forces at L5/S1 according to the cases to be lifted

highest compressive force was about 2,500 N when lifting the case in the lower layer and backward column. Because NIOSH defined 3,400 N as the action limit [1], it can be said that the task of lifting kimchi case does not involve high risk of low back pain. However, it should be remarked that the users of the refrigerator are generally female and elderly people, and the task could involve a high risk for those relatively low capabilities.

4 Conclusion

In this study, a biomechanical analysis system was developed using a 3D motion and ground force measurement system. The system includes the modules to carry out kinematic, kinetic, and 3DSSPP analysis. The case to evaluate the kimchi refrigerator showed that the system could be used in evaluating the physical usability of various products effectively and reliably. In the future, more effort is necessary to make the system easy to use, and standardize and validate the methods of evaluating physical usability.

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An Experimental Study on Physiological Parameters Toward Driver Emotion Recognition

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Abstract. Although many emotion recognition methods have been developed, monitoring a driver's emotions during driving is still a challenge because some special requirements must be met. This study begins with the classification of emotion, and then proceeds to emotion recognition. In particular, this study presents the applications of blood volume pressure, skin conductance, skin temperature, gripping force, respiration rate, and facial expression in emotion recognition. Experiments are designed and carried out to find the mapping relation among heart rate, skin conductance, and skin temperature to two kinds of emotions: fear and amusement. The experimental results demonstrate the feasibility of using the selected physiological parameters to monitor drivers' emotions.

Keywords: physiological signal, emotion recognition, multimodality, driving.

1 Introduction

In a driver-vehicle-road system, the driver's state is essential to achieve safe driving. According to National Highway Traffic Safety Administration (NHTSA), some form of driver inattention was involved within three seconds before 80% of crashes and 65% of near-crashes [1]. Hence, it is important to monitor drivers' states during driving to improve their safety.

A driver's state generally consists of two aspects, physiological state and psychological state. The physiological state can be recognized by using medical knowledge. The psychological state refers to driver's emotion, which is an intense neural state that arises subjectively [2]. People have developed many emotion recognition methods [3]. However, monitoring a driver's emotions is still a challenge for two reasons: (1) the method should achieve a high recognition rate, and produce a real-time output, and (2) the input signals employed must be accessible during driving, and be measured by non-intrusive means. Few of current emotion recognition methods can meet these requirements. Hence, it is necessary to develop a method which can monitor a driver's emotions.

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2 Motivation

In this study, the goal is to find appropriate physiological parameters for recognizing a driver's emotions during driving, and to find the relationship between his or her physiological parameters and emotions. The following sections, first discuss the classification and recognition of emotion, and then introduce five physiological parameters and facial expressions that are suitable for the monitoring of drivers' emotions. Finally, experiments are designed and carried out to verify the mapping relations between physiological parameters and emotions.

3 Emotion Classification and Recognition

So far, there is no universally accepted method of classifying emotions. People usually adopt two approaches to do the classification. One approach is discrete emotional categories. In daily life, people describe individual emotions by using terms such as happiness, fear, etc. It is therefore sound to label emotions in discrete categories such as anger, disgust, fear, joy, sadness, and surprise [4]. However, this approach proves difficult in classifying blends of emotions. In addition, it is restrictive or culturally dependent to name emotions [5]. The other approach is multiple-dimension emotion spaces [6-8]. One popular emotion space is the arousal-valence space in which arousal and valence indicate the activation level and the pleasantness of the stimuli, respectively [6]. By using the arousal-valence space, people can easily quantify human emotions [9]. However, it has not been verified that the arousal and valence are entirely independent [2]. Also, the emotion quantification result is person-dependent. As a result, this study selects discrete emotion categories, anger, disgust, fear, joy, sadness, surprise, and neutral to classify drivers' emotions because (1) a driver's performance is more affected by strong emotions than by weak emotions, (2) this classification method is simple and direct, and (3) it is convenient to evaluate the emotion recognition rate.

People usually recognize others' emotions from their facial expression and speech. However, emotions induce not only outward physical expression but also changes in physiological parameters. Thus, physiological parameters are also useful in evaluating human emotions [2;10;11]. Researchers have studied many emotion recognition methods based on facial expression [12;13], speech features [14;15], or physiological parameters [4;11]. These methods can be classified into two categories: single-modality [11-15] and multi-modality [16;17]. When driving, a driver has little time to speak. Thus, the speech based methods are not suitable for this application. More attention should be paid on physiological parameters and facial expression from which the mapping relations between physiological parameters and emotions are explained as follows:

(1) Blood Volume Pressure (BVP). The human heart is the pump of the human circulatory system, and produces the blood volume pressure (BVP) of whose value changes with each heart beat. Thus, BVP can be utilized to calculate the heart rate (HR) and heart rate variability (HRV). Ekman *et al.* have reported that a larger increase in heart rate is produced in anger, fear and sadness than in disgust [18].

Palomba *et al* have found a deceleration in the heart rates of participants who watched surgery films [19]. Haag *et al* have indicated that the sympathetic and parasympathetic vagus nerves influence HRV [20]. Hence, BVP can be utilized to recognize drivers' emotions.

(2) Skin Conductance. Skin conductance describes the ability of human skin to conduct electricity. Many papers have reported the significant relations between skin conductance and emotions. Ekman *et al* have verified that fear and disgust elicit larger skin conductance than happiness [18]. Gross and Levenson have observed that participants' skin conductance does not change after watching sad films, increases after amusing ones, and decreases after neutral films [21]. Nakasone *et al* have concluded that skin conductance linearly changes with individual levels of overall arousal [4]. Hence, skin conductance is important for drivers' emotion recognition.

(3) Skin Temperature. Skin temperature is an important physiological parameter in medical diagnosis. It is also affected by human emotions. Ekman *et al* have proven that fear produces a smaller increase in finger temperature than anger [18]. Levenson *et al* have found that the finger temperature increases for anger, but decreases for fear [22]. Sinha and Parsons have utilized physiological parameters, such as finger temperature, to recognize emotions, and achieved a 99% classification rate [23].

(4) Respiration Rate. Respiration rate is the number of times that a human inhales and exhales per time unit. Respiration is generally influenced by a person's physical workload. As the physical workload increases, more metabolic energy and oxygen are required, inducing a stronger respiration [24]. In addition, respiration can indicate the activity of the autonomic nervous system in the condition of vigilance, emotional response and mental workload [25]. It is also useful in recognizing a subject's underlying affective state [26].

(5) Gripping Force. Gripping force is the force that the driver applies to the steering wheel. According to common sense, a driver's gripping force varies with the driver's emotions. For example, a driver will increase the gripping force when nervous. Moreover, it has been utilized to evaluate real-time hypo-vigilance during driving [27].

(6) Facial Expression. With the development of image processing technology, people have employed this technology to extract facial features. The features can be utilized to recognize emotions by using the Facial Action Coding System (FACS) [12; 28]. The emotion recognition rate can achieve 74%-98% [29]. However, anger and disgust, fear and surprise are commonly confused in many studies because they share similar facial actions. Thus, facial expression-based methods may be difficult to implement in decreasing emotion recognition error.

After investigating the popular signals in emotion recognition, this study has selected blood volume pressure, skin conductance, skin temperature, respiration rate, and gripping force to recognize human emotions. This multimodal method can fulfill the task of recognizing human emotional state during driving. This preliminary work will be further applied to driver emotion detection.

4 Emotion Recognition Experiments

Considering the experimental resource, this study designed and carried out experiments to find the mapping relations among heart rate, skin conductance, and skin temperature to two emotions: fear and amusement. The experimental factor is human emotion. It is hypothesized that physiological parameters change with human emotions.

4.1 Experimental Apparatus

The experimental apparatus consists of two computers, one 8-channel multi-modality encoder (i.e. ProComp Infiniti, Bio-Medical Instruments Inc.), one USB adapter (i.e. TT USB, Bio-Medical), one skin conductance sensor (i.e. SC-Flex/Pro, Bio-Medical), one blood volume pressure sensor (i.e. BVP-Flex/Pro, Bio-Medical), and one skin temperature sensor (i.e. Temp-Flex/Pro, Bio-Medical). The sensors are connected with the ProComp Infiniti that sends the data to computer No.2 by using TT USB (Fig. 1). Computer No.2 is utilized to record and analyze the data. Computer No.1 is employed to play movie clips to elicit emotions.

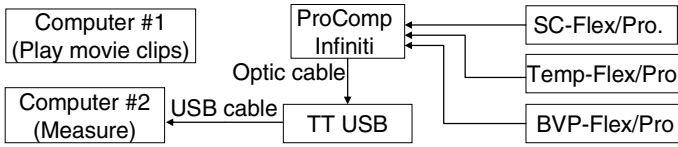


Fig. 1. Experiment set-up

4.2 Experimental Method

How to elicit the targeted emotions? The feasible methods include movie clips [30], texts [31], pictures [6], etc. Movie clips are selected in this study because (1) 60% participants are not native English speakers, and (2) pictures can not elicit as high emotion intensity as movie clips do. Thus, two movie clips from the scary films *The Grudge*, and *The Exorcist*, respectively, are used to elicit the emotion of fear. One movie clip from the comic film *Eurotrip* and one clip from comic television shows are utilized to elicit the emotion of amusement. The clips vary in length between 180 and 500 seconds.

Five university students in the age group of 20~35, one woman and four men, were invited to carry out the experiments. Their age distribution produces a mean of 27.2 and a standard deviation of 5.54. Their available times were random.

After arriving at the lab, each participant firstly rests on a seat about 10 minutes until a metabolic steady-state is reached. The participant can choose a comfortable posture and must remain as still as possible during all experiments. Then, the participant watches the four movie clips one by one. The playing order is randomly selected by using a program. After each movie clip, the participant has a break of 5 minutes, and recovers from the previous emotion. Simultaneously, the participants' heart rate, skin conductance, and skin temperature are measured with a rate of 8 samples per second.

4.3 Results and Discussion

In this study, the participants carried out a total of 19 experiments from which 19 data files were generated. Four of the participants carried out four experiments, respectively, while the fifth participant performed three experiments. As an example, participant No.1’s heart rate, skin conductance and skin temperature against time are illustrated in Figs. 2, 3, and 4.



Fig. 2. Participant No.1’s heart rate (HR) when watching the four movie clips

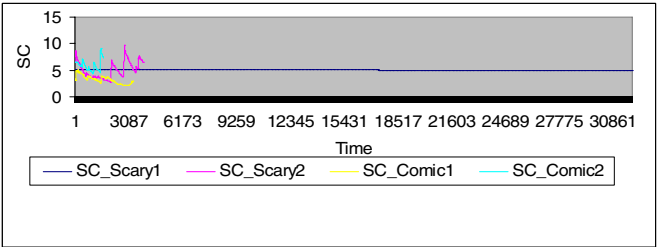


Fig. 3. Participant No.1’s skin conductance (SC) when watching the four movie clips

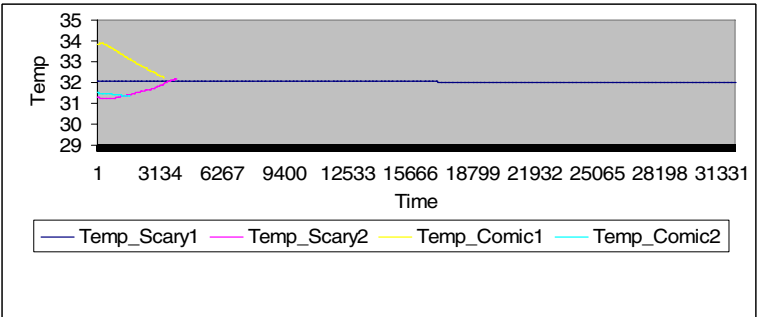


Fig. 4. Participant No.1’s skin temperature (Temp) when watching the four movie clips

All participants’ means and standard deviations of heart rate, skin conductance, and skin temperature are calculated and shown in Table 1. It is noted that participant

No.5’s data in comic clip No.2 is not available because the experiment was missed. Thus, the participant’s data in scary clip No.2 should be removed for satisfying the requirements of analysis of variance (ANOVA).

Table 1. Means ($\bar{x}$) and standard deviations (SD) of heart rate (HR), skin conductance (SC), and skin temperature (Temp)

Participant	Parameter	Comic clip #1		Comic clip #2		Scary clip #1		Scary clip #2	
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
No.1	HR	84.85	34.66	80.18	28.75	67.65	6.28	73.91	19.27
	SC	2.93	0.74	4.75	0.96	5.24	0.09	6.11	1.56
	Temp	33.1	0.51	31.43	0.05	32.01	0.03	31.56	0.29
No.2	HR	61.84	3.56	62.14	9.98	57.94	4.08	59.96	11.34
	SC	3.28	0.21	3.96	0.09	4.69	0.29	4.51	0.08
	Temp	28.2	0.05	26.71	0.12	27.69	0.14	27.12	0.12
No.3	HR	85.06	23.85	81.86	24.89	78.25	15.73	74.49	15.46
	SC	5.09	0.84	6.6	0.48	7.34	0.63	8.26	0.79
	Temp	35.57	0.4	36.07	0.09	35.89	0.1	36.11	0.13
No.4	HR	79.38	4.35	82.58	12.2	76.83	4.72	75.82	4.13
	SC	7.64	0.62	8.74	0.47	8.79	0.72	9.52	0.3
	Temp	34.18	0.14	33.88	0.18	34.67	0.2	34.3	0.1
No.5	HR	93.78	26.56	-	-	76.3	3.41	72.06	6.05
	SC	4.91	0.85	-	-	7.62	0.24	7.09	0.74
	Temp	34.39	0.47	-	-	34.24	0.02	33.78	0.41

In order to verify the difference between the means in comic clips and those in scary clips, analysis of variance (ANOVA) is employed. When the heart rate means in both kinds of clips are compared, the statistics are shown in Table 2. It is found that the heart rate means in comic clips are significantly different from those in scary clips ($\alpha=0.1$, $F=3.269$, $P=0.089$), and are larger. When the skin conductance means in both kinds of clips are compared, the statistics are shown in Table 3. The result indicates that the skin conductance means in comic clips are significantly different from those in scary clips ($\alpha=0.1$, $F=3.084$, $P=0.098$), and are smaller. When the skin temperature means in both kinds of clips are compared, the statistics are shown in Table 4. the result shows that the skin temperature means in comic clips are not different from those in scary clips ($\alpha=0.1$, $F=1.86E-0.5$, $P=0.997$). Thus, it is concluded that the emotion of amusement induces larger heart rate and smaller skin conductance than the emotion of fear. The difference between skin temperature means in both emotions is not significant.

Table 2. ANOVA: heart rate means (2 comic movie clips vs. 2 scary movie clips)

Source of Variation	SS	Degree of Freedom	MS	F	P-value	F_0
Between Groups	276.2817	1	276.2817	3.268932	0.089438	3.048
Within Groups	1628.56	16	84.51742			
Total	1628.56	17				

Table 3. ANOVA: skin conductance means (2 comic movie clips vs. 2 scary movie clips)

Source of Variation	SS	Degree of Freedom	MS	F	P-value	F ₀
Between Groups	11.17069	1	11.17069	3.083679	0.098202	3.048
Within Groups	57.96031	16	3.622519			
Total	69.131	17				

Table 4. ANOVA: skin temperature means (2 comic movie clips vs. 2 scary movie clips)

Source of Variation	SS	Degree of Freedom	MS	F	P-value	F ₀
Between Groups	0.0002	1	0.0002	1.86E-05	0.996616	3.048
Within Groups	172.4427	16	10.77767			
Total	172.4429	17				

In order to investigate the difference between the standard deviations in comic clips and those in scary clips, ANOVA is utilized. When the standard deviations of heart rate in both kinds of clips are compared, the statistics are shown in Table 5. It is indicated that the standard deviations of heart rate in comic clips are significantly different from those in scary clips ($t=1$, $F=4.733$, $P=0.045$), and produce a larger mean (i.e.18.76) than that in scary clips (i.e.9.38). When the standard deviations of the skin conductance in both kinds of clips are compared, the statistics are shown in Table 6. The result shows that the standard deviations of skin conductance in both kinds of clips are not significantly different ($\alpha=0.1$, $F=0.113$, $P=0.742$). When the standard deviations of skin temperature in both kinds of clips are compared, the statistics are shown in Table 7. It is verified that the standard deviations of skin temperature in both kinds of clips are not statistically different ($\alpha=0.1$, $F=1.86E-05$, $P=0.997$). Thus, it is concluded that the heart rate in comic clips changes more actively than that in scary clips. The changes in skin conductance and skin temperature in both emotions are not significantly different.

Table 5. ANOVA: heart rate SD (2 comic movie clips vs. 2 scary movie clips)

Source of Variation	SS	Degree of Freedom	MS	F	P-value	F ₀
Between Groups	395.5547	1	395.5547	4.732553	0.044932	3.048
Within Groups	1337.307	16	83.58166			
Total	1732.861	17				

Table 6. ANOVA: skin conductance SD (2 comic movie clips vs. 2 scary movie clips)

Source of Variation	SS	Degree of Freedom	MS	F	P-value	F ₀
Between Groups	0.017422	1	0.017422	0.112593	0.741571	3.048
Within Groups	2.475778	16	0.154736			
Total	2.4932	17				

Table 7. ANOVA: skin temperature SD (2 comic movie clips vs. 2 scary movie clips)

Source of Variation	SS	Degree of Freedom	MS	F	P-value	F ₀
Between Groups	0.0002	1	0.0002	1.86E-05	0.996616	3.048
Within Groups	172.4427	16	10.7777			
Total	172.4429	17				

5 Conclusions

Human emotions are essential to enhance driving safety. Considering the special requirements during driving, this study concludes that blood volume pressure, skin conductance, skin temperature, respiration rate, and gripping force should be utilized in recognizing drivers' emotions. The experiments verified that the emotion of amusement produces a larger heart rate mean, a larger standard deviation of heart rate, and smaller skin conductance than the emotion of fear. However, the standard deviation of skin conductance, as well as the mean and standard deviation of skin temperature do not change with the two emotions, fear and amusement. Hence, it is feasible and necessary to develop a multimodal drivers' emotion recognition method based on physiological parameters and facial expression.

In the future, the method developed in this study is expected to be applied to a sensor-integrated emotion recognition system which can monitor a driver's emotions in a non-invasive manner.

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A Kinematic Analysis of Directional Effects on Trackball Mouse Control in Novel Normal Users: An Alternating Treatments Single Subject Design

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Abstract. To know the directional efficiency of cursor moving is important for the purpose of guiding the rearrangement of icons and toolbars in the window environment. This rearrangement resolution can achieve better computer access especially in the clients with quadriplegia. However, the information about the directional efficiency of cursor movement is not clear even in the typical persons. Therefore, before surveying the quadriplegics, typical persons were researched in this study. Four typical persons simulated quadriplegics to operate trackball with their right dorsal hand and the kinematic parameters of cursor moving were measured. The single subject experimental research (SSER) with alternating treatments design was used to compare the effects of four cursor moving direction (right to left, down to up, left to right, and up to down) on the kinematic variables. The prior auto-correlation coefficients and Bartlett's ratio values were computed to make sure there was no any series dependence between measuring points before conducting parametric one-way repeated measures ANOVAs. From analyzing the parameter of deviation from the straight line, velocity, movement unit and execution time, the efficiency to move on the horizontal direction (left to right or right to left) was better than move on the vertical direction (up to down or down to up). To further know the cursor kinematic performances in patients with quadriplegics will be important.

1 Introduction

Some persons with physical disabilities can not control the cursor smoothly in some directions even using the adaptive mouse [1-3]. Therefore, to resolve this problem

becomes important for achieving the goal of successful computer accessibility [1-7]. At the moment of developing the resolutions, to know the characteristics of typical persons of cursor moving performance while simulating patients is also important. Through this we can aware the potential troubles that the patients might have and we can figure out the resolution ways before helping the patients with quadriplegics [8].

Many computer access strategies have been proposed. However, those strategies did not formally emphasize the importance of knowing the performances of cursor action toward different directions [1-7]. Therefore, the information of directional effect on cursor action was then neglected while guiding computer access strategy [8]. In fact, some patients can not or are with difficulties to move or to drag cursor toward some important toolbars, menus and icons on the specific positions [8]. The problems related to specific directional disadvantage should be resolved.

Few studies substantiated the effect of moving or dragging direction on cursor control performance. Phillips and Triggs [9] studied the kinematical characteristics of cursor moving task. They found moving rightward was slower than moving toward other three directions. Therefore, the performance of cursor moving was affected by the moving direction. Meng et al. [8] conducted a kinematical experiment to clarify the directional effects on cursor dragging movement. This was the first study to explore the cursor dragging movement on 2-dimensional plane. The results of multiple one way repeated measures ANOVAs and post hoc LSD tests demonstrated that the direction had effects on movement time and movement unit. Dragging leftward showed better efficiency than dragging upward and downward. Both aforementioned studies proposed that the cursor action toward left make people perform better than the action toward right. However, other findings were unable to reach the consistency between two studies.

Moreover, the findings of aforementioned studies [8, 9] were on the quantitative base to neglect the individualized characteristics. The computer access is very individualized especially while serving the individuals with disabilities. Therefore, to deeply understand client's characteristics become important. Different from other quantitative studies, the single subject experimental research (SSER) is usually used to address individualized characteristics. While considering the point of individualization in computer access, the SSER can be appropriately used in the study.

2 Method

2.1 Participants

Four female college students participated in this study. All participants were right handed and ranged in age from 19 to 23 years. They all reported daily use of the computer operated with the standard mouse and had never used trackball mouse. Of course no any participant had ever used dorsal hand to operate mouse. To use the dorsal hand to control trackball is one possible adaptive method for the patient with quadriplegia. In this study, all participants acted with this way to control the trackball (Fig 1).

2.2 Experimental Design

In this study, we used the single subject experimental research (SSER) as the research method. The alternating treatments design without baseline belonged to SSER was applied. The counterbalanced across cursor moving directions and replicated across four participants were assigned for controlling the possible confounded order effects on the result. Each of the subject performed cursor movement of all 4 directions in a totally counterbalanced randomized sequence for 24 sessions.

2.3 Variables

The direction of cursor moving was the independent variable in this study. The dependent variables included deviation from the straight line (Fig 2), movement unit, initiation time and movement time. The larger the value of each variable, the worse was the performance.

2.4 Procedure

Participants were asked to perform a cursor movement task. The task required the participant to move cursor on 4 directions (up to down, down to up, left to right, and right to left). Once the tracing line and the start icon appeared, the participant had to move the cursor on the tracing line as accurately and quickly as possible. The order of directions was counterbalanced to control for any order effect. Each participant controlled a trackball by right dorsal hand for moving the cursor 24 runs on each of 4 different directions. Therefore, totally 96 trials were conducted ($4 \times 24 = 96$).

2.5 Materials

The devices used in this experiment were a trackball Mouse (Fig 1) and a portable computer. The parameters of kinematics of cursor moving were measured and collected by a computer program developed by us. After finishing to move the cursor, the trajectory of cursor moving could be exhibited on the monitor's screen (Fig 2). The serial cursor positions relative to X- and Y-axis in the 2- dimension plane were recorded every 100ms (on the left side of Fig 2). For the further analysis, then the data were transformed to the other variables (ex. velocity, path distance, acceleration, et al).



Fig. 1. The trackball mouse operated by the right dorsal hand

2.6 Statistics

The repeated-measures one way ANOVA followed by post hoc multiple paired t-tests were conducted to substantiate the effect of cursor moving direction on four kinematic variables (deviation from the straight line, movement unit, initiation time and movement time. Before conducting ANOVAs, the prior auto-correlation coefficients and Bartlett's values were computed to make sure the series dependence between measuring points did not exist before conducting ANOVAs.

3 Results

The detailed major results are listed on the table 1. Before conducting the repeated-measures one-way ANOVAs, we made sure that there was no any series dependency between measuring points through calculating the auto-correlation coefficients and Bartelett's values (table 2). The repeated-measures one way ANOVA indicated that the direction in the "down to up" condition had significantly better velocity in subject 1 than when she was in the "up to down" and "right to left" condition (Table 1 and Fig 3). Similarly, subject 2 performed significantly more stable (fewer movement units) in the direction of "left to right" as compared to "up to down" direction (Table 1 and Fig 4). For subject 3, the direction of "left to right" was significantly more stable as compared to each of other three directions. The deviation from the straight line in the direction of "left to right" or "right to left" was smaller (more accurate) than the direction of "up to bottom" or "bottom to up" respectively (Table 1 and Fig 5). Subject 4 performed significantly more accurate in the direction of "right to left" as compared to "up to down" direction. The velocity in the direction of "left to right" and "right to left" was significantly better than each of other directions (Table 1 and Fig 6).

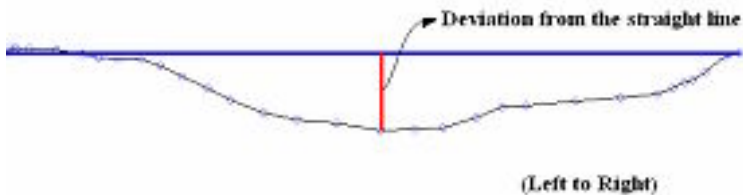


Fig. 2. An example of the cursor moving trajectory depicted by our assessment tool. The vertical line means the parameter of "deviation from the straight line".

4 Discussion

Results showed that kinematic variables are related to the direction of cursor moving. The efficiency to move on the horizontal direction (left to right or right to left) was better than move on the vertical direction (up to down or down to up) in each subject except subject 1. The horizontal efficiency was also found by Meng et al. [8]. Although Phillips & Triggs [9] did not find specific directional advantage, their study

showed the efficiency toward left was efficient as the two vertical directions. However, Phillips & Triggs [9] did not support the better efficiency could be achieved while moving from left to right. In this present study, the four subjects were novel users to control the unfamiliar trackball with their dorsal hand. Differently, the tasks were moving and dragging typical mouse in the study of .Phillips & Triggs [9] and Meng et al. [8] respectively. Therefore, the task difference might be the possible reason resulting in the difference among the results. It is necessary to further substantiate this issue in the future.

Hwang et al. [10] found disabled persons showed more sub-movements while moving cursor. This phenomenon resulted from patients' disadvantaged motor efficiency. Although they have to make mouse keep going, they could not move cursor to the target directly and smoothly. Therefore, they have to stop mouse and initiate mouse again. This cycle (initiate-stop-initiate) was repeated many times during the whole action process. In our present study, the less sub-movements can reflect the smooth operation process even handling the unfamiliar trackball mouse in the normal subjects.

Even the typical person showed the directional effect on cursor moving performance.

This alerts us to notice that patients may get troubles while controlling cursor on one or more specific directions. For example, if they can't move the cursor from left to right side, we might consider arrange the toolbars or blocks on the left side. Therefore, to aware and manage this issue are important [8,11,12,13

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Appendix

Table 1.

Subjects & Parameters	Means of 4 directions				F	p	Eta ²	Posthoc multiple comparison (t-tests)
	UD (Up to Down)	DU (Down to Up)	RL (Right to Left)	LR (Left to Right)				
Subject 1								
Velocity (pixels/ms)	.23±.04	.27±.07	.23±.06	.26±.06	F(3,69) = 3.19	.029	.12	UD<DU: t(23) = -2.79;p=.010 DU>RL: t(23) = 2.96; p=.007
Subject 2								
Movement Unit	19.25 ± 7.41	16.96 ± 6.83	16.46 ± 5.41	13.83 ± 4.26	F(3,69) = 4.17	.009	.15	UD>LR: t(23) = 3.12; p=.005 UD>RL: t(23) = 2.48; p=.021 UD>LR: t(20) = 3.78; p=.001
End Time(ms)	5119.05± 1455.20	4447.62± 1449.35	4466.67± 937.19	3852.38± 1303.69	F(3,60) = 4.30	.008	.18	
Subject 3								
Deviation from the straight line (pixel s)	802.58± 1043.95	396.54± 282.42	106.46± 149.08	72.17 ± 96.65	F(1.16 , 26.60) = 9.41	.004	.29	UD>RL: t(23) = 3.17; p=.004 UD>LR: t(23) = 3.42; p=.002

Table 1. (continued)

<i>Subjects & Parameters</i>	<i>Means of 4 directions</i>				<i>F</i>	<i>p</i>	<i>Eta²</i>	<i>Posthoc multiple comparison (t-tests)</i>
	<i>UD</i> (Up to Down)	<i>DU</i> (Down to Up)	<i>RL</i> (Right to Left)	<i>LR</i> (Left to Right)				
Movement Unit	28.22 ± 6.63	27.74 ± 6.01	23.91 ± 6.78	20.87 ± 6.35	F(3,66)) = 11.19	.000	.34	DU>RL: t(23) = 4.38; p=.000 DU>LR: t(23) = 5.71; p=.000 UD>RL: t(22) = 2.85; p=.009 UD>LR: t(22) = 4.88; p=.000 DU>RL: t(22) = 2.33; p=.030 DU>LR: t(23) = 5.48; p=.000 RL>LR: t(22) = 2.18; p=.040
<i>Subject 4</i> Deviation from the straight line (pixels)	802.5 8± 1043. 95	396.5 4± 281.7 4	145.9 6± 170.7 6	190.2 5± 179.3 6	F(1.16 , 26.70) = 6.97	.011	.23	UD>RL: t(23) = 2.93; p=.008 DU>RL: t(23) = 4.22; p=.000 DU>LR: t(23) = 3.74; p=.001
Velocity (pixels/ms)	.19 ±.07	.16 ±.04	.22 ±.08	.23±.1 3	F(2.14 , 49.13) = 5.40	.007	.19	UD>DU: t(23) = 2.73; p=.012 UD<LR: t(23) = -2.08; p=.049 DU<RL: t(23) = -3.63; p=.001 DU<LR: t(23) = -3.44; p=.002

Note. 1.Only the statistically significant parameters in the ANOVA tests are retained in the table.2.Each subject showed the pattern that was different from others.

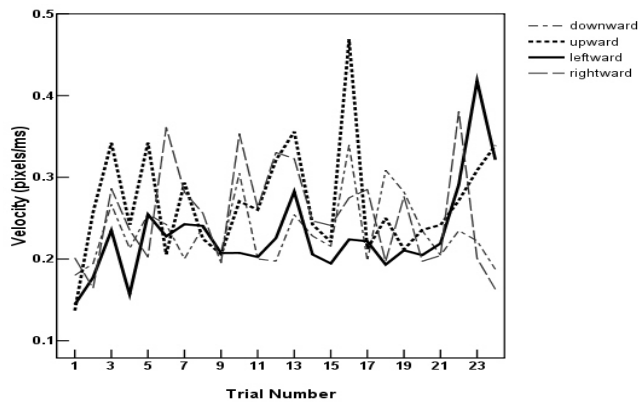


Fig. 3. Subject 1 performed significantly faster in the direction of “down to up” as compared to the direction of “right to left” and “up to bottom”. Other variables did not reach any significant difference among four directions (the figures were not showed).

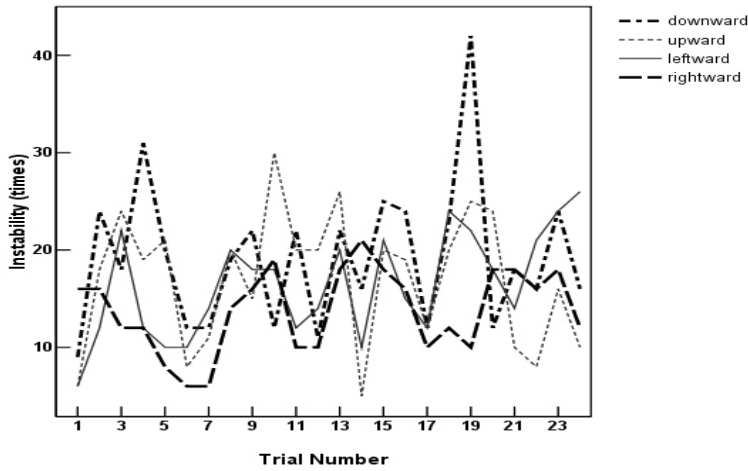


Fig. 4. Subject 2 performed significantly more stable during the cursor moving process (fewer movement units) in the direction of “left to right” as compared to “up to down” direction. The total time spent in the direction of “up to down” was more significantly more than the direction of “left to right” and “right to left” (the figures were not showed).

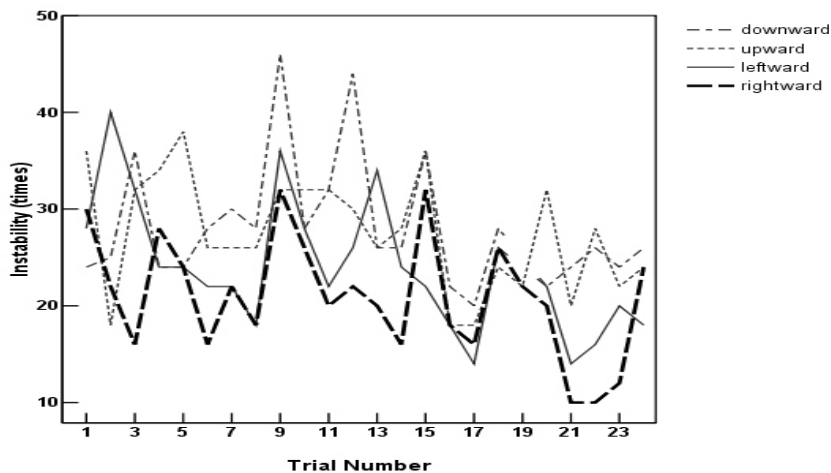


Fig. 5. Subject 3 performed significantly more stable during the cursor moving process (fewer movement units) in the direction of “left to right” as compared to each of other three directions. The cursor movement in the direction of “right to left” was also performed more stable as compared to the directions of “up to bottom” and “bottom to up”. The displacement in the direction of “up to bottom” or “bottom to up” was larger (less accurate) as respectively compared to the direction of “left to right” or “right to left”.

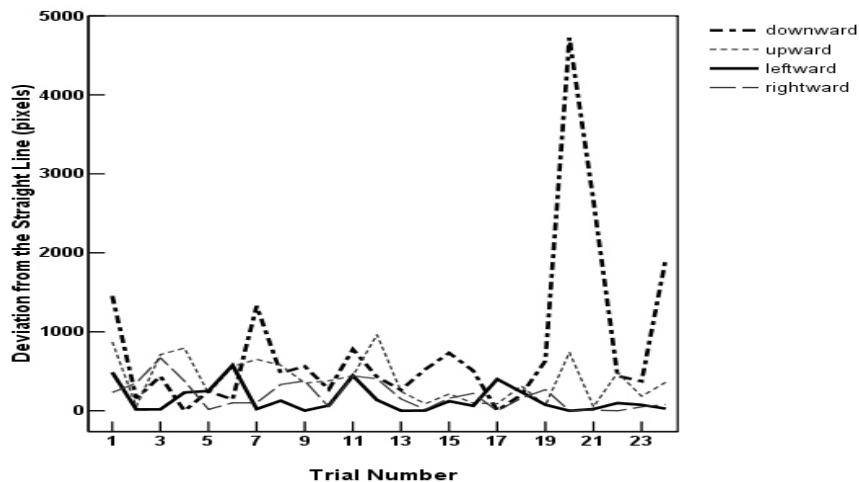


Fig. 6. Subject 4 performed significantly more accurate (fewer deviation from the straight line) in the direction of “right to left” as compared to “up to down” direction

Table 2. Autocorrelations and Bartelett's value

	Subject 1	Subject 2	Subject 3	Subject 4
Velocity				
Downward	-0.2190			
Upward	-0.1663			
Leftward	0.4475			
Rightward	-0.1045			
Instability				
Downward		-0.2031	0.0388	
Upward		0.0081	0.0288	
Leftward		0.1985	0.3914	
Rightward		0.4728	0.1079	
Deviation				
Downward				0.2966
Upward				-0.1073
Leftward				0.0327
Rightward				0.3629

Note. There was no auto-correlation in ach cell. Therefore, the parametric one way repeated measures ANOVAs could be conducted in the single subject experimental research.

An Evaluation Study for a 3D Input Device Based on Ergonomic Design Criteria

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Abstract. To compare traditionally established 3D-input-devices with a new ergonomically motivated equipment, an evaluation software is needed. With this software the control of different 3D-input-devices has to be applicable. The main attention of the evaluation is to determine the advantages of the new developed *HAPTOR-device*. The *HAPTOR* is an user-centred table based 3D-input-device. Intuitively used paths of the hand should be the basics of that device. To evaluate the users comfort additionally to the log parameters of the software, questionnaires and observation are necessary.

Keywords: User-centred design, 3D-input, evaluation software, reachable space of motion, ergonomically motivated equipment.

1 Introduction

For more than twenty years modern technical devices displace old fashioned tools in the everyday life of engineers and technical designers. For example in the 80's a technical designer worked with attraction board and pencil, today he usually works at a workstation with mouse and three-dimensional input devices. An engineer is in a similar situation during the control of machines in micro- and nano-environments as well.

The development of 3D-input-devices in the 90's was predominantly powered by the "European Space Agency" (ESA). In the following years these devices were also made available to the free market. Now the current trends are dominated by the needs of the gaming market and the requirements of 3D virtual realities in caves.

All devices have special fields of application, so there are handheld devices as well as table based units. This raises the question: Which 3D-interface is the best for a special problem? Different tasks and working areas esp. in medicine, CAD, automotive or aeronautical purposes require different interaction devices. But these interface devices also have to be comfortable for the users during a whole working day.

A new development, a 3D table based input device, should reduce ergonomic deficits and makes the 8 hour working day much more comfortable. The used and measured intuitive paths only allows a less reachable space of motion like it is described in DIN 33402-2 [1], and these measured paths had been built the base for the new input device.

2 Development of the Evaluation Study

In 2003 Krauss presented an evaluating concept for 2D pointing devices [2]. He found that it is necessary to have quantitative measurable attributes of the handling of 2D pointing devices. To determine the usability of 3D human interface devices 3 evaluation tasks were created which are based on the “*DEVICE*” test tasks (see [2]). The “*DEVICE*” test task based on two mouse operations well known from all window-based software systems, the “*Click*”- and the “*Drag & Drop*”-action. An additional used third operation is “*Draw*” a line. Krauss proposed to measure the rate of use, the errors during the operational time and the positioning and course accuracy during these three exercises.

Of course these three measurable attributes are just as interesting for 3D-input-interfaces as for 2D pointing devices. But not all mouse operations are operable with 3D interfaces, e.g. the “*Click*”-operation. Though it was necessary to develop a new measuring tool for 3D-input-devices.

With the new software tool it is possible to evaluate all 3D human interfaces which support the “Human Interface Device” (HID) standard of the Microsoft Windows® XP/2000 platform.

2.1 Test Tasks

In the first two tasks the positioning accuracy with and without barriers will be detected. The idea based on the “*Click*” and the “*Drag & Drop*” task developed by

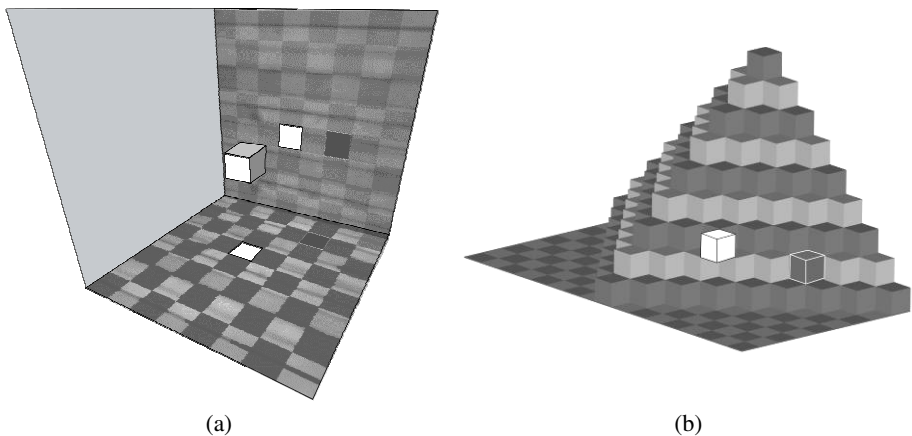


Fig. 1. (a) Modified picture of test task 1, the red box (presented in white) has to be moved on the direct line. (b) Modified picture of test task 2, the red box (presented in white) has to match with the blue area (presented in dark-gray).

Krauss [2]. These tasks have been extended to 3D-environments and modified depending on the capabilities of the devices which should be tested. Not all tested devices supports any kind of button, so a real “Click” even “Drag & Drop” is not possible.

The software is registering log-files containing data of distance and deviation from the straight line. The time-stamps of every event also will be stored. These log-files can be analysed afterwards with common standard statistic tools.

Like shown on fig. 1a a red box should be moved on the direct line to the empty field which is marked with two blue squares in task 1. To support the experimentees the current position is marked by two red squares on the back and the bottom which have to be matched with the blue fields.

The test person’s skills with 3D-Enviroments will influence the results in different ways. If an experimentee has experiences with 3D representation and a good power of imagination, then working with the test tasks will be much easier than without these abilities.

In task 2 (fig. 1b) a red box has to be moved to a position highlighted by a blue box. The direct line is not possible in this task because of the pyramid as a barrier which has to be evaded. If the red box bounces with the barrier, the box will be locked for moving in the bouncing direction. But still the shortest path between starting point and goal, the blue area should be used.



Fig. 2. Test task 3, the ball in the tunnel

The third task was created to test the course accuracy of the input devices. The software shows a random course through a virtual tunnel (like shown in fig. 2). The user has to move a ball without touching the tunnel wall for a specified period. While running the task also data for evaluation are written to another log-file.

The logging parameters for this task are:

- Number of bounces: ball – tunnel
- Time-stamp of bounces
- Distance: centre of ball – centre of tunnel

Additional to the log-files an observer looks at the person executing the tasks (see chapter 2.3: Testing procedure).

2.2 Tested Devices

The three devices, which were be tested in the first stage at the Technische Universität Ilmenau are the *CadMan*, a joystick, and a self developed 3D-input-device called *HAPTOR*. [3]

The non-interchangeability of the 3D-input-devices is a problem while developing test tasks. The devices are strictly designed to fulfil the needs of special tasks. For example it is difficult to play a flight simulation with a *CadMan* as well as to control a CAD-software with a joystick.

The current available 3D-input-devices could be divided into three classes:

1. Line-based (for example *PHANTOM* from SensAble Technologies Inc.)
The *HAPTOR* is also a line-based device like a mouse in 2D. Only points in the area, which is provided by the device and the scale factor, could be reached (see chapter 3).
2. Angle-based (for example a joystick)
To move in one direction the tip of the joystick has to be pressed in this direction, but the bottom is fixed in the ground, so the desired direction can be measured by its deviation angle. By that technology can only 2D be realised. For the 3rd axis the speed controller has to be used. The software provides a mechanism to change the assignment of the axes.
3. Force-based (for example *CadMan* in fig. 3).
To move straight on in one direction just keeps pressing the device in this direction and the courser should be moved.



Fig. 3. *CadMan* from 3Dconnexion

2.3 Test Procedure

The evaluation should be done by two persons. The first experimentee executes the evaluation tasks with one of the devices which have to be tested (see fig. 4). At the same time the observer logs all visible indications of the first person's behaviour. Observer's task is to keep an eye on the handling of devices during the different test tasks with following questions:

- How much training was necessary to reach adequate results?
- Have been used additional resources?

- How does the experimentee complete the tasks?
- If the experimentee has had more training, the results would become better?

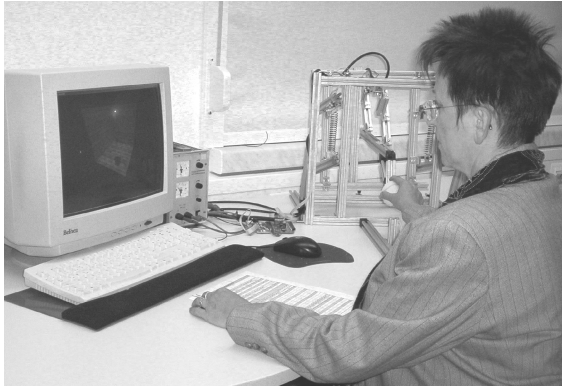


Fig. 4. An experimentee executing the test tasks

After finishing the tasks the experimentees also have to fill out a questionnaire like shown in fig. 4 about their experiences before and during the tests:

- Do you have experiences in using the PC?
- Which kind of input devices do you use usually?
- Assess the following attributes of the input devices: stability, form, robustness, handling, comprehensibility, controllability.
- With which device could solve the test task best?
- Evaluate the potentiality of each device depending on the test task.

The log-files can be analysed with mathematic and statistic algorithms. For example in test task 3 the absolute deviation between the centre of the tunnel and the

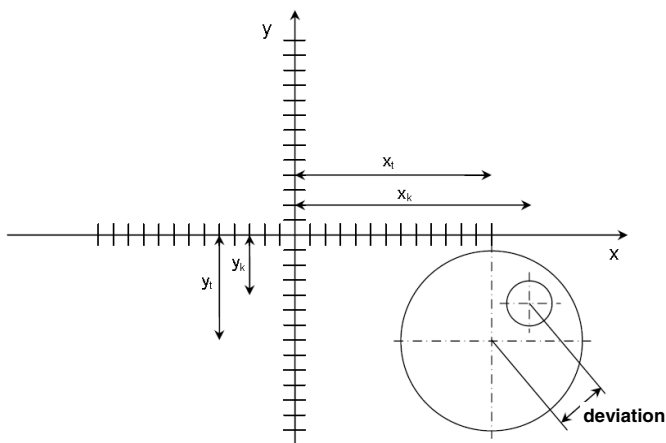


Fig. 5. How to calculate the deviation between ball and tunnel logged in test task 3 [4]

centre of the ball could be calculated for each logged time-stamp (see fig. 5). Subsumed the average of deviations could be compared between the different devices and the different users.

The results of the questionnaires and the log-files of the test task will be compared.

2.4 Expected Results

For the positioning accuracy test (task 1 and 2) the *CadMan* should be as good as the *HAPTOR*. But the personal comfort of these devices might be different. It is not expectable that there will be general differences between the use of *CadMan* and *HAPTOR* in that case.

The hypothesis is that a joystick will be the best 3D-device for the course accuracy test (task 3). The mental model of flying around will be mostly used by the people looking at the test screen. And this mental model will be best represented by joysticks. It will be also interesting if there are different axes setups will be used.

A subsumed expectation is that the best over all results of positioning and course accuracy will be reached by trained people, independent of the used device. In the same context it will be interesting if untrained experimentees get better results with the *HAPTOR* than with the other devices for the positioning accuracy tests.

3 The *HAPTOR*, a 3D-Input-Device Based on Ergonomic Design Criteria

Less strain as possible for the worker is needed for high-quality workplaces and a zero-error production. Especially 3D-navigation-tools cause stress during an 8-hour working day whenever the tool is not optimally adapted to the user. To determine this a test design to analyse the perception of comfort with 3D-input-devices was needed.

To get a first guess the paths based on the model of the hand were generated with combinations of four-bar-linkages. But now this tool was used for more experiments than to proof the original idea.

3.1 Ergonomic Background

The development of the *HAPTOR* had started with several experiments to measure the path of moving a ball comfortably. The arm and wrist was shored up and only the hand could move the ball. The course poles were deduced from intuitively used paths of the hand (see Fig. 6). Based on these comfortable and intuitive paths the mechanical construction had been realised.

The German norms DIN 33402-2 "Body measures of human beings" [1] and DIN 33408 "Body outline pattern" [6] describe the maximum reachable space of motion which can be used by the human's hand. Therein the maximum bending and

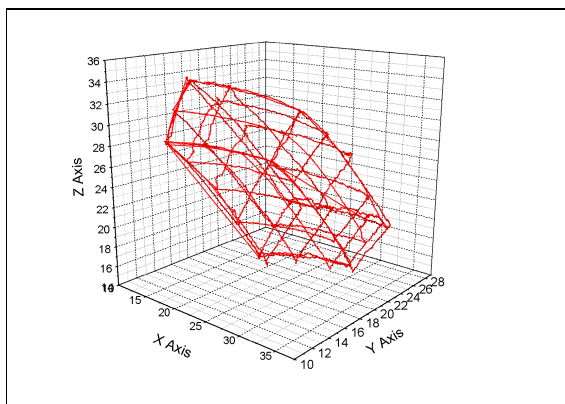


Fig. 6. Spherical shapes of native motions of the hand [5]

stretching angle of the wrist is indicated as 50° - 60° in each case, but some other references indicated the bend angle even as 75° [7].

Contradicting to these values the experiment with shored up wrist showed that a stretching angle of approximately 13° and a bend angle of approximately 38° are specified as the comfortable range. The normal position is bent about 13° [8].

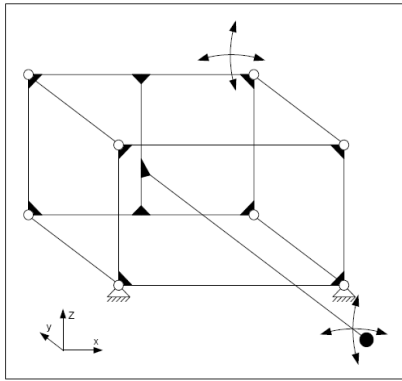
3.2 Mechanical Development

The measured motion area was analysed in the first development step. The intuitive paths of the freely moved ball have a spherical shape (see. fig. 6) and can be approximated by a circular arc. The centre of this circular arc was calculated. This centre point differs from the position of the wrist. The motion of the hand depends on the wrist-bones and that might be the reason for the detected centre point. This nature-related motion is not only a rotation; it is furthermore the result of combined movement of hand, fingers and the forearm.

A principle based on those poles has been developed and a mechanism which generates a spherical motion like the measured hand-motion has been realised. That four bar linkage is able to implement the needed circular arc and to allow the necessary motion space which was detected. Some modifications lead to the parallel-epiped-layout shown in fig.7a.

The second step of the *HAPTOR*-development was to build up a device to examine the concept of ergonomic input (see fig 7b). It was shown that experimentees feel more comfortable with these realised paths. So it is necessary to have a forearm rest to use the full motion capacity of the hand. This is another result of these experiments. Only in this way a comfortable usage of the table based device is possible and acceptable.

The third step of the experimental setup was recording the motion paths on a PC with the new device. For this recording several electrical sensors had been added to the device and an electronic interface for computer-based measurement and connection interface between *HAPTOR* and PC had been developed.



(a)



(b)

Fig. 7. (a) Mechanical principle [5]. (b) Test device at the PC [5].

3.3 Electronic Development

The electronic development had been realised also in three steps until now. To use the VRIB¹ – Inbox [9] developed by a BMBF founded project, an additional measure amplifier was needed in the first step. The VRIB – Inbox is a fully supported 4 Channel I/O-device for analogical sensor data, which will be recognised by Windows[®] as an HID and will be supported by internal Windows[®] drivers. The *HAPTOR* requires three channels for measuring the three axes. Every axis is measured by two independent potentiometers mounted at two different hinges. These two potentiometers should be integrated within a resistor bridge circuit. The first development worked quite well but needed 24V DC as supply voltage which will not be provided by most of the common power supplies.

Even because the VRIB project already finished in 2004 and no additional devices were available, another solution had been developed. This developing stage is still in progress. The supply voltage of this new electronic device should be 12V DC. So the amplifier also has to be redesigned to work with the half supply voltage. Also another concept of analogical-digital converting has to be used. For further stages it is planned not only to measure the position of the device, but even the device itself should be positioned actively. If there is a collision within the virtual reality the user should be given a haptic feedback.

These requirements could be best fulfilled by using an embedded CPU with several digital and analogical I/O-Ports. The AVR 128² CPU could be programmed easily with C-code and provides enough capacity to measure the sensors and to instruct the drives for next development step.

The current solution is a combination of the VRIB – Inbox and the newly designed amplifier board. This intermediate stage was necessary to connect the *HAPTOR* with the evaluation software which only provides the HID support (see chapter 2).

¹ VRIB: German abbreviation for virtual reality interaction construction kit.

² AVR 128: a programmable micro-controller from ATMEL Corporation.

3.4 Upgrades and Further Development

The connection of this tool to several applications and tests of different tasks are the next steps. The efficiency of the *HAPTOR* is to be evaluated and compared with classic 3D-I/O-devices. Experimental applications described in chapter 2 only are the very beginning of these tests. The applicability of the *HAPTOR* will be analysed for special workitems in the next time. One task is the manual control of an assembling tool. This device may be a first step directing to a new user-interface usable in assembly departments for nano and micro technology [10].

4 Summary

A new developed 3D-input-device had to be compared with old-established devices. The advantages of the new device *HAPTOR* only could be demonstrated if different devices could be used with the test tasks. Using means, the software has to allow the operation of different devices by using a common connection protocol as well as that the mental model of the tasks allows the experimentees to fulfil the same task with different input devices. These requirements have been realised with the three test task of the evaluation study. Additional the user's experiences will be evaluated by using the questionnaires.

The new development "*HAPTOR*" differs from the old-established devices by the development basics. Not the functionality is in the focus of the development; the main attention was pointed to the users comfort. During several steps the I/O-device *HAPTOR* had been created, but the development is still in progress. First the intuitively used paths of the hand had been measured. A principle from these paths was derived and a mechanism to realise the spherical motion had been constructed. To validate the construction several sensors had been added and connected via a special interface to a PC.

This research step is jointed with the evaluation software and some pre-tests were executed. Extensive test series will be started soon.

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Investigation and Implementation of the Advanced Wireless Medical Registration Solution in China

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Abstract. Compared with the huge number of Chinese population, the medical treatment resource is very scarce. A universal and serious phenomenon emerges, that is, the registration becomes more and more difficult especially in some famous hospitals. There is always a long queue for registration and time is wasted. Is there not a technique to make the registration process more efficient? In this paper, we provide a new application, a WAP-based wireless registration solution, which aims to solve the medical registration problem in China. It will bring advantages in both healthcare service domain and WAP industry link¹.

Keywords: wireless medical registration, WAP, WML, PUSH.

1 Introduction

The matter of medical registration is universal in many countries. In China, compared with the huge number of population and the scarce medical treatment resource the problem is more serious. Investigation results show that, Chinese population takes 22% of the world's population, while the medical-sanitation resource takes only 2% of the world's total resource [1]. The relative scarce resource makes the problem of medical registration more distinct than other countries.

Besides, compared with secondary level hospital, famous higher level hospital is trusted by more people, which makes the "medical registration" problem more and more serious in these hospitals. The difficulty of medical registration leads to some abnormal phenomenon:

- people living far away from hospital have to get up as early as 4:00 a.m. in order to obtain a registration number;
- the number for specialist doctor can hardly be obtained even by queuing for a long time;
- there are "registration ticket packmen", who always stand in the front of the queue and register lots number of famous doctors, then sell the numbers at a very high price.

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Due to above reasons, the medical registration problem has been a serious social issue in China, especially in some big cities.

In recent years, national policies have initiated to support the advanced Information and Communication Technology (ICT) solution to solve the social issues. The guideline of National Metaphase and Long-term Developing Plan in science and technology [2] clearly declares that Modern Service Industry is an important development domain. As one of the serious social problem, the medical registration problem has been considered on the aspect. Researchers are encouraged to use advanced technology to manage the scarce medical resource and enhance the efficiency of medical registration.

With the development and generalization of mobile communication technology, more and more people possess handsets. The number of worldwide handset users was 2.14 billion in 2005 and will increase to 3.2 billion in 2010 [3]. The possess ratio of handset is much higher than the ratio of computers'. Because of the universality, mobile phone will become a main communication instrumentality between patients and hospitals. According to the 11-th Five Year Plan of National Key Technology Supporting Project in China, "Registration" through mobile phones is proposed as a possible solution in a sub-project of Area Cooperative Medical Service Demonstration Project [4]. The solutions might include the registration by SMS or WAP to alleviate the problem of registration and illogical allocation of medical treatment resource.

2 Registration Technology Comparison

There are several traditional methods for registration in China as follows:

1. face-to-face registration;
2. telephone registration;
3. Internet registration.

Method 1) is the most original method but also the most inconvenient one. People need to queue for a long time to get a registration number. Methods 2) and 3) are brought forward to make people convenient and alleviate registration pressure. However, both schemes are not as successful as expected, and the following problems still exist:

- the *registration ticket packmen* is rampancy due to the lack of correct manage mechanism;
- people need to queue a long time to see a doctor after they got a registration number, which will waste a lot of time;
- people need to wait to obtain testing results.

The WAP-based advanced wireless medical registration solution can solve these problems. It utilizes real-name management mechanism to deter *registration ticket packmen*; it depends on handset's universality to make ubiquitous registration come true; it introduce PUSH technology to inform patients to see a doctor at the right time intelligently after they achieve registration number and message patients to take testing results. Therefore, the solution enhances the efficiency of registration process.

3 System Implementation

The WAP-based wireless medical registration solution provides the following functions:

- wireless medical registration: use mobile phone to register hospital number through WAP;
- push-based queuing informing: use SMS or WAP-PUSH to inform patients to see a doctor or get testing results through PUSH;
- EHR (electrical health record) browsing: browse user's EHR by mobile phone;
- intelligent remote monitoring: system checks the parameters submitted by users intelligently and point out whether the health status is normal.

3.1 System Specification

The WAP based registration system consists of WAP clients, WAP gateways, and content servers. The handheld WAP client is usually a mobile terminal; it communicates with the content server, which stores information and responds to the user's request. The gateway translates and passes information between the client device and server [5]. Fig.1 shows the system infrastructure.

The system utilizes WAP technology to realize the connection between the wireless domain and the WWW domain. The related application data were stored or generated by the content server. The user-interface is written in WML (Wireless Markup Language) and dynamic web programming script language, executed at the WAP device after it is downloaded from the server. This infrastructure ensures that mobile terminal users can access a wide variety of Internet content and applications. Also application programmers are able to build content services and applications that run on a large base of mobile terminals [6].

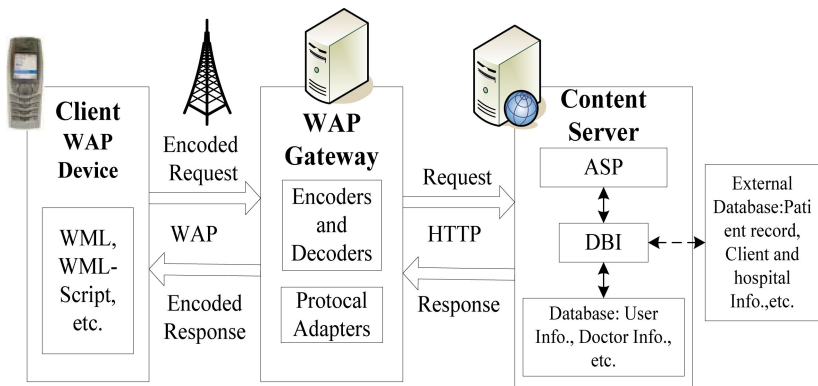


Fig. 1. Infrastructure of WAP-based wireless medical registration system

3.2 WAP Programming

WML is designed for creating WAP applications, and is user-interface independent. It supports text, images, user input, variables, navigation mechanisms, multiple languages, as well as state and management server requests. WML has been designed to adapt to the high-latency and narrow-band of the wireless network, and is mainly intended for displaying text-based contents. When a user accesses a WAP site, it sends back contents in the deck of cards which the user can browse through. Wireless bitmap (WBMP) format is a graphics format optimized for efficient transmission over low-bandwidth networks and minimal processing time in WAP devices. It uses no compression in order to suit the limited processing power of the WAP client device.

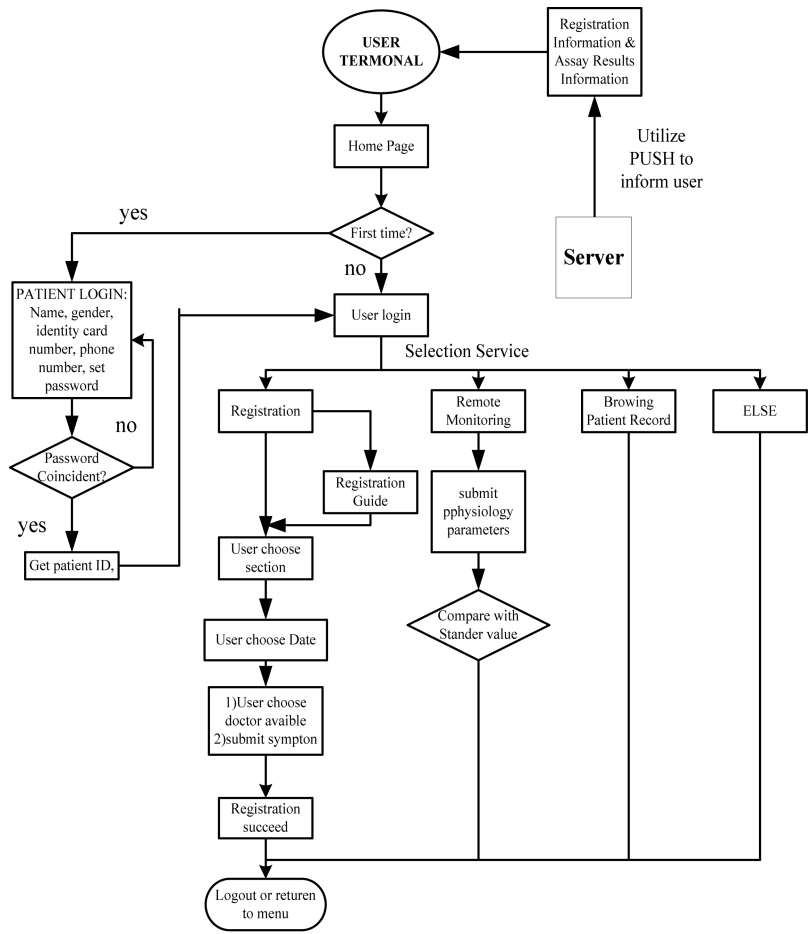


Fig. 2. Flow chart for WAP-based Registration menu

The flow chart of the program shown in Fig.2 starts when the user accesses the first WML deck at a predefined site. The following WML decks that the user interacts with are then generated by dynamic script language.

As shown in Fig.2, when patients use the system at the first time, they need to enroll first (Fig.3-a, Fig.3-b). The enroll information includes patient's name, gender, identity card number, handset number and password. After successful enrollment, the patient can get a patient ID number. The ID number and identity card number consist of the exclusive identifier of the patient, which can be used to manage registration information. Then the patient logs in the system to select different services, such as registration, remote monitoring, browsing EHR, etc.

If the patient chooses the registration service, they need to select a department first (shown in Fig.3-c and Fig.3-d), then select the date and the available doctor, or input their symptom, and finally the system will feed back a registration result containing department, cost, registration number and the order (Fig.3-e). According to the user's order and intraday diagnosing speed, the system can intelligently inform patients to come to hospital at the right time by using PUSH technology.

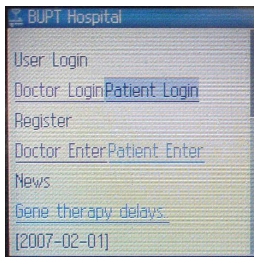


Fig. 3a. Page of Patient enroll and login

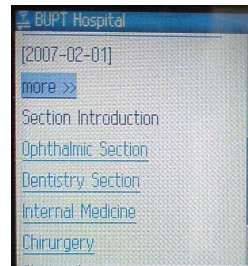


Fig. 3b. Page of Registration Guide

Based on the platform of the registration system, some extended functions can be developed. As an example, the remote intelligent diagnose is shown in Fig.3-f. The enrolled consumer can input the physiology parameters and the system will judge whether these parameters are normal by comparing them with the standard value and the patient's history health record.

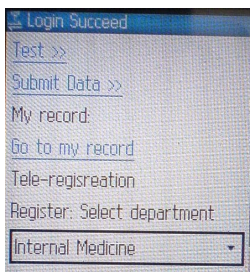


Fig. 3c. Page of Registration

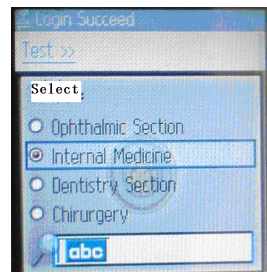


Fig. 3d. Page of Selection Department

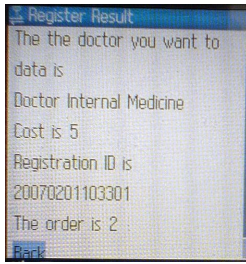


Fig. 3e. Page of Registration Result

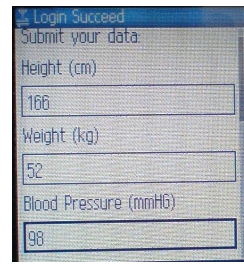


Fig. 3f. Page of Remote Intelligent Diagnose

4 Discussion and Conclusion

4.1 Discussion

The demonstration system of the WAP-based wireless medical registration works well in hospital test environment. However, some problems still emerge during the testing.

The first problem that needs to be pay attention to is the access speed of the WAP client device. The average access speed of handset to open a WAP web page is about 2~ 4 seconds and even more than 5 seconds for some handsets at the first time of accessing, which is much slower than that of computer's. The slow connecting and processing speed will prohibit the widely acceptance of users to wireless registration method if the users can not obtain the final registration information after 3-5 pages.

The next problem is how many users can access to the servers simultaneously. Although WAP-based registration system can be employed anytime anywhere, the users' simultaneous accessing number should not be ignored, because more and more WAP based services will be supplied in future. Some of the services may take a little longer time to operate and transmit, for example, the WAP-based amusement by handset. Therefore, the priority of services based on WAP should be well organized by the mobile operators.

5 Conclusion

The WAP-based advanced wireless medical registration system exceeds the traditional registration services in both technology and management aspects. The system has the following advantages:

- because of the portability of mobile phone and the wide coverage of mobile networks, it is convenient for people to register anytime anywhere with a WAP-based wireless registration;
- WAP-based registration can alleviate the problem of registration by patient pre-identification; *Ticket packmen* can be avoided by real-name management mechanism;
- medical registration information saves the unnecessary long waiting time.

However, deploying such advanced wireless medical registration scheme in China is not a simply technological issue. It still requires the following conditions to cooperate and even in some extend these conditions take the main position:

1. Government recognition

- to operate the new registration method successfully should be supported by hospital itself first. However, to get the service, people have to pay the GPRS cost or pay some cost about handset mobile web service. The payment increases the cost of registration. So, how to balance the WAP-based additional handset cost and the real medical cost should be negotiated by the government institution and telecommunication operators.

2. Public support

- although the WAP-based registration system can bring convenience to most people, this system has some restrictions to people's handsets. It requires the handset to support WAP function and some handset must go to open the related function in sales department. In addition, the public need to learn how to use handset to browse website first, then they can understand how to use the WAP-based registration service. So technology training must be considered for promoting this kind of service.

In a word, to let the WAP-based registration prevalent is not only the technology problem but also a social problem. A successful story should only be made based on the collaboration among technology provider, service operator, policy maker, and so on.

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Effectiveness of Multimedia Systems in Children's Education

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Abstract. Presently multimedia has become part of youngsters' daily life, although the quality is not always satisfactory. Sadly, many multimedia resources are not used as tools for socializing, transmitting knowledge and know-how for improving society. This paper presents methodological features for the development of a multimedia tool that combines Participative Design and User Centred Design methodologies, to improve knowledge in the Ergonomics and Occupational Safety and Health for children domain.

Keywords: Multimedia Systems, User Centred Design, Participative Design, Usability.

1 Introduction

Presently, there is a crisis in teaching and in traditional learning processes based on lectures, usually not very stimulating for young people. This problem amplified when dealing with youngsters who are familiar with multimedia systems, that are more interactive and exciting.

We often mention that students do not want to learn and are uninterested in studying theoretical subjects. This is a superficial way of analysing the situation, as there are many examples of students *interact* with theoretical and complex problems and learn, and like to learn. The problem might be – *interaction*. In this context, there are several alternatives connected to information and communication technologies that offer adequate systems for carrying out innovative work in this area. The use of multimedia systems, in particular computer games, has drastically increased in the last years. According to “The New York Times” of 2003/10/23, the investments volume proposed for 2002 for designing multimedia systems in the whole world, either for diversion or training exceeded the investments intended for research in the pharmaceutical industry. This proves the large number of projects developed in this area.

Forwell [2], supports the idea that there are two reasons why Information Systems should be included in to education. The first reason concerns the great capacity of this tool has to adapt to different kinds of education materials. The second, regards to the proved improvement and development of an individual while learning.

According to Knezek [4], using technological resources for educating primary and secondary grade school children significantly raises their performance levels.

Another author [11], state that there is unquestionable evidence of positive effects when using educational games as an educational tool. According to them, progress is more intense in areas such as mathematics and reading.

Educational games offer an environment in which learning is enhanced by stimulating tasks, and skills are developed as a result of playing the game, [7].

Murray [8], confirm this concept and show how the system can become uninteresting and non-motivating, generating the opposite effect of what is expected. In other words, emphasis on the conceptual aspects, results in low progress for students, who do not find situations in which they can develop the expected skills by using the softwares, or develop them in the right way.

Despite this data, projects for the development of multimedia systems, in most situations, do not involve the users in a systematic way during the systems development process, [10].

Normally, emphasis has been given only in technological aspects, designers' empirical knowledge, experience of successful projects, or formal scientific research, do not take any notice of the potential user during the design phase, [9].

Consequently, in this paper we present a methodology, based on Participative Design (DP) User Centred Design on the (UCD) methodologies, for developing educational information multimedia systems, that involve potential users in all the development stages, proposing the integration of developing teams.

2 Contribution of Participative Design (DP) and User Centered Design (UCD) Methodologies

According to Mandel [5], one of the difficulties in producing good quality educational software seems to be linked to the fact that in the design process there is a significant difference between representations that designers, programmers and teachers have on the teaching and learning processes.

According to Tchounikine [13], the problems with the majority of educational software seems to be the difficulty between the elements designers have at their disposal and the way in which educator specify their ideas. According to the author, interaction between programmers and educators is a problem due to the difficulty of sharing concepts in different areas.

To solve this problem, a set of techniques was developed in Scandinavia intended to manage design with multidisciplinary teams and potential users. The proposed approach named Participative Design, emphasizes the importance of democracy in a work environment, improving work methods, design process efficiency (through users experience and comments), and supporting multidisciplinary teams.

From this point of view, the use of Participative Design has brought the following benefits:

1. The company could follow-up and evaluate the project;
2. Researchers had a greater understanding and power over the elements, as problems were shared between the directly involved participants. With this interaction researchers could carry out their theoretical proposals;

3. Greater possibility of satisfying the company's objectives, as they directly took part in the system's development;
4. Possibility of mutual learning and improving work practices;
5. Greater efficiency and quality.

The involvement of potential users' involvement in the project could not be disregarded in any of the software development phases, even the initial ones, such as the concepts, software architecture and content development. The users' cooperation during the whole design process provided the work group with the necessary information. Besides the DP activities, the result system quality is improved due to a better understanding of the work accomplished by the potential user, combining the participants' different know-how's during the design process [1].

Presently, potential users' involvement only appears in the final development stages of a product, making it impossible to produce meaningful changes. To this fact, we can still add temporal commitments or financial difficulties.

Therefore, by associating the methodologies proposed by the UCD, we are trying to minimise the distances between the user's real needs and the technological and didactical contributions of educational software.

According to ISO 13407, the UCD is a move towards developing interactive systems with the purpose of developing usable products. This should be a multidisciplinary activity that combines human factors, knowledge and Ergonomic methodologies.

Applying Ergonomics in the design of interactive systems improves efficacy and efficiency, improves conditions of use, and avoids possible adverse effects on health, safety and performance.

Systems centred on users support and encourage their learning. Benefits can include:

1. Increased productivity;
2. Improved users' performance quality;
3. Decreased costs for support and training;
4. Increased satisfaction of user.

According to Rieman [12], the most important role of educational software goes beyond the promotion of learning. Therefore, it is not only a question of learning how TO DO something with an interface, but of learning how to deal with an interface to LEARN a new concept. In this context, educational interfaces hinder the cognitive development of users, with an impact on the learning of certain concept areas, [14].

To access data about users' cognitive activities, either related to learning domain or to the teaching context (activity), it is necessary to guide the adequate cognitive models to the subject's approach. Consequently, we propose divulging the concept applied to this project in studies that either involve, or do not involve, multidisciplinary teams. Applying this method helps people in charge of design, hardware or software processes, to identify and plan user centred design activities, in an efficient and punctual way, complementing the existing design approaches and methods.

3 ErgoShow Development Methodology

The Ergoshow project was based on a methodology developed in three phases:

1. System definition concept;
2. Preliminary and detailed studies;
3. Final validation;

These phases intersected in time, and a symbiosis became visible, this helped Ergoshow's development process using the Design Centred on the User and the guidance of the whole team through Participative Design.

3.1 Defining Concept System

Analyzing Reference Situations. We started this project by analyzing educational computing programs with similar characteristics to those planned for ErgoShow. By educational software we mean, the class of educational interfaces or the ensemble of artifacts designed to function whilst being mediators, in training activities in specific areas of Human knowledge.

This activity served two purposes: the first one was to present the different kinds of views regarding these information systems. Accordingly, designers, ergonomists and pedagogues described and presented their viewpoint about certain software to the whole team. The second was, identifying positive and negative aspects of the analyzed programs. This process can be carried out by analysis with pre-defined heuristics or by usability tests with potential users.

Only after securing this information is it possible to establish strategies aimed to work when improving or innovating an information system.

Defining Types of Contents. Defining types of contents was developed in *brainstorming* meetings with ergonomists, pedagogues and Occupational Health specialists. Defining and categorizing types of contents was carried out to inspire the public targeted for these systems and to prepare them to be, in the future, responsible workers in relation to Ergonomic and Occupational Health matters.

The topics concerning these contents were presented to a sample of potential users, who gave their opinion and pertinence about it.

Developing Contents. The selected contents were developed and adapted into a simple and direct language, understandable for the prospective users' age group. Therefore, the technical terms were replaced by simple explanations, or when this was not possible, they were put into context with images and other elements such as navigation interaction.

Part of the contents was shown to a potential user list, who expressed their opinion on the way these were developed.

The same contents were shown to teachers, who expressed their agreement or disagreement on the way they were developed. The final contents emerged from a negotiation process, a mixture of casual speech and a more colloquial language used by teachers.

Defining Metaphors. During the definition and development process we defined the metaphors for the multimedia system and its contents. This process was developed during the *brainstorming* meetings with the multidisciplinary groups of ergonomists, teachers and potential users.

Visual metaphors were defined for the characters and physical contexts in which the organizational contents and metaphors unrolled.

3.2 Preliminary and Detailed Studies

After defining the Ergoshow concept, we advanced to the development phase, initially with simple mock-ups, drawn on paper and in the following phases, with increasingly complex semi-functional prototypes.

All along the development process, usability tests were carried out, using samples of five potential users. Their opinions and interaction difficulties, allowed us to modify several system mock-ups in order to improve usability.

Focus Group meetings and *walkthrough* type interactions were carried out, where potential users were called upon to verbalize all they were thinking during their interaction with the software. At the end of each test, they were subjected to a semi-structured interview and a questionnaire that evaluated a number of aspects, such as a person's reaction or memorizing contents.

3.3 Final Validation

The first DEMO version was submitted to a sample of 30 possible users in order to obtain varied and critical opinions that should be considered for reformulating the software. For this analysis we had meetings with the Focus Group and *walkthrough* type interactions, where users were asked to verbalise everything they were thinking while interacting with the software. At the end of each test, the users were submitted to a semi-structured interview, that evaluated different aspects that went from a person's reactions to memorising contents.

While interacting with the *walkthrough* technique, we registered user reactions and verbalisations. The objective was to gather information about the difficulties of interacting with the system, regarding committed errors and communications.

Regarding the registration of verbalisations, the prime objective was to register spontaneous verbalizations made by the users while interacting with the system, as well as the moment they occurred.

Interviews were carried out immediately after interaction with the system and were based on an ensemble of pre-established questions. This method allowed greater flexibility and richness in gathering information, and also, because it was a more expedite and easy method to use.

The interview objective was to assess the *difficulties* felt during interacting with the program and to get to know the users' *opinions* and *suggestions*.

4 Introducing an Example – Ergoshow 1

Ergoshow 1 was developed for youngsters from 8 to 14 years old and deals with subjects related to transports, load's manipulation and seated work. We started by

assuming that the consolidation of the teaching-learning process happens when a youngster understands the “reason of things”, as opposed to being confronted with an ensemble of “prescriptions”. Therefore in Ergoshow 1, no prescription is given for manipulating loads or to be well seated. The youngster is confronted with the vertebral column, muscle-skeletal and the circulatory systems' behaviour, in order to understand why one should not assume some postural behaviour on a daily basis.

To present the text contents, we decided to create an animated mascot (BONE) that is the host in all the software's stages and phases. “BONE” is an adolescent skeleton, was designed in live colours and with a *hip-hop* appearance that makes the contents in an easy way and uses adolescent lingo (Figure 1).

After selecting the text contents, language was adapted to an informal speech presented by the “BONE” character. To organize and hierarchize the contents, we proceeded to separate the software into two distinct modules, each one subdivided into three levels. These texts were used as a source for a guide book prepared to aid in the film's animation and interaction sequences.

Ultimately, spoken itineraries and some suggestions of content animations were structured, and use as a starting point for developing each one of the system's final animations.

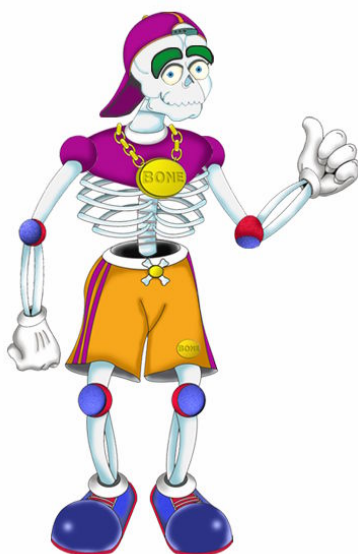


Fig. 1. BONE, mascot designed for contents describing

At the end of this stage we defined the whole program *layout*, by pinpointing interaction elements that were grouped according to its importance, easy to use and/or setting into motion. According to these concepts, the items were grouped in one of the following 4 functional areas:

- a) *Top Toolbar*: On this toolbar we can find the software's control elements, as well as the system user's situation and reference indicators.
- b) *Host Area*: On the left side there is an area set apart for the host. In this area the mascot performs several movements without interfering with the *Animation Table's* elements.
- c) *Animation Table*: This area characterized by a white board, in which animations described by "BONE" are posted and where all the animations, films and also questionnaires appear. On the top of the animation table we can always see a text about the subject being viewed.
- d) *Lower Toolbar*: Directly below the animation Table is a bar designed exclusively for subtitling. The prime objective of this area was to make the contents accessible to hearing impaired people, thus broadening the number of possible users of this program.

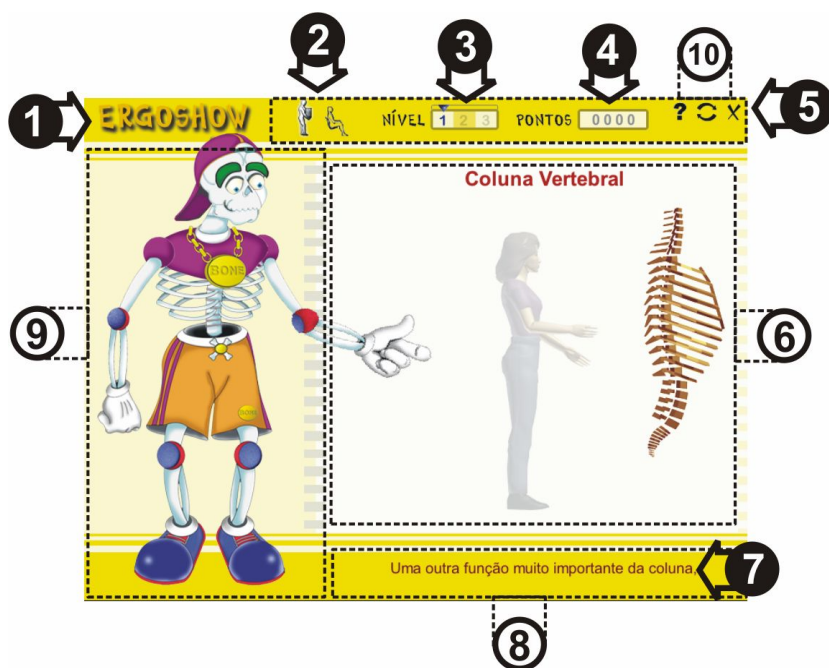


Fig. 2. *layout* items 1- program name; 2 - module indicator showing where the user is; 3 - indicator of the level at which the user is; 4 - indicator of the score obtained by the player; 5 - help button; 6 - return to previous page and leave the program; 6 - animation table; 7 - area reserved for locution subtitling; 8 - lower toolbar; 9 - host's area; 10 - top toolbar

In order to memorize the contents, a little game of multiple choice questions and answers was developed, shown at the end of each level, in which, the player is confronted with a string of questions concerning the contents shown on the previous Level. Each question was awarded 100 points, therefore, it was necessary to answer at least 60% of the questions correctly in order to allow the user to advance to the next

Level. The user had the possibility of skipping the question or reviewing the contents. These resources could be used to help the user answer the question correctly.

As an incentive for improving performance, the question game had an evaluation system for the player's performance, where a collection of expressions (*smiles*), placed next to the scores, showed four levels of satisfaction Satisfied – Serious – Sad and Bombastic

5 Conclusions

Understanding potential users' difficulties, needs and expectations and the main negative and positive aspects that could complicate or optimize the relationship with the system or the learning, made the system become more adjusted to users, as well as, avoiding the great number of surveys proposed for usability analysis after product completion.

Thus, the methodology presented in this work had the merit of involving potential users along the whole development process of an information system. We contextualized this methodology in the design of an educational software ensemble, in game format, for adolescents from 8 to 14 years old.

The main conclusions allowed us to:

- Evaluate the characters' concept from the beginning, although in the beginning there was some doubt about the success of some of them.
- Make small adjustments in the characters, allowing to better identify adolescents' expectations.
- Evaluate the success of transmitting contents in a game format, with difficulty levels and scoring.
- Verify if the presented examples comply with the future users' everyday realities.
- Identify and correct the first graphic and navigational environment proposal's small problems.
- Evaluate the used language, introducing some expressions used by adolescents, without damaging the transmitted information's thoroughness.

Systematizing the potential users' involvement in the various development phases of this information system allowed to:

- Better adjust of this system to the users' mental model, their needs and expectations.
- Identify mistakes that would be difficult to correct at the end of the project.
- Reduce the expenses for development, as corrections at the end of the project would mean added costs.

Regarding the use of PD, we became aware that applying these kind of techniques and others, originating from organizational psychology and management areas, are extremely important for managing the development of educational products, for controlling each one of the development stages and reinforcing individual competencies of each one of the involved persons.

The UCD has brought enormous benefits to the project. Only by frequent enquiries in each of the product's development phases, is it possible to adjust, in the best

possible way, what designers think of the project regarding imagination and expectations of the target population. Mainly because imagination varies regarding to [6]:

- Culture of the analysed people;
- Age group of the target population;
- And gender.

It was surprising to observe that the system attracted the attention of individuals out site the proposed age group, mainly adults, with different kinds of profiles and cultural levels. Therefore, this product generated the interest of some companies that requested them for training their staff in Safety and Health at Work.

Information technologies have been used in school environments for over twenty years, with most of its development taking place in the eighties, when personal computers emerged [3]. It spread through different kinds of social interest areas, and teaching was no exception, and the advantage these systems offer, being well-known. An important reason that justifies applying information technologies in this environment is the capacity to improve student's learning, due to the fact that it gives the student an opportunity to develop different kinds of competencies, continuously increasing in today's information society.

The making of this project proves as it was show, to be a welcome tool capable of transmitting important issues.

Through tests done by future users and from opinions collected from people of different age groups, is it possible to conclude that Ergoshow conveys the intended know-how a whole, viewers were generally satisfied. Regarding developments from the first version to the second version, these were significant concerned to graphic quality, increasing empathy with the final user and decreasing the distance with similar software. Contents are more dynamic and interaction with the player was increased.

The developed tools confirm, through the first tests done with users, an enormous potential for transmitting contents to different age groups. The product was enthusiastically approved. All students referred they liked the characters, the colours and were, also, able to understand and assimilate all the transmitted contents.

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An Expert System to Support Clothing Design Process

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Abstract. In the context of expert systems technologies and human computer interaction, the goal of this project is to construct an interactive design support to fashion designers when designing workwear or corporatewear clothes. This system will be fed by a semantic database that describes the relations between function and clothes specific context of use under the user's perspective. This application will contain relevant information for clothes designers and producers, alerting them to the user's clothes preferences adequate to a certain task, and hopeful, an added value to be included in the beginning of the design process. To gather all this information it will be studied the user's real work situation and preferences under Kansei Engineering and Rough Set methodology. The outcomes of this study could help clothing designers to suggest effective user centred design clothes.

Keywords: Expert system; Clothing design; Design process; Kansei; Rough Sets; Uniform / Workwear clothes.

1 Introduction

Fabric textiles are used in a wide range of applications in clothing design. However, due to the panoply of possibilities and materials quality of existing fabrics, the adequate choice, according to the usage context and other specific requirements, is not an easy and rational process. Therefore, proposing an expert system that meets the requirements of a certain case could bring many advantages to the clothing industry and its inherent complexity. This can be achieved by a careful selection of inputs, but also by global or local tailoring properties of future potential users, condensed in a knowledge data base.

Clothes design developing process is surrounded by subjectivity, not only in uniform/workwear/corporatewear area, but also, in ready-to-wear. During the design process, firstly, information is explored in orientation ideas concerning moods, themes, concepts and product types. Secondly, all gathered data is processed and transformed into product ideas combining silhouettes, materials and colours [1]. Influences come from both external and internal sources, both from the environment and personnel related to the design process, directly or indirectly [2]. It is very

common to forecast and to identify trends as key elements in the fashion industry, but the doubt remains—is this really a reliable source [3].

A design team members brief will usually initiate the process by defining “the garment type, age group, purpose, climate and price range”; a complete involvement in fashion ideas and different means of communication is also indispensable [1]. References on cultural, social and political events should also be regarded [2], as well as we suggest, the inclusion of the user’s real work situation and preferences analysis study, to allow the development of adequate clothes subject to the context of use.

Therefore, the main purpose of this work is to present an interactive system concept based in an expert system to support clothing design process, making the design development process more objective. Simultaneously, the system will provide clothing designers the necessary elements for user centred design, subject to the context of use, throughout a user’s preferences data base. There are three phases to achieve this purpose: (1) to define how data should be introduced in the knowledge data base of the expert system; (2) to define the data entry categories, according to the population target; (3) to define the data output type more useful for clothes designers, the potential users of this system.

Previous studies using expert systems have been applied in different design areas:

- Expert system conceptual design for computer software [4];
- Expert system for selection of coatings for metals [5];
- Expert system for composite laminate design [6].

In these studies the systems have proven to be effective, and better, when compared with previous ones [6]. According to Ichiko [4], it should be noted that, future intelligent man-machine interface, needs design aid technology to facilitate easy understanding of the design coverage, without distressing high level human intelligent activity.

Accordingly, we propose an interactive expert system to support the clothing design process under Kansei and Rough Set methodology development. For preferences analysis we will use Kansei Engineering to transform the evaluation data, of user’s senses and feelings, in design elements for clothing design. Human Kansei and Rough Set methods have been used in previous studies to obtain decision rules on experimental data set and design elements [7, 8, 9]. In the system, user accessibility was taken into consideration due to the possibility of changing input and output parameters amongst others: garment type, age group, purpose, environment; through the graphic user interface.

2 A Concept Expert System to Support Clothes Design

Our proposed concept expert system to support clothing design process includes the following phases:

1. Knowledge data base collection
2. Data entry expert system categories
3. Data output expert system categories

In the following subsection, each phase will be described.

2.1 1st Phase – Knowledge Data Base Collection

This phase defines how data will be collected and introduced in the knowledge data base of the expert system.

We used Kansei Engineering and its semantic differential to ensure that user's perception and the entire surrounding environment are considered in the expert system.

Kansei Engineering is an ergonomic technology of customer-oriented product development, it focuses not on the manufacturer's intention of the product, but rather, on the customer's feelings and needs (*Kansei*) [10]. "*Kansei*" is a Japanese word that means the customer's feelings and needs relating to a product.

Kansei Engineering was developed in Japan, at Hiroshima University, in 1970, by Mitsuo Nagamachi and it has spread out, firstly in Japanese industries and then around the world. For many decades, manufacturers have provided hundreds of products which were developed from the manufacturer's intention. However, wise customers want products that fit their demands. This implies the need to incorporate the customer's needs and mind in the product, instead of manufacturer's objectives. To be able to do this, they should know what customer's needs have and what their feeling regarding the new product is. Kansei includes the customer's feelings about product design, size, colour, mechanical function, feasibility of operation, and price as well. We also propose to change some aspects of the Kansei methodology, introducing an Ergonomic Analysis before semantic variables definition, to be considered when deciding the semantics.

This methodology consists on:

Ergonomic analysis

This process starts with observation of the real work situation. An activity analysis of customer's working while interacting with their regular work environment is carried out with a camcorder and followed by a customer's behaviour survey, about their preferences and context of use. We will analyse and look for the influence of workwear in the interaction with other elements of the work system, evaluating and understanding if it causes problems.

Kansei semantics compilation

The collection of Kansei semantic variables is obtained through the selection of the compiled words from specialized bibliography and from potential user's and expert's opinions captured in different brainstorm sessions. All these words are then selected and reduced to a manageable number of relevant words for each characteristic and context.

Knowledge database

The previous ergonomic analysis and Kansei semantics compilation is condensed in a Kansei engineering knowledge database that responds to the user preferences market trend orientation. Consumer data can be inputted in the system depending on the users and context of use, every time it is required, or, when using the same data, adjusted every three or four years.

Rough Sets

Related to this point, we developed an expert system to build a systematic framework based on Kansei engineering technology. We utilized Rough Sets in the Kansei engineering system to construct the concerned database and computerized inference system.

Because Kansei has shown non-linear characteristics in the meaning statistics, usually it is used Neural networks measurement, Fuzzy Logics, Rough Sets and others without awareness of linearity or non-linearity of the Kansei. [11]. One of the problems found in Kansei is that human's Kansei concept does not have constant linear characteristics in statistical distribution. For example the Kansei big/small has a linear continuity, but the Kansei beautiful/not beautiful, has a curved aspect in physiological axis [11].

As verified by some experts, Rough Set theory enables to obtain more specific decision rules than traditional use of statistical regression analysis method in Kansei engineering, ensuring in better approaches to the characterization of design elements [7].

Rough Set theory is a mathematical approach to vagueness proposed by Pawlak in 1982. Its philosophy was set up on the assumption that we relate information to every object. Objects that we typify with the same information are indiscernible (similar) when we access any of them. This generated indiscernibility is the mathematical basis of the Rough Set theory [12]. The indiscernibility approach used in Rough Set is characterized in relation to a specified set of functions or attributes.

A set of indiscernible objects is entitled to an elementary set, and has a shape of a basic grain (atom) of knowledge about the universe; any combination of elementary set is described as crisp (precise) set – if not the set is rough (imprecise, vague). Subsequently, each Rough Set has boundary-line cases, i.e., objects that can not be classified with certainty as members of the set or of its complement; crisp sets do not have any boundary-line elements [12]. Thus, vague concepts, in contrast to precise ones, cannot be characterized in terms of information about their elements. Therefore, in Rough Set approach it is assumed that any vague concept is replaced by a pair of precise concepts – called the *lower* and the *upper approximation* of the vague concept. The lower approximation consists of all objects which certainly belong to the concept and the upper approximation contains all objects which may belong to the concept. Apparently, the difference between upper and lower approximation represents the boundary region of the vague concept [13].

An additional essential concept in Rough Set is that a minimal set of attributes can classify objects with the same accuracy as the original set of attributes. Exclusion of redundant attributes can help to recognize strong, non-redundant classification rules [14].

The most important advantage of Rough Set theory in data analysis does not require any initial or supplementary information about data, like probability distributions in statistics [12].

2.2 2nd Phase – Data Entry Expert System Categories

This section defines the data entry categories, according to the population target.

This expert system is primarily directed to clothing designers and clothes producers; they will use this platform as a design tool with all relevant users database

collected on the previous phase. To determine the important design inputs for designers we have made interviews to clothing designers with experience in workwear and corporatewear. From the interviews we have selected the main categories and respective options. These categories and options will enable designers to understand user's preferences and expectations related to the uniform they use to perform their tasks, in their work places, adequate to their basic use.

2.3 3rd Phase – Data Output Expert System Categories

The following part defines data output type more useful for clothing designers, the principal users of this system.

The given outputs, after the input selection, will give clothing designers a better understand of their work directions, based on user's requirements. These outputs will refer to design specifications to be considered from the beginning of the design phase, providing the base for a future user centred design uniform.

The system will facilitate designer's tasks by giving them a clear notion of potential user's needs, without trying to interfere or reduce their creativity. The interface was developed to provide effective and simple interactions between users and the system, with a human-centred design approach. We tried to give a positive experience to end users.

3 Conclusions

We have proposed a user centred technology to support clothing design process based on Kansei Engineering and Rough Sets. Kansei Engineering has been very useful for users, to select the fittest product to his/her Kansei, and even more useful, to designers [11], to understand the demands of the correct product whose specifications are suggested by the system. Rough Sets methodology appears to be of fundamental importance in artificial intelligence and cognitive sciences, particularly in machine learning, intelligent systems, decision analysis, and expert systems, along with other research areas.

The expert system prototype is being validated by a group of potential users – clothing designers. We are also trying to estimate user's and designer's satisfaction with this system outcome, as well as, how it can be improved and implemented in the future.

This interactive system simplifies the utilization of statistics data by clothing designers, who rather prefer to use a more specific design help tool, which provides specifications to be considered when designing.

We believe this system could be an additional value to the workwear and corporatewear industry.

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Interaction and Ergonomics Issues in the Development of a Mixed Reality Construction Machinery Simulator for Safety Training

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Abstract. We present the work on a simulator of construction machinery developed to train workers in their safe use. The simulation setup consists of a real versatile cabin placed on a motion platform in order to provide a realistic interaction with the system and a stereoscopic augmented reality system for visualization. We present some insights into the mixed reality setup we used for complex construction machines and discuss the interaction and usability problems that have arisen during its development and testing. Visualization has been implemented as a chroma-key-based mixed reality system, which combines the 3D virtual environment, the real cabin interior, and some superimposed messages to the user. As a result of our experience, we describe the main problems encountered from a usability and ergonomics point of view.

Keywords: Interaction, Ergonomics, Mixed Reality, Construction Machinery, Simulator, Safety, Training.

1 Introduction

The use of simulators as training tools for machine operators is spreading rapidly. Although some years ago simulators were mainly used for leisure and in the defense and aeronautics sectors, in recent years their use has also extended to new areas such as construction [1] and the automotive sector [2][3][4][5].

When the simulation of machines is targeted at training people, the realism of the simulation becomes a relevant aspect. This realism is closely related to the way in which the dynamic behavior of the machine is modeled in reaction to the operator commands, the visual quality of the simulated construction site scenario, and to the interaction between the machine and the virtual working environment.

The paper describes work done in the European Collective Research project VAR-Trainer from a usability and ergonomics point of view. In this project dynamic models of four different types of construction machinery have been developed (wheeled excavator, dumper, work goods lift and mast climb platform). The project aimed at

the creation of an affordable training platform for construction operators focusing on safety at work, based on the use of real-time simulators and a mixed reality setup.

First, some related works are commented followed by the VAR-Trainer architecture explanation. Next, the results of user tests are shown. Finally, some conclusions and the future work are presented.

2 Related Work

Despite nowadays the use of machine simulators for training purposes is expanding in different fields, there is virtually no commercial simulator for training workers in the safe use of construction machinery, which takes into account the pedagogical aspects by design and not like an added value to the product or such a technology is not commonly used by educational entities.

One of the products of CMLABS [6] is a harvester simulator for training, consisting of an articulated vehicle for traversing uneven terrain and a boom with a complex head to cut and manipulate tree trunks used to fell trees, de-limb and cut them.

The Institute of Robotics Research [7] has developed another harvester simulator, which may be used with different display equipment (passive stereo projection, shutter glasses with a monitor or head mounted display (HMD) with tracking system). It is based on the virtual reality simulation system (COSIMIR/VR) and has been used in the development of some excavator simulators.

The training simulator of hydraulic excavator (SHE) project [8] implemented an immersive simulator prototype of an excavator based on a motion platform on which a fake cabin is assembled. The virtual reality system provides sensations resembling the use of an actual excavator, but studying ergonomics and interactions issues was not the major goal.

3 VAR-Trainer Architecture

The main goal of the project VAR-Trainer is to develop a versatile real-time simulator, based on the integration of mechanics, electronics, automation technologies, and mixed reality (virtual & augmented reality) in order to train workers in the safe operation of construction machinery [9].

Most of the available simulators are specifically oriented towards a single machine or process type and are not open reconfigurable platforms able to adapt to different machine types, different levels of realism or different pedagogical aspects. Besides, machine training simulators usually aim at covering the training in all the machine's functionalities and are not focused on specific training aspects, such as safety.

The developed training simulator is sufficiently versatile and user-friendly to train in different types of construction machinery: lifting equipment (work goods lift), aerial work platforms (mast climbing platforms), and heavy works hydraulic machinery (wheeled excavator and dumper) (see figure 1). In the rest of the paper we will focus on the Mixed Reality setup and the interaction and ergonomic issues.



Fig. 1. Hardware setup: Exterior (left) and interior view (middle) of the real excavator cabin used for excavator and dumper simulation. The blue-box used for mast climb platform and lift simulation, also mounted on the motion platform (right).

3.1 Hardware Setup

Driving simulators typically use large projection screens where the virtual environment is displayed, but augmenting real images with additional information requires a different design. The use of real cabins mounted on a motion platform limits this approach, since the external projection screen should be huge to provide an immersive environment.

Another approach considered was to mount flat panel screens replacing the windows in the cabins which eases the virtual reality rendering but increases the total weight on the mobile platform. Stereoscopic vision would be nearly impossible.

In our system, the mixed rendered stereoscopic view is displayed using a video see-through head-mounted display (HMD) specifically designed [10], while the machine cabin and its controls are the real devices. The main elements of the setup are described in the following sections.

3.2 Virtual Reality

The virtual reality scene consists of virtual elements and their physically-based behavior and interactions. A specific subsystem simulates the dynamics of the driven machine and the interaction with the operator via the cabin controls [11][12]. Another module deals with the physics and visualization of the virtual environment. Some of the main tasks of the virtual reality system are the animation of vehicles and human characters, collision detection and vehicle-ground interaction, simulation of excavation and rendering in different weather conditions.

Safety issues when operating heavy construction machinery are also related to environmental situations like lighting and weather conditions and to the nature of the soil on which the machine is operated. Thus, particular care was taken to achieve a realistic perception of the virtual construction scenario [13][14] (see figure 2). Therefore several GPU shader programs have been implemented.



Fig. 2. Virtual reality. The virtual scene has been implemented using OpenSG as the graphics engine and ODE for the physical behavior. GPU shaders have been used to render the weather conditions (rain, fog, clouds) and the soil to enhance the realism of the scene.

3.3 Mixed Augmented Reality

The adopted mixed reality setup for visualization is motivated by the different layers of information that should be visible to the user, keeping low hardware costs [15].

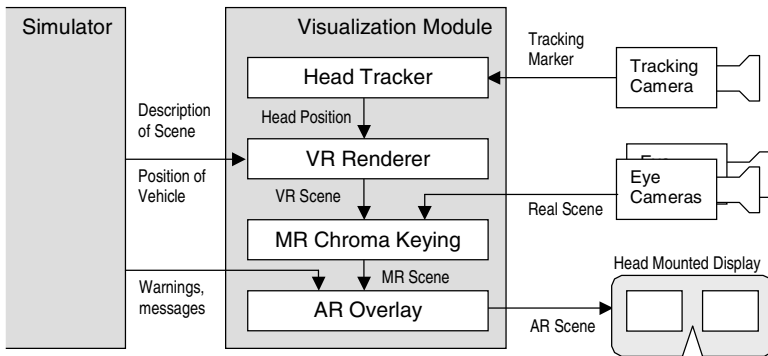


Fig. 3. Mixed reality architecture. Two cameras mounted on the HMD capture the real images, which are combined with the virtual reality and rendered in the same position using the tracking data. Finally, the augmented messages are superimposed and this final image is shown to the user. These steps are performed for the left and the right eye independently.

These layers are: (i) the virtual construction site scenario and the virtual part of the vehicle being the virtual background of the scene, (ii) the real parts of the cabin in front of the virtual scene, i.e. the real foreground, and (iii) the augmented messages on top of the real foreground to display messages or to provide hints (see figure 3).

The combination of the second and third layers represents the classical augmented reality (AR) situation, where a real background is augmented with virtual superimposed elements. The main approach here is the opposite: the background is virtual and the foreground (the cabin and everything inside) is real, with an additional virtual layer on top.

Once we have a composed image for each eye, they are augmented with the additional text that will inform and help the trainee with messages and hints to properly carry out the assigned exercise. Special care must be taken in the integration of 2D and 3D information in a stereoscopic visualization system, otherwise unpleasant depth perception effects show up.



Fig. 4. The eMagin Z800 HMD has been modified by adding two Firewire cameras to capture one image for each eye and an active marker that is used to track the user position. The total weight of this first prototype setup is about 350 grams but it could be reduced in the final setup.

3.4 HMD

Because of the costs, driving simulators are typically equipped either with monoscopic non-immersive visualization systems, or with a head mounted display (HMD), the latter reducing the visual quality because of the common low resolution and limited field of view.

Historically HMDs have introduced different ergonomic problems. This aspect has to be taken into account. Not all HMDs are comfortable to wear due to excessive weight, shape or troublesome cabling, or bad resolution. The HMDs technical characteristics and the achieved stereovision effect are also very important. Continued use of HMD devices and stereo displays is known to produce potential problems such as sickness or disorientation.

For VAR-Trainer (see figure 4), however, the decision had to be in favor of a low-cost fully stereoscopic immersive setup, as it is mandatory to provide a full panoramic view outside the cabin and because of the importance of depth when accomplishing a given training task. The used HMD partially overcomes or improves some of the limitations stated above. It is the eMagin Z800 3D Visor that consists of two high-contrast SVGA OLED microdisplays delivering a bright, crisp image, and with less than 230 grams being compact and comfortable. The image covers a diagonal field of view of 40 degrees.

The first HMD prototype has two cameras mounted on it, in order to capture the images from the user's point of view. The captured images are processed to adjust the field of view of the camera to that of the visor, and to correct any possible optical distortion.



Fig. 5. Chroma-key: Original image (left) and final image, after blue screen matting (right)

3.5 Chroma-Key Technique

The images captured by the cameras on the HMD must be correctly mixed with the virtual reality scene. Therefore, the blue screen technique has been adopted, also known as chroma-keying. Blue screen is a film-making technique of shooting foreground action against an evenly-lit monochromatic background for the purpose of removing the background from the scene and replacing it with a different image or scene. The blue filtering is easier if the blue color range is determined and stable.

In VAR-Trainer, (see figure 5), the blue screen itself has been realized by coating the windows of the cabin with a translucent blue foil. Some illumination and filtering problems appeared, disturbing the user's perception, and fine tuning of the system was necessary. The addition of some diffuse lights in the interior producing uniform blue surfaces which can be easily filtered greatly reduced the problem.

Additional problems arise due to the chroma subsampling, which reduces color resolution.

Although the cameras mounted on the HMD deliver a high-quality image which is very pleasing when viewed on a screen, the image quality in the cabin setup could be further improved. In conjunction with the blue screen matting, some artifacts appear. They could be removed by using a pair of lightweight cameras, which do not make use of the chroma compression technique like the ones used in this project. Nevertheless, the current image quality is quite good and the artefacts do not disturb the perception of the immersive environment too much.

3.6 Optical Tracking System

The virtual world must be rendered from the user's point of view provided by some head tracking system. In VAR-Trainer, a low cost one-camera optical head tracking solution developed at IGD, was used [16][17].

The optical tracking was the most suitable tracking system since the movement range of the user's head is limited and a wide angle lens was sufficient to cover the excavator cabin. Magnetic tracking was tested but, as expected, the tracking error was

too big due to the distortions introduced by the metallic structure of the cabin [18]. The movement of the cabin during operation also forbids relative tracking systems e.g. using inertial sensors.

The infrared camera is installed in the cabin's ceiling on a special box on the roof looking down, where the relation between tracking stability and tracking area coverage is maximized. An active marker (with infrared LEDs) was attached on top of the HMD prototype due to its higher reliability compared to reflective markers. Our tracking software calculates head position and orientation based on the camera view of the marker.

The tracking system's accuracy is acceptable for this application, although some instability, particularly in the roll angle, is perceived which can add uncomfortability. Inaccuracy increases as the user moves away from the central sitting position but such a movement is likely to be small or infrequent.

4 Results

The simulator setup has been tested by a group of users with different profiles, all of them sharing a background on construction machinery and safety at work. The group tested the excavator and the platform simulator, providing their impressions about realism, usability, ergonomics and usefulness.

Previous to these final tests some experiments have been made to analyze the importance of realistic rendering of the construction site.

4.1 HMD Ergonomics

The first time testers put the AR-HMD on, most of them felt uncomfortable, since they had never tried such a device. However, after some time, this feeling mostly disappeared. As the simulation went on, most of the testers encountered some strange sensations in the neck and head due to the weight of the HMD. Although its weight is not excessive, the usage of the HMD during large sessions causes this kind of side effects. Another impression of almost all users was the hot feeling when they were wearing the HMD, but the testers with some VR devices experience commented that the chosen model is not as hot as others. This sensation is increased in the platform setup, since the cabin is completely closed lacking proper ventilation.

After all, the group of people taking part in the trials considered the HMD quite comfortable and commended its image quality.

4.2 Virtual Reality, Augmented Reality and Chroma Key

All testers were surprised by the effect of the virtual and augmented reality mixed in the visor. It is certainly a strange sensation to see the real world including our own hands through cameras while also seeing the nonexistent outside environment through the windows. The users quickly got used to the system and found a very convincing stereoscopic effect. These features combined with the motion platform offers a fully immersive and realistic simulation of construction machinery.

The testers found some problems related with superimposed texts. Since they are rendered at the zero-parallax plane, they may be perceived further away than objects behind them, resulting in a very strange effect. The depth of text overlays must be correctly set to a closer plane.

As expected, the lighting conditions affect the quality of the chroma key image composition. It is very important to get a uniform blue in the images captured by the cameras, in order to be able to substitute the bluish pixels with the virtual reality image. Insufficient or non-uniform lighting causes glittering or blinking of some frontier pixels. During the trials, the testers noticed some of these artifacts when they were looking at the darkest areas of the cabin. Specular highlights on the blue surfaces were another source of problems as the white reflected light changes the light hue and saturation passing through the blue filter unaffected.

During tests taking place earlier users were asked to evaluate the realism of different parts of the construction site scene [14]. The scene was presented twice, first using the HMD (immersive), and second using a 17-inch monitor.

The results of the experiment showed that shaders bring more realism, but they also showed that some visual effects are highly application dependent. For a mostly static environment where the viewer does not often look up into the sky, a less sophisticated static sky rendering is sufficient. Furthermore, the rendering appears to be more realistic when presented using a HMD instead of a standard monitor.

4.3 Optical Tracking System

The tracking system is the element of the setup that made the testers more uncomfortable. When they did some very aggressive movements or moved out of tracked area, they noticed that the image got frozen, because the tracking system lost the user's point of view. After some training, the users learned where they can move their head, and this problem was reduced. In the platform setup, this effect is dramatically increased because the users are standing up and they tend to walk in all directions, causing frequent tracking failures. In this case, it is more difficult to teach the user to stay in the tracked area.

The tracking system has an inherent instability (even with the user at an optimal position) that should be limited to tolerable ranges. The inclusion of image stabilizer filters can improve the user experience, but in this case, no filter additions were needed, as the achieved tracking stability is enough.



Fig. 6. Screenshots taken during the trials. A dumper exercise (left) and an excavator exercise (middle) from the user's point of view. A user testing the system (right).

5 Conclusions and Future Work

This work has presented a construction machinery simulator with a mixed reality setup (virtual and augmented reality) aimed at training workers (see figure 6).

The tests have provided useful information about which aspects of the simulator should be improved. The optical tracking has been the module that has received the most remarks from the users. Despite this, the overall impression of the testers has been positive.

The deployment of the simulator to be used in different places is one of the future work tasks, where the simulator will be tested by skilled real trainees that should be instructed previously in its correct use. This phase will be used to improve the automation of the simulation deployment process, including lighting configuration and other aspects. Trainees will provide interesting additional feedback about the simulator usability.

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Performance Improvement of Pulse Oximetry-Based Respiration Detection by Selective Mode Bandpass Filtering

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Abstract. In this paper, an improved method to detect respirations by pulse oximetry during exercise is proposed. As a method for robust respiration detection, fixed bandpass filtering to block the heart beat signals is commonly utilized. But the fixed bandpass filtering cannot guarantee reasonable performances when the HR(Heart Rate) is varied highly. Therefore, the respiration detection performance is degraded. In the proposed algorithm, the HR information is used to estimate the RR(Respiration Rate). Using the RR, the corresponding bandpass filter(BPF) is selected to detect respiration points. The selection of the passband makes the proposed algorithm possible to guarantee the performance during exercise. Our test results show that the overall estimation error of the proposed algorithm was 20.32% during exercise.

Keywords: pulse oximetry, SpO₂, health care system, biometric signal processing algorithm, respiration detection.

1 Introduction

During aerobic exercise, respiration rate control is essential to increase its effectiveness[1]. That is, the effectiveness can be raised by the respiration rate suitable for a given exercise. On the other side, wrongly trained respiration habits increase the possibility of damage to human organs. In order to investigate respiration efficiency of an exercise, the amount of required oxygen can be directly derived from its load. Besides, the amount of oxygen actually absorbed in the human body is also important. To estimate it, additional sensors and corresponding signal processing from them are indispensable.

Typically, as the method of respiration measurement, the ECG(Electrocardiogram) system is the best in the view of precision[2] [3]. For this reason, it is widely adopted to hospitals or sports research institutes. But, in spite of the advantage, it has several

critical problems. Its sensor attachment is not convenient, and the cost of maintenance is not affordable to households. These are obstacles to popularize the system as home exercise equipment.

To overcome the problems, pulse oximetry, which is focused on our research, is applied to the respiration detection during exercise. When pulse oximetry is employed to automatic exercise prescription systems, its usage can be stretched from medical monitoring systems to household health care systems. In the sense of usability, the simple snap of a pulse oximeter improves the convenience in sensor attachment and it needs no additional cost for maintenance.

Because pulse oximetry is simple but powerful, related researches and applications have been continuously developed for the last decades. In some cases, it is used for heart beat-related researches, and in the other cases, it is applied to respiration analysis systems[4]. Among them, researches related with respirations are difficult and challenging. But, reliable performances are guaranteed only in the limited conditions like paced respirations or less intensive exercises[5] [6].

In order to detect respirations by pulse oximetry during intensive exercise, the proposed algorithm is concentrated on the robustness in detecting the RR. When the conventional fixed bandpass filtering with the possible RR(0.1~1.4Hz) is simply performed to the SpO₂ signal, unexpected artifacts makes the detection of respirations difficult. Moreover, the conventional method cannot guarantee robust performances because the range of the HR(1.0~2.8Hz) and the RR becomes overlapped during exercise. So, it is difficult to set the passband for respiration. In addition to the problem, artifacts are possibly included into respiration wave due to the broad range of the RR. Consequently, dynamic adjustment of the passband is necessary to the respiration detection.

Our algorithm has following procedure to dynamically adjust the passband. First, heart rates which are less vulnerable by artifacts are measured with SpO₂ signals in the time domain. Next, through frequency analysis, the strongest frequency component among the spectral bins slower than the HR is recognized as the estimated RR. Finally, respiration points are detected after filtering the SpO₂ contour using the BPF based on the estimation. The dynamic adjustment of the passband makes the proposed algorithm cover all possible intensity of exercise.

The paper is organized as follows. Section 2 describes related work. Section 3 deals with pulse oximetry for exercise. From Section 4 to 6, the proposed algorithm is described. The Experiments and the results are presented in Section 7. Finally, the discussion and the conclusion are given in Section 8 and 9.

2 Related Work

The ECG can be used to detect respirations[2] [3]. Among various methods, it must be the most reliable. But, it requires cumbersome electrode attachment to the skin. It also has a problem of disposable electrodes. Wastes and costs occur in the measurement process.

Pulse oximetry is widely used for patient of intensive care units. During paced respiration, respiration can be detected by pulse transit time[5] [7]. Once an inspiration

occurs, pulse transit height is recovered to the original magnitude. But, fluctuations or sudden noises in SpO_2 signals disturb using this method to the detection of the RR during exercise.

Pulse oximetry is importantly applied to patients in hospitals to detect HR's. During the HR measurement, removal of artifacts caused by an unfixed clip-type sensor is requested. Most artifacts in SpO_2 signals are due to the loose attachment of a sensor, motion effects and electronic noises, etc[8]. Spectral analyses and the independent component analysis are employed to reduce those artifacts and extract HR's[4] [8].

Without the swing of the sensor and the motion of the body, a fixed BPF which has the passband near the RR can be useful to block the artifacts and heart beat components in SpO_2 signals[9]. But, the HR is varied highly during exercise. So, the fixed BPF method cannot show a stable performance.

3 Pulse Oximetry for Exercises

3.1 Necessity of Dynamic Passband Adjustment

When the intensity of an exercise increases, the oxygen consumption of the human body is increased, and the blood circulation system reacts faster[10] [11] [12]. Subsequently, heart beat and respiration components in the SpO_2 signal have higher frequencies[13] [14]. During exercise, the frequency range of HR's and RR's are 1.0~2.8Hz and 0.1~1.4Hz, respectively.

As a result of the higher intensity in the SpO_2 signal during exercise, the range of the HR and the RR become broader and sometimes overlapped. In this case, the BPF which is designed to cope with the whole possible RR range cannot exclude the HR successfully. The error of the HR and the RR is due to the failure of the peak point detection after the bandpass filtering. In order to prevent this kind of failure, the passband should be adjusted dynamically by using the HR information. Moreover, in the case of fixed bandpass filtering, broad range of the passband is disadvantageous to avoid possible artifacts including heart beats.

On the other side, in the case of less intensive exercise, the range of RR's is 0.1~0.6 Hz, and that of HR's is 1.0~1.5Hz. Because each range is not overlapped, the necessity of the dynamic adjustment is not issued.

3.2 Internal Respiration and External Respiration

Respirations are classified into the external respiration (mechanical motion of the lung) and the internal respiration(oxygen refreshment of hemoglobin). While the external respiration consists of inspiration and expiration, the internal respiration is the biochemical process of hemoglobin with oxidation-reduction reaction[15]. Because of the difference between these two kinds of respirations, they are not tightly related to each other. That is, in some cases, the oxygen refreshment of hemoglobin may not follow the motion of the lung. They also show less correlation in case a subject is unhealthy.

3.3 Intensities of Exercises and SpO₂ Signals

The proposed algorithm is concentrated on the case that has a distinctive respiration frequency like fig. 1(b). Intensive exercise increases the magnitude of the respiration. When it overcomes the magnitude of artifacts, the proposed algorithm can properly work.

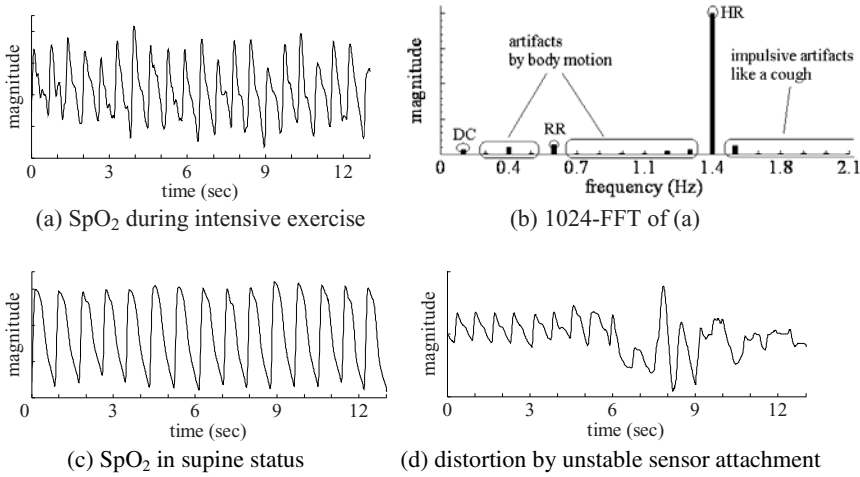


Fig. 1. Signal characteristic related with artifacts (sampling rate: 120Hz)

4 Detection of HR

The impulsive artifacts of the SpO₂ are usually caused by abrupt motions of subject's fingers and it can be generated by utterances, coughs, etc. gives impulsive artifacts to SpO₂ signals. So, simple peak detection methods based on differentiation cannot be effective to the HR estimation. Generally, pitch detection based on auto-correlation can be thought robust and appropriate to the HR estimation.

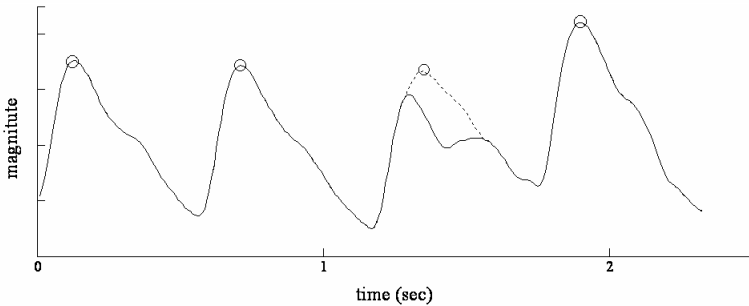


Fig. 2. Example of heart beat point distortion in SpO₂ signal(dotted line: expected SpO₂ curves without artifacts, circle mark: heart beat point)

Even though auto-correlation can find stable pitches, the problem such as halvings or doublings of their true values can occur frequently. Besides, severe noises can be included to the SpO_2 signal. To prevent the problems, median filtering is used to ensure the performance of HR detection.

5 Frequency Domain Analysis to Detect Respirations

A BPF with a fixed passband has no functionality for the overlapped range of an HR and an RR. It can be only applicable to little intensive exercises having no overlapped range. For an exercise with the RR of 0.1~1.4Hz, the filtering cannot detect respiration points in the SpO_2 signal faithfully.

On the other hand, because the proposed algorithm can move the passband dynamically, it can work robustly for exercises of various intensities in detecting respirations. Especially, the SpO_2 signal which contains maximum intensity of exercise is also under coverage.

As a preliminary estimation of the RR, the frequency analysis is performed. The pre-estimation make it possible to adjust the BPF to have a narrow passband near the RR. The properly chosen passband achieves successful results in detecting respirations by blocking heart beats and artifacts.

Fig. 3 shows why a fixed BPF with a wide passband is not appropriate. The result of the bandpass filtering is nothing of heart beats or respirations. But, the result of the bandpass filtering near the RR successfully extracts respiration points from the SpO_2 signal.

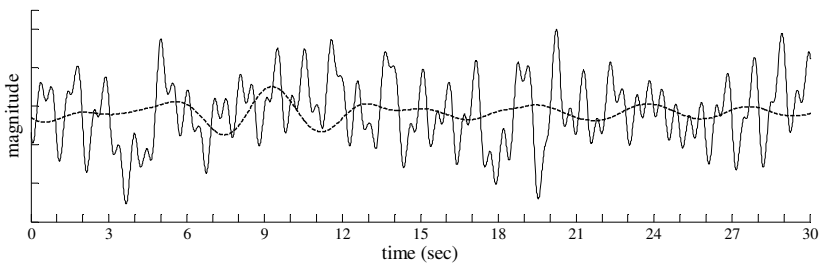


Fig. 3. HR: 2.0Hz and RR: 0.5Hz at 150Watt-loaded exercise (solid line: bandpass filtering(0.1~1.4Hz), dashed line: bandpass filtering(0.4~0.6Hz))

6 Overall Procedure of Proposed RR Detection

Fig. 4 shows the overall block diagram of the proposed algorithm to detect respirations using the input SpO_2 signal. Initially, the HR is obtained by calculating the autocorrelation contour. Because the HR reflects the circulation of blood, it can be used as a factor of the load of an exercise. In calculating the HR from the autocorrelation contour, the time between two adjacent peak points may be half or doubling frequently. So, median filtering as a post-processing is useful to reduce those kinds of errors.

In the frequency domain analysis by the FFT(Fast Fourier Transform), candidate RR elements are selected by the HR. Among the candidates, the most strong frequency element is recognized as the true RR. Subsequently, the estimated RR determines the passband of the BPF. Finally, the detection of respiration points is easily performed by finding local maxima after the bandpass filtering because the BPF blocks various artifacts including heart beats in the SpO_2 signal.

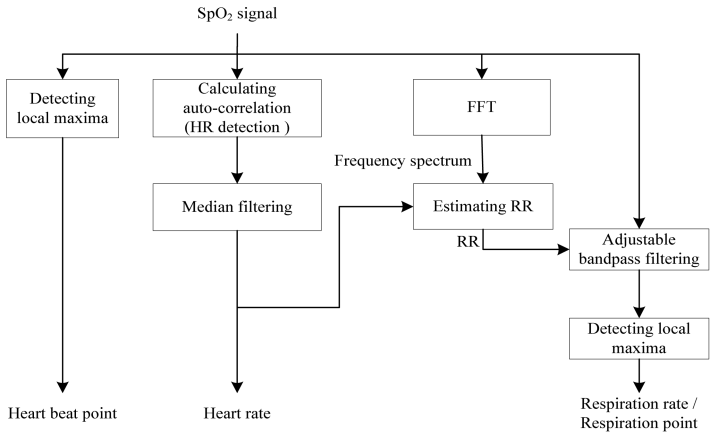


Fig. 4. Block diagram of proposed algorithm

7 Experiments and Results

The first experiment was designed for the evaluation of the proposed algorithm when general intensity was imposed to subjects during exercise. To evaluate the performance of the proposed algorithm, 50~150Watt was loaded to pedals of a bicycle-type exercise machine. Five men in the ages from 20's to 30's were tested. They were exercised for 5 minutes with the loads of 50, 100, and 150Watt on the machine. At the end of each session, a short break of 1~2 minute was served. During exercise, no artificial restriction was given to the subjects, that is, they were able to breathe freely.

When we record SpO_2 signals, the ECG impedance data was also recorded simultaneously to verify the result of the respiration detection. If the time difference between a detected respiration and its true respiration is larger than a wavelength of the latter, we declared an error. The sampling rate of the recorded date was 120Hz, and it was quantized by 10 bits.

The second experiment was designed to evaluate the performance when maximum intensity of exercises was imposed to the subjects. This experiment was aimed to verify the necessity of the broadband processing of the proposed algorithm. Three men in the ages of 20's were tested. Within the maximum load(150Watt) of the exercise machine, we tried to induce the maximum HR and RR.

Whole results of the experiments are arranged in Fig. 5 and 6. All error rates were calculated by Eq. (1).

$$\text{error rate}(\%) = \frac{z}{x} \times 100 \tag{1}$$

Where, x and z are the true and the detected RR, respectively. The true RR is obtained by the information of ECG impedance. The total average of the proposed algorithm and the conventional fixed BPF method shows respiration detection error of 20.32% and 196.40%, respectively. The conventional method detected false respiration points frequently as shown in its performance.

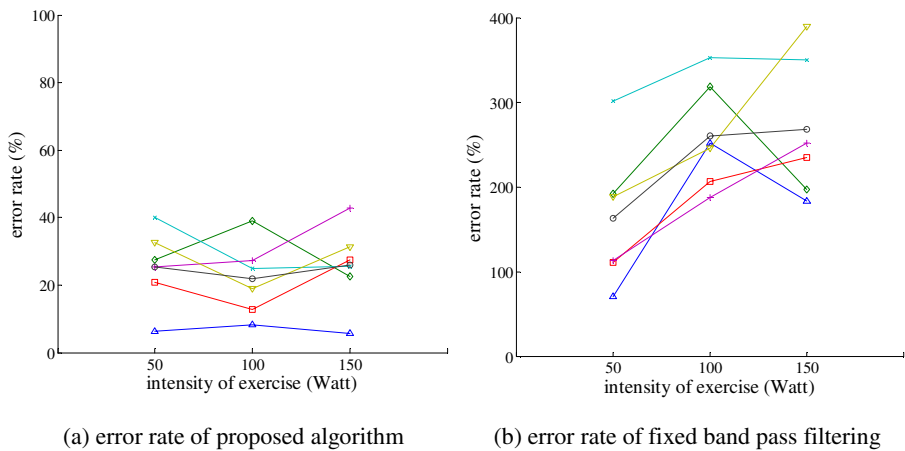


Fig. 5. Results of normal exercises(circled line: average of all subjects, the others: each subject)

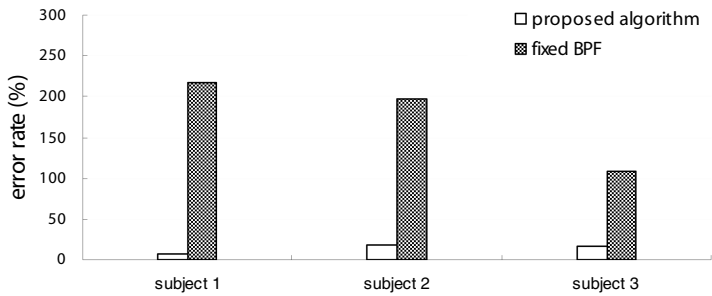


Fig. 6. Results of exercises loading maximum intensity

For the exercises imposing normal loads, the RR estimation errors were 25.40%, 21.84%, and 25.88% for the exercise loads of 50Watt, 100Watt, and 150Watt, respectively. The average error rate of the proposed algorithm was 24.37%. When the conventional fixed passband BPF method was utilized, the RR estimation errors were 162.67%, 260.20%, and 267.66% for each load. The average error rate of the conventional method was 230.17%.

For the exercises imposing maximum loads, the RR estimation errors were 14.10% and 174.43% for the proposed and the conventional method, respectively. The experimental results are summarized in Fig. 6.

8 Discussion

In order to verify the performance improvement by the proposed algorithm, the conventional bandpass filtering with a fixed passband and the adjustable bandpass filtering were evaluated in the respiration range of 0.1~1.4Hz. The proposed algorithm showed significantly better performances than the conventional method for various experiments. Moreover, it is more effective for the RR estimation in intensive exercise conditions than in relatively less intensive ones. This is because the internal respiration in bloods become more intensive as the load of an exercise is increased.

When the intensity of exercise is changed, the 100Watt load exercises show the highest error reduction. It means that, under a proper intensity of exercise, the magnitude of the respiration component in SpO₂ signals can be much stronger than that of artifacts. When the load of an exercise increases a certain threshold, subjects tend to increase the amount of breathing to obtain much oxygen rather than to increase the counts of respirations. It widens the difference between the actual external respiration and the respiration detection result from SpO₂ signals.

9 Conclusion

Through the experiments, it was shown that the proposed algorithm guarantees robust performances for various exercises. Although the performance may not be appropriate for medical monitors in hospitals, it is affordable for home exercise machines sufficiently. Our algorithm can be applicable to various embedded health care systems and contributes to the acceleration of the supply of them to users at their own home.

As a further work, it is important to investigate the relationship between the respiration and the condition of users in exercising. To do this, studies for the evaluation of exercise habits of individuals are essential. In addition to pulse oximetry, breathing or groan sound will be analyzed to evaluate exercise habits of users. This makes possible user-specific guidance to the adequate load of an exercise.

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Development of Electric Wheelchair with Operational Force Detecting Interface for Persons with Becker's Muscular Dystrophy

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Abstract. Even if some adjustment is provided, it is still harder for disabled people to use the joystick to operate the wheelchair although they can move their bodies. There is considerable difference in disabled characteristics among individuals. To deal with this difficulty, clarifying each person's characteristics and understanding one's individual characteristics are important issues for the proposal of their operation systems. This paper aims to propose the new operation interface, which generates no stress in operation, considering the physical characteristics among those who feel difficulty in operating with joystick. The subject for system validation is set to be a man who has Becker's muscular dystrophy as patient.

Keywords: Human Interface, Electric Wheelchair, Operation, Severely Disabled, Becker's Muscular Dystrophy.

1 Introduction

Nowadays, the number of the severely disabled has been increasing every year in Japan [1]. By providing a mobility device for them, their social activities can be still carried out to improve their QOL. An electric wheelchair is expected to be one of their mobility devices.

A severely disabled person is classified from the human interface for operating an electric wheelchair. Since the severely disabled are difficult to move the body, they need the realization of the input device by utilizing a sound, brain waves, etc [2][3][4][5]. The slight disabled use the joystick by adjusting reaction force, the available amount of operations, an attachment position, etc. to fit each individual's residual function. The disabled can use the joystick by using their upper limb and head to operate an electric wheel chair. However, even if the adjustment is provided, it is still harder for disabled persons to use the joystick to operate the wheelchair although they can move their bodies. Furthermore, there is considerable difference in disabled characteristics among individuals. To deal with this difficulty, clarifying each

person's characteristics and understanding one's individual characteristics are important issues for the proposal of their operation systems.

The plan of this research is based on the following two issues. The first issue is the clarification of the feature of the physical stress which the disabled feel in joystick operation, and the proposal of the input device considering the feature. The other issue, in order to reduce a stress of operation an electric wheelchair, concerns the proposal of a technique to stabilize the behavior of an electric wheelchair with respect to environmental disturbance, such as a slope and a level difference of a sidewalk.

This paper aims to propose the new operation device, which generates no stress in operation, considering the physical characteristics among those who feel difficulty in operating with joystick. The subject for system validation is set to be a man who has Becker's muscular dystrophy as patient. The experiment in this research was conducted under approval of Ethical Review Board of the National Rehabilitation Center for Persons with Disabilities in Japan.

2 Examination of Patient

We conducted the experiment to examine the feature of disabled at the clinic for the wheelchair and seating design currently performed in the National Rehabilitation Center with Disabled.

2.1 Condition of Becker's Muscular Dystrophy

The Becker type muscular dystrophy, as target in this research, is a kind of creeping palsy, muscular power, and muscular power may decline from proximal muscles, and it is categorized as sickness [6]. The patient load is estimated to be about 22000 people in Japan [1]. Since muscular power declines, it is mentioned that rise-and-fall operation on stairs becomes difficult, they cannot run and falls over easily in such condition etc. Therefore, in order to lead their independent life, it is effective to use an electric wheelchair [2]. As abovementioned, in order to develop the operation input device for a muscular dystrophy patient to operate an electric wheelchair, it is important that it can be operated with weak force.

2.2 Survey of Subject

The patient in this research is a university student, who has Becker's muscular dystrophy. Because he cannot run and walk by himself, he usually uses an electric wheel chair in daily lives.

In order to extract the requirement item of an input device, we interviewed the muscular dystrophy person concerning the dissatisfaction and problem about usage of the joy stick for operating an electric wheelchair. The representing replies are shown as follows:

1. He can write with a pen, and move a mouse of a PC.
2. When he continues grasping a pen, moving a mouse and operate the joystick, he cannot operate an electric wheel chair for a long time because his elbow becomes painful.

3. He becomes fatigue with operation of electric wheelchair with joystick only in 30 minutes even if he is in good physical condition. Therefore, he has almost no chance to operate it independently. His parents and friends help him to move in his life.
4. He has not been so fatigued while pushing buttons of a mouse. This means that such operations need only terminal muscle.
5. It is desirable to move his muscles in the viewpoint of keeping up his physical function when he is in good condition. The input device is ideal to be changed easily between a normal joystick and a low-fatigue input device.

As abovementioned, in order to reduce a stress for the person to move, it is necessary to develop a new operation input instead of joystick.

3 Development of Force Detecting Interface

3.1 Extraction of Requirement Items for Proposal an Interface

Based on the mentioned survey as shown in section 2, the requirement items for proposal an interface are shown as follows:

- It can be operated with small force from the viewpoint that the force of operation a joystick is lost when it is used continuously.
- It is possible to operate in small available range from the viewpoint that the vicinity of elbow becomes painful when it is used for a long time.
- From the viewpoint of maintaining a residual function effectively, it is an interface using the physical terminal function (finger) moderately.

3.2 Physical Characteristics for Proposal of an Interface

We also examined patient's terminal function characteristics. We measured his maximum button-pushing force of fingers when he didn't feel fatigued. The person could exert about 2N, which is 1/7 of the button-pushing force in the case of general person as shown in Figure1. This result indicates that the pushing force of interface should be designed to be less than 2N for the person.

3.3 Proposal an Interface Considering Physical Characteristics

The electric wheelchair is controlled based on displacement of a joystick, and, generally the maximum displacement of a joystick is about 3 - 6cm in all directions. An input device with small displacement is needed because of people cannot operate a joystick satisfactorily. In order to make operation displacement become zero, we focused on the force detecting interface. Unlike the displacement-input method of joystick, the force detecting method realized an interface which does not input displacement at all ideally. Therefore, the person A of muscular dystrophy can operate it without a physical stress by using a force detecting method.

To realize these points, the device is considered a force-detection interface like button shape without long operating distance. A force-detection interface is able to be operated with small force input when the sensitivity of output with respect to input was higher. However, it is hard to switch the situation of operation quickly when the sensitivity is high. It is easy to operate the switching device in on or off condition quickly. The switching device is not possible to be controlled precisely. Therefore we propose a new interface which is combined their effective functions. The shape is imitated with a mouse of PC, from the questionnaire survey. Because it is hard for the person to hold on the joystick, his palm can put on device like the mouse shape, which is called on the palm-rest as shown in Figure2. This aims to support getting the swing of person's body.

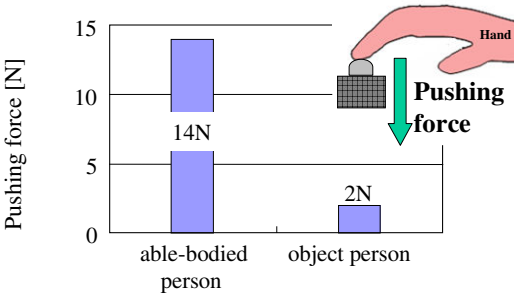


Fig. 1. Forces of able-bodied person and object person

3.4 Correspondence Between an Operation Method of Force Detecting Interface and an Electrical Wheelchair Behavior

Figure 2 shows the operation method of force detecting interface. In order to operate an electric wheelchair, the input system for operating eight degree of freedom is need as shown in Figure2(a). The interface is designed to be 3-button interface, which consists of a switching function and a force detecting function, to realize 8 degrees. As a function of the interface, when the button of middle is pushed, an electric wheelchair runs at straightly. When the left (right) button is pushed, an electric wheelchair performs the left (right) rotation on the spot. Moreover, when a center button and the left (right) button are pushed simultaneously, an electric wheelchair turns left (right) and when three buttons are pushed, the wheelchair goes reverse.

The button consists of a switching sensor, which judges whether the button was pushed or not, and a force detecting sensor to measure the pushing force. In addition, the velocity of wheelchair can be controlled with respect to the button-pushing force. From this function, when the left button and the right button were pushed simultaneously, it is set to run reverse, while bending to the direction of large force by compared with left and right force.

As abovementioned, it becomes feasible to operate an electric wheel chair with the proposed input device which consists of three force sensors and button switches. Figure 3 shows the prototype of electric wheelchair with force detecting interface.

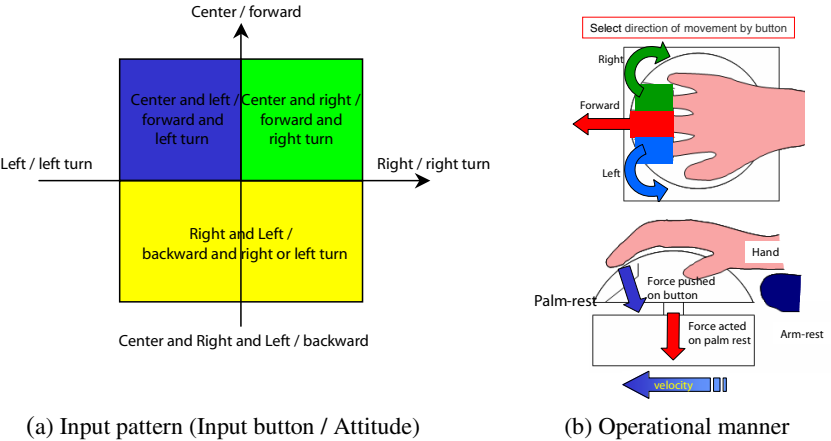


Fig. 2. Operational manner of Operational Force Detecting Interface



Fig. 3. Description of electric wheelchair with force detecting interface

3.5 Problem of a Force Detecting Interface

Force input method generally tends to be directly influenced with respect to disturbance. The force detecting interface proposed in this paper may cause an operation mistake to the influence of vertical vibration while running on sidewalk too. Therefore, in order to operate an electric wheelchair stably, vertical vibration needs to judge the influence which it has on an operation input, and needs to propose the method of removing its influence on running stability.

4 Disturbance Rejection Method for Extracting an Operation Intention

4.1 Extraction of Disturbance for Stable Operating

The force detecting interface is sensitive to unintended input to electric wheelchair under the influence of the running environment such as bump and slope and the caster behavior etc. The level difference is considered to influence both operation and behavior of an electric wheelchair and a level difference is directly considered as "disturbance given to an operator."

A caster is a front wheel of an electric wheelchair and the direction of movement of an electric wheelchair is determined by the caster angle as the feature of an electric wheelchair. When an intention of an operator and a caster's angle do not agree each other, the behavior of an electric wheelchair is considered to be disturbance to an intention of operator. Therefore, a caster's behavior is indirectly considered as "disturbance given to an operator" through the behavior of an electric wheelchair.

A slope changes the balance of force which works at the center of gravity of an electric wheelchair. It is considered as disturbance for an electric wheelchair to move. Therefore, a slope is indirectly considered as "disturbance given to an operator" through the behavior of an electric wheelchair.

4.2 Proposal of Disturbance Rejection Method While Operating

To examine an influence of operator's intention against disturbance, we conducted the experiment using an electric wheelchair running on the road including shock or vibration.

We propose an intention extraction system using experimental results. Based on the measured palm-rest force as shown in Figure2, the system judges whether there is operator's intention input or not. The method is simple as applying the low pass filter with respect to the detected force of button. The cutoff frequency is proportionally varied with respect to force deviation from palm weight. In order to propose this method, it is necessary to determine the following information.

1. Distinguishing between an operation intention of an operator and the influence of disturbance.
2. Determining the cutoff frequency with respect to the information input into the operation device.

Without influence of disturbance, the force measured on a palm rest is considered as a constant value in which an operator holds on an interface. Then, definite-period-of-time measurement of the power concerning a palm rest was carried out, and the average value was set as a threshold value.

Moreover, the force concerning the palm rest with respect to an operation input is a constant value without fluctuation. From such a relation, an intention of operator is considered as a value near the threshold value, and a component influenced by disturbance is a fluctuation from the threshold value.

In order to determine the cutoff frequency, we conducted the experiments which the device is influenced by the vertical vibration such as a bump, a step and a step. As

an experimental condition, an operator made an electric wheelchair go straight by pushing a button by fixed power on various roads. Based on the obtained running data, the optimal cutoff frequency was drawn to reject the influence of disturbance. However, because of the cutoff frequency depends on two parameters, which are near the threshold and the fluctuation from a threshold, as shown in Figure4. Therefore, between their parameters, it becomes discontinuous situation. As a result, a switching situation of cutoff frequency occurs and it worsens maneuverability. Therefore, the cutoff frequency is considered as the linear function with respect to the force acting on the palm rest. If the force acting on a palm rest is below the threshold value, the proposed system can recognize the intention of an operator as shown in Figure4. Therefore, the cutoff frequency is changed in proportion to the fluctuation from the threshold, and when the fluctuation from a threshold is large, it is judged that it was influenced by disturbance.

The effectiveness of the proposed system is investigated in the case of actual road such as bump, slope and studded paving block. Figure5 shows the effectiveness of the proposed disturbance rejection system at bump situation at 2km/h. Although the forced pushing button is influenced by disturbance at 7sec., the force can be satisfactorily removed the influence from disturbance with the proposed system.

Moreover, the intention of an operator is confirmed as operation input removes disturbance from 3 sec. to 6 sec.

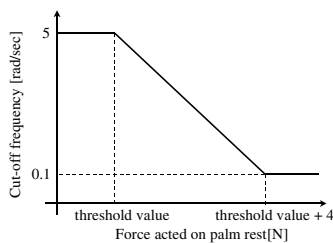


Fig. 4. Cutoff frequency

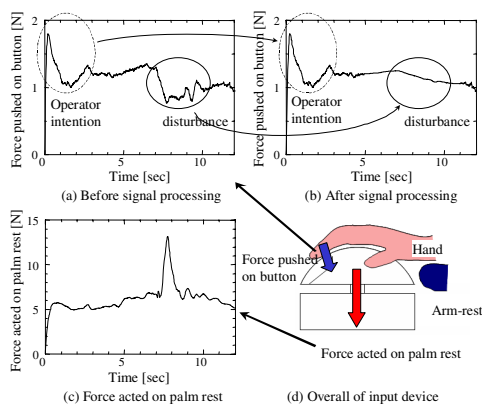


Fig. 5. Effectiveness of the proposed disturbance rejection system at bump situation at 2km/h

As mentioned above, the validity of the disturbance rejection method for extracting the proposed operation intention has been confirmed in the case of actual road such as bump, slope and studded paving block.

5 Evaluation of Force Detecting Interface

Two muscular dystrophy persons are employed to examine the validity of the proposed force detecting interface. Concretely, when the persons operated an electric

wheelchair using proposed force detecting interface, by comparing with the conventional joy stick, we examined the validity of a force detecting interface and grasp the problem in the present condition. For securing experimental safety, the persons operated freely within the enclosure of the National Rehabilitation Center for Persons with Disabilities. We made an interview to each person in the end of experiment.

5.1 Evaluation Results

Patient A: Fundamental operation of going straight, a right and left turn, etc. was possible. An affirmative opinion is obtained as follows: he can operate with weak force, easy use without operational stress. Moreover, he was able to input the force of 0.5N as same as the time of an operation start after 30 minutes. This means that a degradation of the force accompanying the passing time cannot be noticed. This is an epoch-making effect. As a negative opinion, operation size is too large and it is hard to input force for him.

Patient B: Fundamental operation of going straight, a right and left turn, etc. was possible. Comparison with joystick, he evaluated the system that it is not easy to use as expected, from the viewpoint of maneuverability and stress. When the person inputs force to the interface, his modifications of between second and third finger become larger than patient A as shown in Figure6. As a factor, the forms of the person's hand and fingers do not suit the shape of interface and the position of button. Moreover, as an operation function, when the third finger was used, the system is evaluated that it becomes hard to use.

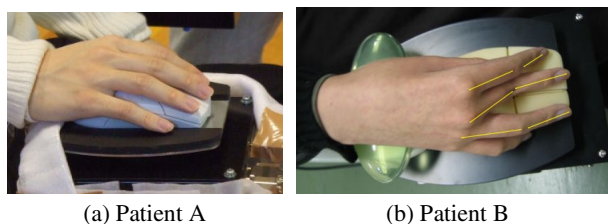


Fig. 6. Difference of hand modifications between patient A and patient B

5.2 Evaluation of Patient B's Finger Function, and a New Input Device

In order to evaluate the performance of the finger, which used for force detecting interface, based on a quantitative index, we conducted the experiment as a subject of patient B. We measured three evaluation indices such as the maximum force, reaction time and target following capability against each finger. However, the little finger is not measured.

Figure7 summarizes the evaluation results using the index in the case of each finger. As this result, the thumb is a good performance in the target follow capability although the maximum force of thumb is smaller as compared with the third finger. Moreover, most differences among each finger cannot be noticed in the case of reaction time.

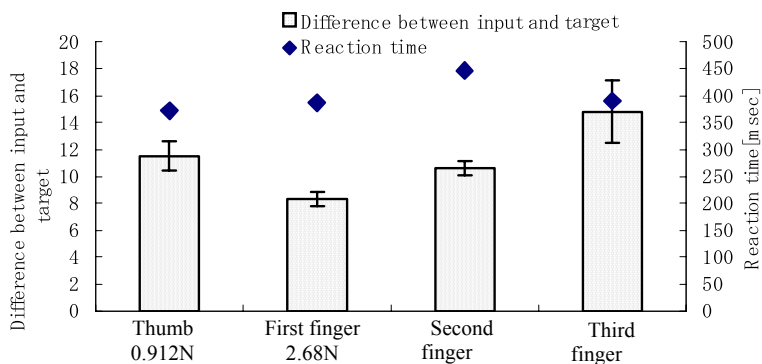


Fig. 7. Result of finger performance measurement

From the above consideration, the new force detecting interface which operated a button by the thumb, the first, and the second finger is proposed not using the third finger as shown in Figure 8. Moreover, as substitution of the function to push three buttons at the time of reverse, the second joint of thumb was proposed to use with weak force. At the time of forward running, the operator pushed the button by the first joint of the thumb with weak force.

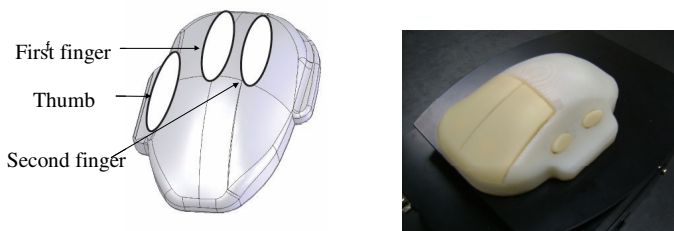


Fig. 8. Sketch of newly proposed interface

6 Conclusions

This paper proposed an operation interface for a muscular dystrophy patient as severely disabled based on the analysis of the physical characteristics from the observation of actual operation of an electrical wheelchair.

1. The new idea of button type force detecting interface for a muscular dystrophy person was proposed: the interface is realized for operating an electrical wheelchair with weak force.
2. The disturbance rejection system was proposed to recognize the operation intention while operating automatically without physical stress.
3. The effect on enhancing the maneuverability of muscular dystrophy patient while operating, in order to relief the physical stress was proved by experiments using the electric wheelchair with the proposed interface.

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How Users with RSI Review the Usability of Notebook Input Devices

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Abstract. Musculoskeletal problems are increasingly occurring and are predominately attributed to a frequent and highly repetitive use of input devices. Earlier studies [e.g. 1, 2, 3] showed that the exposure to input devices cause health risks. Even young and healthy users reported severe discomfort in finger and hand after executing cursor control tasks over 2-4 hours. For motion-impaired users also a distinct increase of discomfort was observed, but combined with longer work and rest periods compared to healthy users [4]. The present survey aims at RSI-impaired users. Three RSI-case studies were reported. Compared to healthy users RSI-impaired users were distinctly more sensitive towards exposure [cp. 3]. It can be concluded that RSI-impaired computer users limit the usefulness of notebook input devices as found for keyboard and mouse [4]. They face great barriers in terms of effort and highly rely on low demanding, low repetitive input tasks, and on adequate rest periods.

Keywords: RSI, Musculoskeletal Discomfort, Exposure, Notebook Input Device.

1 Introduction

Musculoskeletal problems are increasingly occurring and are predominately attributed to a frequent and highly repetitive use of input devices. Earlier studies [e.g. 1, 2, 3] showed that the exposure to input devices cause health risks. Even for young and healthy users [2, 3] severe discomfort in finger and hand was observed, with a significant increase of discomfort by 20-27% after executing cursor control tasks over 2-4 hours. However, input performance remained unaffected. Trewin and Pain [4] reported also a distinct increase of discomfort for motion-impaired users operating keyboard and mouse compared to healthy users. But at the same time a raise of work and rest periods was observed: Working periods were 2-3 times prolonged as for healthy users and errors occurred 8 times more often. For touchpad and trackpoint similar results were found [3]: For an RSI-patient (RSI = Repetitive Strain Injury) discomfort was concentrated on the right forearm, hand and fingers and symptoms rose by 40%. Input performance collapsed over the exposure and was by 16% slower compared to healthy users.

The present survey aims at users suffering from RSI. The case studies reported deals with three computer users, who fell ill with tenosynovitis or cervical spine syndrome due to manual overuse and uncomfortable posture. Their jobs all highly depend on computer-based tasks. Thus, in spite of severe symptoms they all operate keyboard and mouse on a daily basis. As an alternative to these input devices this study will address the usability of notebook input devices for RSI-patients. Discomfort and input performance of motion-impaired users will be compared to the benchmark of young and healthy users [cp. 3]. The results provide an insight into the needs and barriers motion-impaired computer users have to face and will guide towards an adaptive hard- and software design.

2 Method

2.1 Variables

The *independent variable* was time on task with three measuring times: before the exposure (pre-test), after a 1st exposure with the touchpad (mid-test) and after a 2nd exposure with the trackpoint (post-test).

As *dependent variables* muscular discomfort and total time of task execution were assessed. The discomfort was estimated with the ISS [2]. This questionnaire specifically focuses on body parts that are involved in input device operation, i.e. fingers, hand, forearm, upper arm and shoulder separately for each body side as well as back and neck. For each body part discomfort was assessed by three verbal categories first: “relaxed”, “tense” or “impaired”. Second, the extent of discomfort was estimated on a 50-point category partitioning scale (= CPS-score). The CPS-score was single-weighted for “tense”-judgments and double-weighted for “impaired”-judgments. Each weighted discomfort score may range between 0 and 100 points. Body parts that were reported to be “relaxed” were not further considered. The performance of input device was measured by total time of task execution This is the time interval from pressing the space bar to releasing the mouse button at the end of the task.

2.2 Apparatus and Task

For the experiments the notebooks Toshiba Satellite 1700-300 with an integrated trackpoint and Dell Inspiron 7500 with an integrated touchpad as input device were used. The trackpoint is a small force-sensitive joystick. It is placed between the “G”, “H” and “B” keys on the keyboard, the mouse buttons are located in the wrist rest. The touchpad is a flat touch-sensitive panel (2” by 1.5”). It is integrated in the wrist rest beneath the keyboard with two mouse buttons underneath. For both notebooks the cursor velocity of the integrated input device was set at 1500 p/s [5]. To control the visual quality of display presentation each notebook was connected to an external TFT flat screen (Philips 150x; 1024x768).

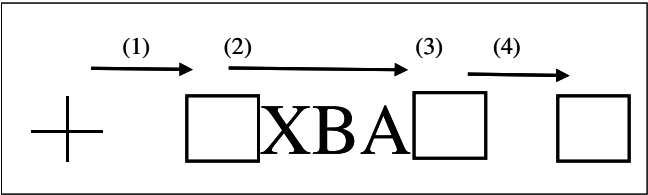


Fig. 1. Point-drag-drop task with clicking subtasks (1 & 3) and dragging subtasks (2 & 4)

The point-drag-drop task (Figure 1) represents a complex serial task and consists of several single actions that are executed one after another. Each trial gets started with the space bar. The task appears 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 (for further task features see [5]).

2.3 Participants

All participants were highly experienced with the mouse and neither of them had any experience with touchpad or trackpoint. The cases investigated suffer all from diseases appertaining to RSI: Case 1 (37 years of age, female) and Case 2 (30 years, female) are chronically impaired by tenosynovitis. Case 3 (32 years, female) suffers from a chronic cervical spine syndrome. The reference sample [cp. 3] consisted of 14 women and 7 men, aged between 16 and 42 years (m = 24; sd = 6.0 years). They were under- and graduate students who fulfilled a course requirement. All participants in the reference sample were in a very good physical shape and reported to have no ex ante muscular discomfort.

2.4 Procedure and Data Analysis

An interview provided demographic data, ex ante muscular discomfort and habits in computer usage. All cases were exposed to two conditions: (1) touchpad operation, (2) trackpoint operation. Participants were instructed to execute the input task as fast and accurate as possible. They were further instructed to operate the input device itself with the dominant hand and the mouse button with the non-dominant hand. Muscular discomfort was measured before the exposure (pre-test), at the end of the 1st condition (mid-test) and at the end of the 2nd condition (post-test). Within each condition Case 1 executed 256 trials of the point-drag-drop task. Case 1 aborted the 2nd condition after 60 trials due to severe pain. Thus, for the following two cases the exposure was decreased to 160 trials per condition. For Case 3 a record failure left only 60 trials of the 1st condition. For reference [3] 10 healthy touchpad users and 11 healthy trackpoint users executed 800 trials of the point-drag-drop task. The procedure included the interview, and a pre- and post-test of discomfort comparable to the cases. Since there were no differences found between muscular discomfort of healthy touchpad and trackpoint users average discomfort scores are used for reference to the cases.

3 Results

First, absolute and relative overall body discomfort scores are reported for the pre-, mid- and post-test. Second, the relative increase of each single body score is analyzed for the 1st exposure (pre-mid-test increase) and the overall exposure (pre-post-test increase). For comparisons between cases and healthy subjects data was analyzed by t-tests. The level of significance was set at 5 %.

3.1 Case Report 1

The participant is a 37 years old female and works as a self-employed occupational therapist. In 1990 a tenosynovitis was diagnosed. The disease involved inflammation of the tendon and tendon sheath of her right hand in consequence of manual overuse. Since conservative management had failed a surgical incision was undertaken. The surgical therapy had been successful and pain subsided for a short time. But, whenever manual activities were repetitively executed the disease chronically appears with severe pain in the right hand. She is completely unable to use a mouse or touchpad over a longer period of time and therefore limited her computer use strictly to half an hour per day only. She complains about numbness in the right thumb, and pain in wrist and lower arm during (begin after 30 minutes of work) and after operating an input device. Symptoms are most significant for tasks that require wrist extension (e.g. typing, browsing the WWW). With the completion of computer work pain alleviates slowly and it takes 24 hours until the participant is free of symptoms. Once a year the participant is seeing a doctor but without any medical treatment. Thus, her health condition was unchanged during the last years.

Overall discomfort: The participant reported to have major musculoskeletal symptoms in neck and back as well as the upper extremities. In comparison to the ex ante muscular discomfort of the reference sample her pre-existing symptoms have obviously increased. Considering the muscular discomfort the overall body discomfort score rose from 38 points (pre-test) to 224 points (mid-test = after 1st condition) and to 526 points (post-test = after 2nd condition). The body discomfort scores for Case 1 did not differ from the reference sample in the pre- (38 vs. 43 points, n.s.) and mid-test (224 vs. 197 points, n.s.), but were significantly higher in the post-test (526 vs. 197 points, $T_{(20)} = -14.3$, $p < 0.01$). In the 1st condition (pre-mid-test increase) the increase of discomfort is comparable to that of healthy users ($\Delta 186$ vs. $\Delta 154$ points, n.s.). However, in the 2nd condition discomfort rose further, the overall increase (pre-post-test increase) was significantly higher compared to healthy users ($\Delta 488$ vs. $\Delta 154$ points, $T_{(20)} = -17.2$, $p < 0.01$).

Specific body parts: The single discomfort scores are visualized in Figure 2 for the pre-test (solid line), mid-test (dashed line, circle) and post-test (dashed line, square) and the reference sample (dashed line only).

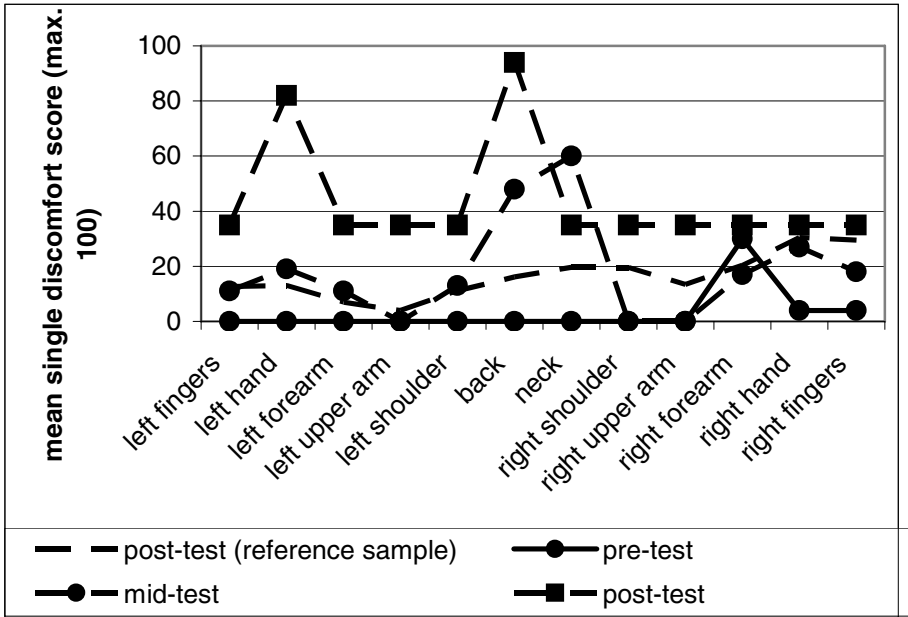


Fig. 2. Mean single discomfort score for pre-test (solid line), mid-test (dashed line, circle) and post-test (dashed line, square) and the reference sample (dashed line only)

After the 1st exposure (pre-mid-test increase) the increase of symptoms for neck and back was distinctly stronger compared to healthy users (neck: $\Delta 60$ vs. $\Delta 21$ points, $T_{(20)} = -7.0$, $p < 0.01$; back: $\Delta 48$ vs. $\Delta 8$ points, $T_{(20)} = -9.9$, $p < 0.01$). The increase of discomfort was comparatively low in the left side's shoulder ($\Delta 13$ vs. $\Delta 15$ points, n.s.), forearm ($\Delta 11$ vs. $\Delta 18$ points, n.s.) and hand ($\Delta 19$ vs. $\Delta 23$ points, n.s.). For the right upper extremity Case 1 reported less discomfort compared to healthy users (right shoulder: $\Delta 0$ vs. $\Delta 20$ points, $T_{(20)} = 4.2$, $p < 0.01$; right upper arm: $\Delta 0$ vs. $\Delta 17$ points, $T_{(20)} = 3.1$, $p < 0.01$; forearm: $\Delta -13$ vs. $\Delta 33$ points, $T_{(20)} = 7.2$, $p < 0.01$; right hand: $\Delta 23$ vs. $\Delta 40$ points, $T_{(20)} = 2.8$, $p < 0.01$; right fingers: $\Delta 14$ vs. $\Delta 45$ points, $T_{(20)} = 6.2$, $p < 0.01$). Also for the left upper arm ($\Delta 0$ vs. $\Delta 7$ points, $T_{(20)} = 2.4$, $p < 0.05$) and fingers ($\Delta 11$ vs. $\Delta 25$ points, $T_{(20)} = 2.2$, $p < 0.05$) discomfort rose significantly less compared to the reference sample. The 2nd exposure (pre-post-test increase) revealed overall a significant higher increase of symptoms for Case 1 compared to healthy users for the neck ($\Delta 35$ vs. $\Delta 21$ points, $T_{(20)} = -2.5$, $p < 0.05$), back ($\Delta 94$ vs. $\Delta 8$ points, $T_{(20)} = -21.3$, $p < 0.01$), shoulder (right: $\Delta 35$ vs. $\Delta 20$ points, $T_{(20)} = -3.0$, $p < 0.01$; left: $\Delta 35$ vs. $\Delta 15$ points, $T_{(20)} = -5.3$, $p < 0.01$), upper arm (right: $\Delta 35$ vs. $\Delta 17$ points, $T_{(20)} = -3.4$, $p < 0.01$; left: $\Delta 35$ vs. $\Delta 7$ points, $T_{(20)} = -9.8$, $p < 0.01$), left forearm ($\Delta 35$ vs. $\Delta 18$ points, $T_{(20)} = -4.1$, $p < 0.01$) and left hand ($\Delta 82$ vs. $\Delta 23$ points, $T_{(20)} = -10.1$, $p < 0.01$). Overall increase of discomfort was comparable to the reference sample for the right hand ($\Delta 31$ vs. $\Delta 40$ points, n.s.) and left fingers ($\Delta 35$ vs. $\Delta 25$ points, n.s.), and was lower for the right forearm ($\Delta 5$ vs. Δ

33 points, $T_{(20)} = 4.4$, $p < 0.01$) and right fingers (Δ 31 vs. Δ 45 points, $T_{(20)} = 2.8$, $p < 0.05$). For both, Case 1 and the healthy users, discomfort concentrated on the distal upper extremities, i.e. fingers, hand and forearm. However, Case 1 reported up to 2.6 times stronger symptoms compared to healthy users.

With respect to the performance of input device the total time dropped enormously, by 419 ms, during the 1st condition (= touchpad, 32 trials: 6874 ms to 256 trials: 6455 ms). This improvement came from an unspecific learning effect. In the 2nd condition the case was not able to continue the experiment after 64 trials due to severe pain in the distal upper extremities and the back. The performance of the trackpoint was very bad (32 trials: 24020 ms to 64 trials: 16932 ms), however, performance still improved during that short period by 7088 ms. When input device performance was compared to the reference sample Case 1 was about 800 ms slower with the touchpad (6417 vs. 5610 ms, $T_{(9)} = 3.6$, $p < 0.01$). But, in the 2nd condition performance difference enhanced and trackpoint performance was even worse for Case 1 (19510 vs. 6396 ms, $T_{(9)} = 55.4$, $p < 0.01$).

3.2 Case Report 2

The participant is a 30 years old female and a white-collar employee in the service sector. She operates a computer up to 8 hours a day. In 1993 a tenosynovitis was diagnosed. The disease involved inflammation of the tendon and tendon sheath of her right hand in consequence of manual overuse. The conservative management was so far successful and the case is free of symptoms as long as she restricts her computer use to less than 5 hours a day. She complains about pain and numbness in the wrist, hand and fingers of her right body side after 5 hours of computer and input device work. Symptoms are most significant for tasks that require wrist extension (e.g. browsing the WWW) and clicking actions (e.g. editing graphics). With the completion of computer work pain resolves slowly and disappears completely after 1 to 24 hours.

Overall discomfort: Case 2 reported to have major musculoskeletal symptoms in her neck and right hand and fingers. In comparison to the ex ante muscular discomfort of the reference sample her pre-existing symptoms are obviously higher. Considering the muscular discomfort the body discomfort score was constantly very low, about 34 points (pre-test), 32 points (mid-test) and 36 points (post-test). Only in the pre-test the body discomfort score of Case 2 did not differ from the reference sample (34 vs. 43 points, n.s.), in the mid-test (32 vs. 197 points, $T_{(20)} = 7.1$, $p < 0.01$) and in the post-test (36 vs. 197 points, $T_{(20)} = 7.0$, $p < 0.01$) overall scores of Case 2 were significantly lower. In the 1st and 2nd condition the increase of discomfort is below that of healthy users (Δ -2 vs. Δ 154 points, $T_{(20)} = 8.0$, $p < 0.01$; Δ 4 vs. Δ 154 points, $T_{(20)} = 7.7$, $p < 0.01$).

Specific body parts: The single discomfort scores are visualized in Figure 3 for pre-test (solid line), mid-test (dashed line, circle), post-test (dashed line, square) and the reference sample (dashed line only). After the 1st exposure the increase of symptoms for the back were comparably low to healthy users (Δ 0 vs. Δ 8 points, n.s.). For all other body parts Case 2 reported a significant lower increase of discomfort as for

healthy users: neck ($\Delta -7$ vs. $\Delta 21$ points, $T_{(20)} = 4.9$, $p < 0.01$), shoulder (right: $\Delta 0$ vs. $\Delta 20$ points, $T_{(20)} = 4.2$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 15$ points, $T_{(20)} = 3.8$, $p < 0.01$), upper arm (right: $\Delta 0$ vs. $\Delta 17$ points, $T_{(20)} = 3.1$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 7$ points, $T_{(20)} = 2.4$, $p < 0.05$), forearm (right: $\Delta 5$ vs. $\Delta 33$ points, $T_{(20)} = 4.4$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 18$ points, $T_{(20)} = 4.3$, $p < 0.01$), hand (right: $\Delta 0$ vs. $\Delta 40$ points, $T_{(20)} = 6.7$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 23$ points, $T_{(20)} = 4.0$, $p < 0.01$), fingers (right: $\Delta 0$ vs. $\Delta 45$ points, $T_{(20)} = 9.1$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 25$ points, $T_{(20)} = 4.0$, $p < 0.01$).

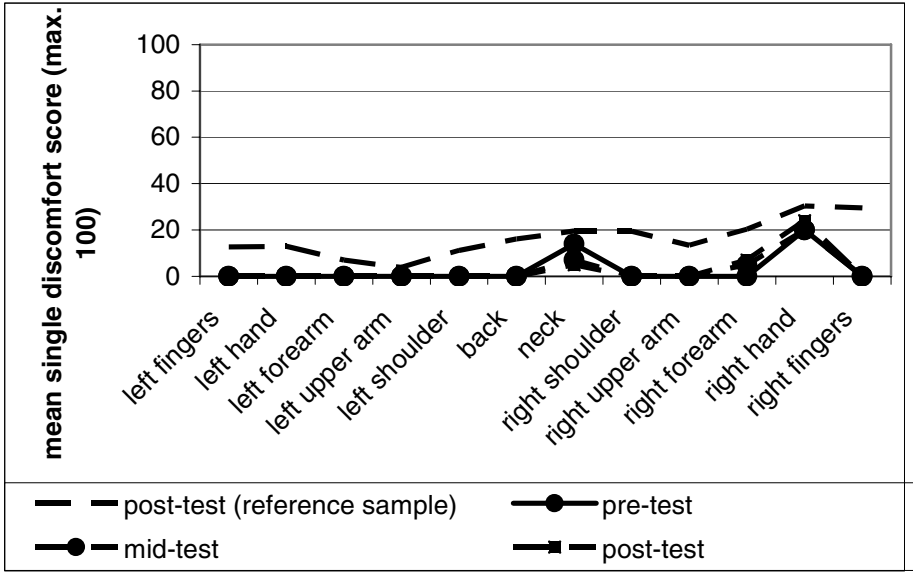


Fig. 3. Mean single discomfort score for pre-test (solid line), mid-test (dashed line, circle) and post-test (dashed line, square) and the reference sample (dashed line only)

The 2nd exposure revealed the same pattern of discomfort. Comparing pre- and post-test measurements Case 2 reported a comparable increase of symptoms to healthy users for the back ($\Delta 0$ vs. $\Delta 8$ points, n.s.). But, all in all Case 2 reported nearly no increase of symptoms at all, thus the increase of symptoms was significantly below that reported by healthy users: neck ($\Delta -9$ vs. $\Delta 21$ points, $T_{(20)} = 5.3$, $p < 0.01$), shoulder (right: $\Delta 0$ vs. $\Delta 20$ points, $T_{(20)} = 4.2$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 15$ points, $T_{(20)} = 3.8$, $p < 0.01$), upper arm (right: $\Delta 0$ vs. $\Delta 17$ points, $T_{(20)} = 3.1$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 7$ points, $T_{(20)} = 2.4$, $p < 0.05$), forearm (right: $\Delta 7$ vs. $\Delta 33$ points, $T_{(20)} = 4.1$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 18$ points, $T_{(20)} = 4.3$, $p < 0.01$), hand (right: $\Delta 4$ vs. $\Delta 40$ points, $T_{(20)} = 6.0$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 23$ points, $T_{(20)} = 4.0$, $p < 0.01$), fingers (right: $\Delta 0$ vs. $\Delta 45$ points, $T_{(20)} = 9.1$, $p < 0.01$; left: $\Delta 0$ vs. $\Delta 25$ points, $T_{(20)} = 4.0$, $p < 0.01$). Case 2 reported to have very light symptoms due to the exposure, and discomfort was for nearly all body parts lower compared to healthy users.

With respect to the touchpad performance the total time was very high and increased over time on task by 1551 ms (32 trials: 13112 ms to 160 trials: 14663 ms).

The performance of the trackpoint was very bad (32 trials: 22858 ms to 160 trials: 18572 ms), however, performance still increased over time by 4286 ms. This improvement came from an unspecific learning effect for the trackpoint. When input device performance was compared to healthy participants, Case 2 was about 8495 ms slower with the touchpad (14338 vs. 5843 ms, $T_{(9)} = -38.5$, $p < 0.01$). But with the trackpoint performance was getting worse for Case 2 (19782 ms) and performance difference between Case 2 and healthy users was even bigger (Δ 13126 ms: 19782 vs. 6656 ms, $T_{(9)} = -52.5$, $p < 0.01$).

3.3 Case Report 3

The participant is a 32 years old female and a white-collar employee in the administrative department. She operates a computer up to 4 hours a day. In 1998 a cervical spine syndrome was diagnosed. The disease involved pain in the neck that radiated to the left shoulder and upper arm. In the fingers of her left hand she felt prickling sensations and in the longer term numbness. Symptoms appeared in consequence of restricted posture at the visual display unit. The conservative management (duration 7 months) had been successful and pain subsided for a short time. But, whenever she works more than 1 hour at the computer the symptoms chronically appear with severe pain in the neck and left side's upper extremities. Symptoms are most significant for extensive display tasks (e.g. text reading or editing). With the completion of computer work pain alleviates slowly and it takes 24 to 48 hours until the participant is free of symptoms.

Overall discomfort: The participant reported to have major musculoskeletal symptoms in neck and back as well as the left side's proximal upper extremities. In comparison to the ex ante muscular discomfort of the reference sample her pre-existing symptoms are obviously more serious. Considering the muscular discomfort the body discomfort score rose from 95 points (pre-test) to 275 points (mid-test) and to 457 points (post-test). The body discomfort scores of Case 3 were significantly higher compared to the reference sample in the pre- (95 vs. 43 points, $T_{(20)} = -3.5$, $p < 0.01$), mid-test (275 vs. 197 points, $T_{(20)} = -3.3$, $p < 0.01$) and post-test (457 vs. 197 points, $T_{(20)} = -11.3$, $p < 0.01$). However, in the 1st condition the increase of discomfort is comparable to that of healthy users (Δ 180 vs. Δ 154 points; n.s.). But in the 2nd condition discomfort rose further, the overall increase was significantly higher compared to healthy users (Δ 362 vs. Δ 154 points; $T_{(20)} = -10.7$, $p < 0.01$).

Specific body parts: The single discomfort scores are visualized in Figure 4 for pre-test (solid line), mid-test (dashed line, circle) and post-test (dashed line, square) and the reference sample (dashed line only). After the 1st exposure the increase of symptoms for the left side's shoulder and upper arm was distinctly stronger compared to healthy users (left shoulder: Δ 70 vs. Δ 15 points, $T_{(20)} = -14.6$, $p < 0.01$; left upper arm: Δ 33 vs. Δ 7 points, $T_{(20)} = -9.1$, $p < 0.01$). For all other body parts the increase of symptoms was lower or comparable to the reference sample: back (Δ 8 vs. Δ 8 points, n.s.), neck (Δ 19 vs. Δ 21 points, n.s.), shoulder (right: Δ 11 vs. Δ 20 points, n.s.), upper arm (right: Δ -17 vs. Δ 17 points, $T_{(20)} = 6.2$, $p < 0.01$), forearm (right: Δ 32 vs. Δ 33 points, n.s.; left: Δ 0 vs. Δ 18 points, $T_{(20)} = 4.3$, $p < 0.01$), hand (right: Δ 9 vs. Δ 40 points, $T_{(20)} = 5.2$, $p < 0.01$; left: Δ 0 vs. Δ 23 points, $T_{(20)} = 4.0$, $p < 0.01$) and

fingers (right: Δ 15 vs. Δ 45 points, $T_{(20)} = 6.0$, $p < 0.01$; left: Δ 0 vs. Δ 25 points, $T_{(20)} = 4.0$, $p < 0.01$). The increase of symptoms after both exposures was distinctly higher for Case 3 compared to healthy users for the left body side and the neck: neck (Δ 34 vs. Δ 21 points, $T_{(20)} = -2.3$, $p < 0.05$), shoulder (left: Δ 64 vs. Δ 15 points, $T_{(20)} = -13.0$, $p < 0.01$), upper arm (left: Δ 25 vs. Δ 7 points, $T_{(20)} = -6.3$, $p < 0.01$), forearm (left: Δ 30 vs. Δ 18 points, $T_{(20)} = -2.8$, $p < 0.01$), hand (left: Δ 40 vs. Δ 23 points, $T_{(20)} = -2.8$, $p < 0.01$), fingers (left: Δ 40 vs. Δ 25 points, $T_{(20)} = -2.3$, $p < 0.05$). Discomfort increased comparable to that reported by healthy participants in the back (Δ 6 vs. Δ 8 points, n.s.) and the right body side: shoulder (right: Δ 21 vs. Δ 20 points, n.s.), upper arm (right: Δ 8 vs. Δ 17 points, n.s.), forearm (right: Δ 30 vs. Δ 33 points, n.s.), hand (right: Δ 29 vs. Δ 40 points, n.s.) and fingers (right: Δ 35 vs. Δ 45 points, n.s.). For Case 3 symptoms increased severely in the left body side and the back. Additionally for the right body side Case 3 showed the same pattern of discomfort as healthy participants. However, symptoms of Case 3 were up to 2.3 times stronger compared to healthy users.

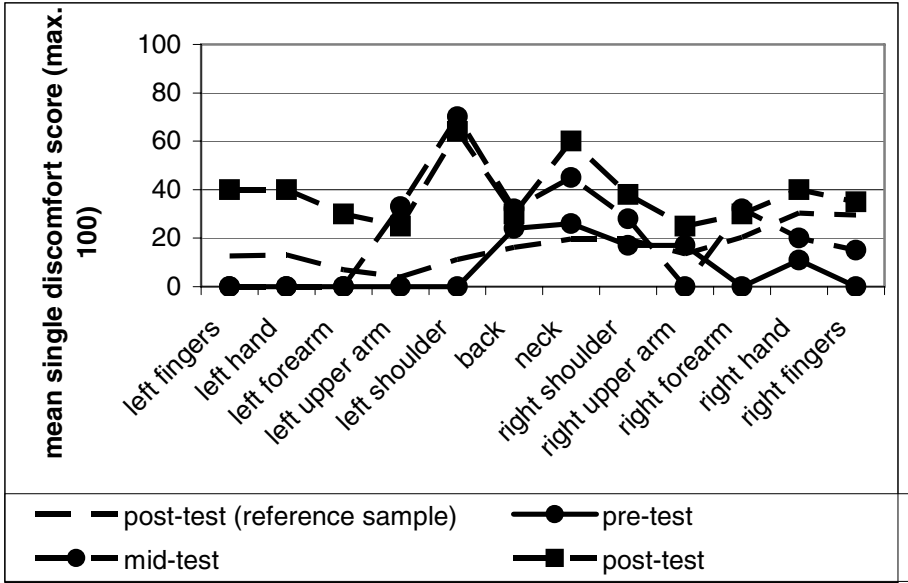


Fig. 4. Mean single discomfort score for pre-test (solid line), mid-test (dashed line, circle) and post-test (dashed line, square) and the reference sample (dashed line only)

With respect to the performance of input device the total time was about 4619 ms for the touchpad (32 trials: 4595 ms to 64 trials: 4653 ms). Only the first 64 out of 160 trials were recorded due to a system's failure. The performance of the trackpoint was constantly by 6387 ms (32 trials: 6499 ms to 160 trials: 6516 ms). When input device performance was compared to healthy participants Case 3 was about 1224 ms faster with the touchpad (4619 vs. 5610 ms, $T_{(9)} = 5.5$, $p < 0.01$). With the trackpoint the performance of Case 3 was comparably close to healthy users (6387 vs. 6396 ms, n.s.).

4 Discussion and Conclusions

The focus of the presented study was set on the usability of notebook input devices for motion-impaired users. A major result can be summarized from the case studies: All cases showed severe restrictions in the usage of the input devices from either distinct musculoskeletal discomfort and / or a dominant decrease of input performance. Even for young and healthy input device users discomfort rose by 20-27% after working periods of 2-4 hours [2, 3]. But in contrast to the RSI-cases musculoskeletal discomfort in the healthy user group was all in all very low and input performance still very good. RSI-cases showed a raise of discomfort that was up to 3 times higher (Cases 1 and 3) compared to healthy users [3], and musculoskeletal discomfort was assessed in the upper half of the discomfort scale. The localization of discomfort depended on the specific impairment, in contrast to healthy users, who reported most discomfort in finger, hand and forearm [2, 3]. Discomfort was up to 2.6 times higher than with healthy users (Cases 1 and 3). RSI-cases reported severe pain, which forced Case 1 to quit the experiment. On the other hand RSI-cases (Cases 1 and 2) remarkably slowed down their input performance and were by 3 times slower compared to healthy users. This finding confirms the motor restrictions of motion-impaired users of input devices [4]. It seems as if well-being and /or optimized input performance are unsustainable even for short working periods. Under exposure discomfort of RSI-cases rose very fast until they were nearly unable to continue their work or the effort to continue work was extremely high.

In conclusion findings show that RSI-impaired computer users limit the usefulness of notebook input devices as compared to keyboard and mouse [4]. They face great barriers in terms of effort. Therefore, they highly rely on low demanding (e.g. point task without click) and low repetitive input tasks, and especially on adequate rest periods.

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Dynamic Mouse Speed Scheme Design Based on Trajectory Analysis

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Abstract. Windows GUI allows user to define pointer speed and precision, however, the settings are fixed and not adaptive to different pointing tasks in real time. This study proposes a dynamic mouse speed (DMP) scheme that dynamically changes the pointer speed by calling `SPI_SETMOUSESPEED`. Results show that DMP setting, on average, outperformed some commonly used Windows built-in settings. However, the advantage of DMP setting occurred more significantly for longer moving distance. For short moving distance, the advantage was not clear. In addition, the advantage of DMP was not on all directions. For some directions, especially when moving distance was short, Windows built-in settings outperformed DMP setting.

Keywords: Mouse, Cursor trajectory, Overshooting, Dynamic mouse speed, Control-response ratio.

1 Introduction

The development of widespread computer technology has changed many of our daily practices, in which humans typically use a keyboard and a mouse as input devices. The performance of using a mouse and its impact to human health thus become important issues and being investigated for the past three decades (e.g., [1], [2], [13]). Many of the studies regarding performance evaluation are largely based on the Fitt's Law, which states that the time to move and point to a target of width W at a distance A is a logarithmic function of the spatial relative error (A/W) and the term $\log_2(2A/W+c)$ is called the index of difficulty (ID) [3]. Early work by Card et al. [2] comparing the posing time of a mouse and joystick for different target size and moving distance is one of the examples using Fitt's law. Kantowitz and Sorkin [8] also indicated that while maintaining the same level of index of difficulty, increase of the target distance does not increase the movement time. Following this theme, other studies regarding the trajectory and precision control using a mouse exist, suggesting that different control-response ratio (C/R ratio), or, inverse of gain, affect positioning performance; and directions of movement and deviation angles are correlated to total movement time. For example, Mackenzie and Buxton [9] indicated that for a right-handed user, moving toward 45° (upper right) takes more time than moving toward 0° or 90° .

Phillips and Triggs [11] performed a kinematic analysis of cursor trajectories and outlined two possible ways in which moving to the wrong target icon could occur, either by uncertainties in the initial cursor trajectory or by overshooting targets. The study suggested that cursor trajectories controlled by the mouse were not very efficient, exhibiting overshooting, and large numbers of cycles of acceleration and deceleration. As an extension of the kinematic analysis of cursor trajectories, Tang [] conducted a hierarchical regression analysis and suggested that the most significant factor impacting cursor pointing time is overshooting, among other factors such as maximal velocity, total movement distance, deviation angles, etc.

From literature, it can be concluded that factors affect cursor pointing tasks include: target size [4], [14], [15], target distance [4], [14], movement direction [9], [11], [13], C/R ratio [1], [7], [10], [14], cursor trajectory and angle deviation [5], [11], [12].

As new technology introduced to improving HID (Human Interactive Devices), both hardware and software for mouse control have been continuously enhanced for the past decades. For example, the ballistic Windows XP pointer algorithm overcome some of the limitations and fallbacks of the ballistic algorithms in the previous operating systems, such as acceleration is applied separately to X-axis and Y-axis and thus biases the axis of greatest magnitude [16].

The current ballistic pointer algorithm for Windows uses a transfer function that relates the actual velocity of the mouse to the actual velocity of the pointer on the screen. Then an algorithm was applied to that transfer function to calculate the transferred pointer data. The parent transfer function was constructed based on a usability study, and a family of curves is extrapolated from the parent curve to yield a transfer function with varying speed and acceleration properties. The parent transfer function is stored as a lookup table, and the points between the stored values are interpolated. It is possible to modify and customized the curves and allow custom control of the pointer ballistics to meet a wide variety of needs [16].

2 Dynamic Mouse Speed (DMS)

Although current Windows GUI allows user to define pointer speed and precision, however, the settings are fixed and not adaptive to different pointing tasks in real time. Since research suggests that cursor adjustment time accounts for most part of the total movement time [12], it is therefore possible to define a set of threshold values at different mouse speeds and movement stages to trigger accelerated cursor movement as illustrated in Figure 1.

The dynamic mouse speed (DMP) works in the following way. If, within the interval between mouse interrupts, the mouse moves by more than the number of pixels specified in the value of, say, Threshold 1, then this system can dynamically change the pointer speed by calling `SPI_SETMOUSESPEED`. The `pvParam` parameter in `SPI_SETMOUSESPEED` is an integer between 1 (slowest) and 20 (fastest). A value of 10 is Windows default. By using a lookup table, appropriate mouse speed can be set in accordance to different threshold values, which can be determined through usability study to enhance the speed during the beginning traveling stage and the

accuracy during the final adjustment stage. It can be seen from Figure 1 that threshold values are usually defined asymmetrically during acceleration and deceleration.

In contrast to DMP, the Windows uses `MouseSpeed`, `MouseThreshold1`, and `MouseThreshold2` to determine mouse speed. When the mouse moves slowly, the system moves the cursor at a constant rate that is directly proportional to the rate at which the mouse moves. But if the mouse moves faster than the value of `MouseThreshold1` or `MouseThreshold2`, the system can respond by accelerating the movement of the cursor. If the value of `MouseSpeed` is 0, there is no acceleration. If `MouseSpeed` is 1, when the mouse speed reaches or exceeds the value of `MouseThreshold1`, the cursor moves at twice the normal speed. If `MouseSpeed` is 2, when the mouse speed reaches or exceeds the value of `MouseThreshold1`, the cursor moves at twice the normal speed; and when the mouse speed reaches or exceeds the value of `MouseThreshold2`, the cursor moves at four times the normal speed.

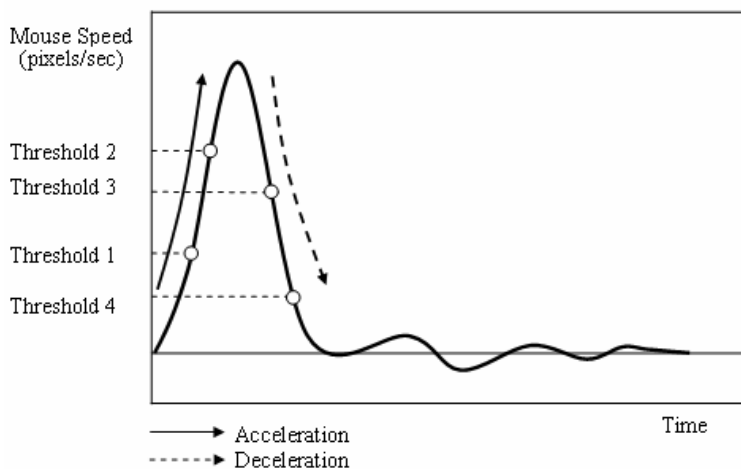


Fig. 1. The concept of dynamic mouse speed (DMP) shows that threshold values for calling `SPI_SETMOUSESPEED` are defined differently for a mouse pointing task during acceleration and deceleration

3 Experiment I

In order to investigate whether DMP improve the performance of pointing tasks, a set of two experiments were conducted. The purpose of Experiment I is to evaluate different threshold combinations for pointing tasks under a relative well controlled experimental environment. The best threshold combination from the results of Experiment I was then used in Experiment II to compare with Windows defined mouse motion parameters in an environment involved real daily use of Windows tasks.

3.1 Experimental Design and Procedure

The experiment was conducted on PCs with a 17-inch LCD monitors and a Logitech mouse. The testing environment was developed using Microsoft Visual Basic and C++. The experimental task was a simple pointing and clicking task. Eleven paid volunteers from the Engineering School of Feng-Chia University served as participants. All participants were familiar with Windows operation system and were right-handed.

A 2X8X7 within-subjects design compared two levels of target distance, namely, NEAR (300 pixels) and FAR (900 pixels); eight levels of movement direction, from directly above the home position to every 45° clockwise; and seven levels of threshold combination (TC) shown in Table 1 for the parameter settings. The dependent variables were total movement time of each pointing task measured in milliseconds and total cursor moving distance measured in pixels.

Each participant was tested individually for 14 test blocks. One of the fourteen combinations of two target distances and seven threshold combinations was presented for each test block. The assignment of the target distances and threshold combination to the participants was randomized across the experiment. Within each test block, 20 trials for each of the eight directions were presented to a participant randomly. Thus, there were total 160 trials within one test block and total 2240 trials for each participant.

Table 1. The 7 Threshold Combinations (TC) defined for the Experiment I. TC1 and TC2 are defined by Windows settings while TC3 through TC7 are defined by dynamic mouse speed (DMP) approach proposed by this study.

	MouseThreshold1	MouseThreshold2	MouseSpeed (Acceleration Multiplier)
TC1	0	0	0
TC2	6	10	1

		Threshold 1	Threshold 2	Threshold 3	Threshold 4
TC3	Mouse speed (pixels/second)	500	1000	800	300
	pvParam	14	16	14	12
TC4	Mouse speed (pixels/second)	500	1000	800	300
	pvParam	14	16	12	10
TC5	Mouse speed (pixels/second)	500	1000	800	300
	pvParam	14	18	14	12
TC6	Mouse speed (pixels/second)	500	1500	800	300
	pvParam	12	14	12	8
TC7	Mouse speed (pixels/second)	800	1500	1000	300
	pvParam	14	16	12	10

3.2 Results

For total movement time, a three-way ANOVA was used to analyze collected data and revealed three significant main effects: target distance, $F(1, 24039)=9408.74$, $p<0.001$; movement direction as shown in Figure 2, $F(7, 24039)=17.50$, $p<0.001$; and threshold combination as shown in Figure 3, $F(6, 24039)=131.86$, $p<0.001$. There were two significant two-way interaction terms: target distance and movement direction, $F(7, 24039)=16.68$, $p<0.001$; and target distance and threshold combination, $F(6, 24039)=38.25$, $p<0.001$. None of the higher-order interaction terms were significant. A Tukey test with $\alpha=0.05$ on the threshold combination factor revealed that the TC3 had the shortest movement time.

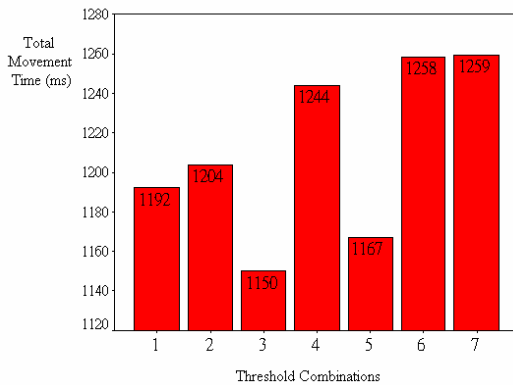


Fig. 2. The total movement time in milliseconds for seven threshold combinations

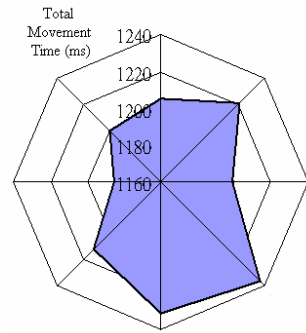


Fig. 3. The total movement time in milliseconds for eight movement direction

For total moving distance, ANOVA analysis revealed three significant main effects: target distance, $F(1, 24039)=684484.89$, $p<0.001$; movement direction as shown in Figure 4, $F(7, 24039)=37.61$, $p<0.001$; and threshold combination as shown in Figure 5, $F(6, 24039)=104.32$, $p<0.001$. There were also two significant two-way interaction terms: target distance and movement direction, $F(7, 24039)=4.857$, $p<0.001$; and target distance and threshold combination, $F(6, 24039)=25.426$, $p<0.001$. None of the higher-order interaction terms were significant. A Tukey test with $\alpha=0.05$ on the threshold combination factor revealed that the TC1 had the shortest movement time.

The findings from Experiment are consistent to those of Phillips and Triggs [11] that leftward movements are faster than rightward movements, among others. The results also suggest that TC3 and TC5 are both faster than Windows built-in settings (TC1 and TC2). It is worth noting that this comparison, however, is more significant when target distance is large.

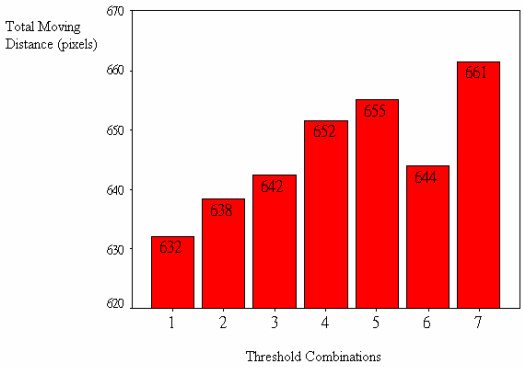


Fig. 4. The total cursor moving distance in pixels for seven threshold combinations

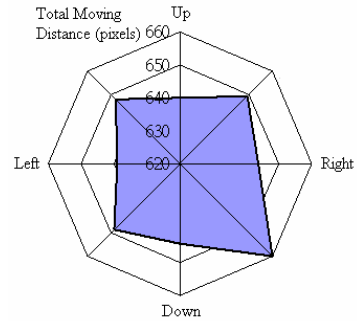


Fig. 5. The total cursor moving distance in pixels for eight movement direction

4 Experiment II

Upon the completion of Experiment I, the best DMS threshold combination, namely, TC3, was adopted for further evaluation in Experiment II, where a more realistic computer using environment was applied to compare TC2 (Windows built-in setting) and TC3 in terms of pointing performance.

4.1 Experimental Design and Procedure

For Experiment II, a program running at system background was developed to collect all mouse movement related information such as cursor position, system time, and mouse event type, etc. All these collection processes did not interfere with participant's normal use of a computer. In other words, this data collection program was transparent to the participants. One can image that such a program may generate a lot of data from using a computer. However, since the use of a mouse in Windows may involve many types of mouse event (e.g., clicking, double clicking, and dragging) and the time collected may reflect not only travel time and adjustment time of a mouse but also other time such as search time and think time. Thus, all collected data need to be filtered and transformed into well defined mouse movement.

The participants of Experiment II were the same as those in Experiment I. Participants were asked to perform their normal computer work instead of specific experimental task to provide a higher validity. For each participant, 300,000 data points were collected during a prolonged period of time. Among them, 150,000 data points were from TC2 and 150,000 data points were from TC3.

For further analyze collected mouse movements, two more independent variables were defined in addition to threshold combination, namely, cursor moving distance and movement direction. There were nine levels for cursor moving distance from 0 to 900 pixels, each level represents a range of distance covering 100 pixels. Thus, if the

cursor moving distance for a mouse movement equals to 552, then the level is set to 6. There were eight levels of movement direction. Each level represents movement direction within a range of 45° . The dependent variable was total movement time of each mouse movement measured in milliseconds.

4.2 Results

Among all 3,300,000 collected date points, upon filtering and transforming, a total of 96,482 mouse movements were defined. These included clicking, double clicking, dragging and many other types of mouse movement. For these mouse movements, the average highest speed occurred at the 31.1% of the movement time. However, upon excluding those movements with unreasonably long movement time and those movements changing directions for more than twice, 54,009 mouse movements were further selected and considered as more typical and meaningful mouse operation. For these mouse movements, the average highest speed occurred at the 24.8% of the movement time, and the average of the highest speed was 1,742 pixels per second.

Among 96,482 mouse movements, left button events account for 91,615 mouse movements (95.0%) while right button events account for 2.3% of total mouse movements. Further analysis shows that click account for 71.0% of left button events and double click 14.3%. Figure 6 shows the distribution of different types of left button mouse movement.

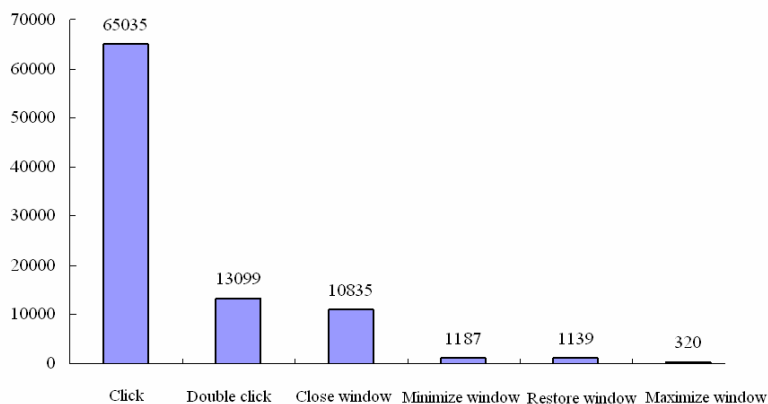


Fig. 6. The frequencies of different types of left button mouse movement

For total movement time, ANOVA analysis revealed three significant main effects: cursor moving distance, $F(8, 53865)=1279.189$, $p<0.001$; movement direction as shown in Figure 7, $F(7, 53865)=25.486$, $p<0.001$; and threshold combination as shown in Figure 8, $F(1, 53865)=4.526$, $p<0.01$.

There were two significant two-way interaction terms: cursor moving distance and movement direction, $F(56, 53865)=11.945$, $p<0.001$; and movement direction and threshold combination, $F(7, 53865)=5.498$, $p<0.001$. There was also one significant three-way interaction term: movement direction, cursor moving distance and threshold combination, $F(56, 53865)=11.945$, $p<0.001$.

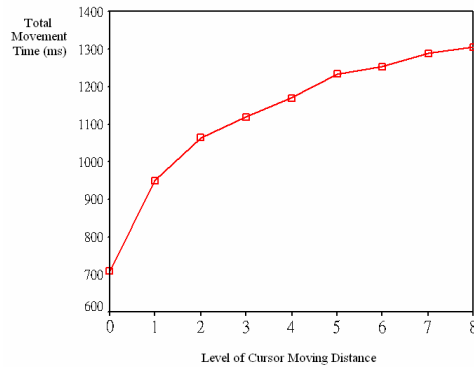


Fig. 7. The total movement time in milliseconds for eight levels of cursor moving distance

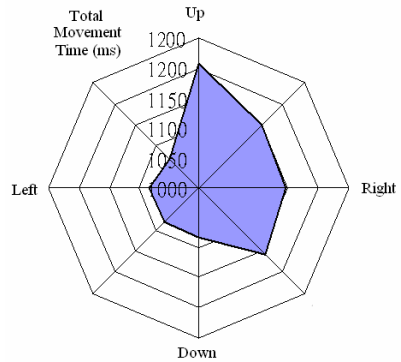


Fig. 8. The total movement time in milliseconds for eight movement direction

Although the results from main effect show that TC3 outperformed TC2 by about 13 milliseconds on average, however, A Tukey test with $\alpha=0.05$ shows that TC3 outperformed TC2 only for those mouse movements moving toward upper-left and right while TC2 actually performed better for movements toward lower-right. The advantage of TC3 was more significant for longer moving distance, while the advantage is not as clear for short moving distance ($\alpha=0.05$). Further analysis on the three-way interaction term suggests that for longer moving distance, TC3 performed significantly better than TC2 on all directions except downward and leftward movements, while this advantage is not statistically significant for short moving distance ($\alpha=0.05$).

5 Discussion

These two experiments investigated the performance of dynamic mouse speed (DMS). The general results regarding moving distance, movement direction and movement time from this study are consistent to previous related studies. More importantly, the results seem to suggest that some of the selected DMS settings outperformed some commonly used Windows built-in settings to a certain extent. At the least the results show that DMS is potentially effective and encourage further investigation of DMS usability.

The key factors to have a good DMS performance are to determine a set of threshold values and corresponding pvParam settings for SPI_SETMOUSESPEED. In this study, five levels of threshold combinations were investigated. The choosing of these five settings was based on a series of pilot tests not reported here. The experiences show that better performance generally obtained when threshold values and pvParam settings for acceleration are greater than those for deceleration, as shown in Figure 1. For example, for TC3, (Threshold1=500) > (Threshold4=300) and (Threshold2=1000) > (Threshold3=800); also, (pvParam for Threshold1=14) >

(pvParam for Threshold4=12) and (pvParam for Threshold2=16) > (pvParam for Threshold3=14). Most likely, the current TC3 setting is not the best possible threshold combination given that a systematic approach to determine threshold combination is not yet available. This also implies that the underlying knowledge regarding how dynamic change of pvParam setting affects pointing tasks and the trajectories is yet to be explored.

An adaptable interface allows users to customize the application to suit their needs whereas an adaptive interface performs the adaptation for the users. Users generally customize very little, likely because customization facilities are often powerful and complex in their own right and therefore require time both for learning and for doing the customization. This is a primary argument for an adaptive interface [6]. With the design concept of DMS, the settings for the threshold values are possible designed in an adaptive way in the future research.

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Problematic Internet Use in South African Information Technology Workers

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Abstract. The majority of studies that have looked at Internet addiction and problematic Internet use have focused either on university students or high school pupils as groups at high risk of experiencing problems as a result of their Internet use. This study adopts the approach that within the context of limited access to the Internet, those with access are obviously more at risk than those without access. With this in mind, this paper looks at the prevalence and correlates of problematic Internet use in a sample of 1399 information technology workers. The results indicate that the prevalence of problematic Internet use in this sample was 3.22%, significantly lower than in other studies. Information technology workers were more likely to display symptoms of problematic Internet use if they were younger and male, if they spent a large amount of time online, but not if they had only recently started using the Internet. The best predictors of problematic Internet use were procrastination, using online chat, spending a long period of time online in a single session, and going online more frequently per week. These results are discussed in relation to previous studies of problematic Internet use from around the world.

Keywords: Problematic Internet use, information technology workers, online procrastination, Internet addiction.

1 Introduction

In recent years there has been a growing number of published research investigating the “addictive” use of the Internet and predictors of Internet addiction [1, 2, 3, 4, 5]. Considerable debate has centred on whether the Internet is indeed “addictive” given that there is no psychiatric classification for “addictions” [6]. Instead, what we see in the literature is a range of terms used to describe the compulsive “overuse” of the Internet or “dependence” on Internet facilities. Terms in common usage include “compulsive Internet use” [7], “Internet dependence” [8], “excessive Internet use” [9], “pathological Internet use” [10], and “problematic Internet use” [11]. Each of these terms describe a range of symptoms that results in decreases in physical and psychological well-being, and problems with social and family interactions, and work commitments. In this study the term problematic Internet use (PIU) is preferred as it based within a theoretical framework of a deficient self-regulation continuum within

Bandura's [12] theory of self-regulation. According to this theory, episodes of deficient self-regulation may be self-remedied. This theory might explain why some studies have found that people who have recently started to use the Internet are more likely to display PIU symptoms [13] or why older users are less likely to display PIU symptoms [13, 14].

1.1 Internet Use and PIU in South Africa

While access to the Internet has grown by approximately 112% in South Africa in the last 6 years, the Internet penetration rate is still rather modest compared to industrially developed countries at approximately 10% of the total population [15]. By comparison, the Internet penetration rates in industrially developed countries such as the United States (69%), Canada (67%), Sweden (75%), United Kingdom (63%), Japan (67%), and South Korea (66%) are significantly higher [15]. The low Internet penetration rate has been attributed largely to the high costs of telecommunications provision [16]. Within South Africa, however, there are certain sectors where the Internet penetration rate is much higher, such as the employed, skilled, urban population [17]. Published studies on the South African Internet population are scarce but support this finding by characterising the South African Internet user as male, English-speaking, in the age group 30 to 39, with a University qualification, a salary within the upper portion of the middle class income range, and access to the Internet primarily from work [18, 19]. The only published study on PIU in South Africa identified the PIU prevalence rate as 1.67% [19]. Compared to PIU prevalence rates in other studies from around the world, this is extremely low. The PIU prevalence rate of 4% in a general South Korean sample [4] is the closest to the South African prevalence rate. However, prevalence rates of 21%-31% in Pakistan [9], 18% in India [20], 18% in the United Kingdom [10], 16% in the Czech Republic [3], and 15% in the United States [8] are several orders of magnitude higher. One possible explanation for the low PIU prevalence rate in South Africa is the relatively modest Internet penetration rate. However, it is quite difficult to make direct comparisons between these different studies due to the variance in instruments used to assess PIU, the different cut-offs applied to determine PIU, the different samples investigated, and the different theoretical models used to understand the phenomenon. For example, all the prevalence studies listed above, with the exception of Whang et al. [4] and Thatcher and Goolam [19], have either used University students or high school pupils as samples. Possibly an adult working population is too busy working to be distracted by excessive non-work-related Internet use.

1.2 Groups at Risk of PIU and Information Technology Workers

The majority of studies that have identified groups "at risk" of PIU have focused on students [3, 8, 9, 10, 11, 21, 22, 23] or high school children [20, 24, 25]. There are a number of reasons why students and high school children have been considered to be high risk for PIU. Firstly, many of the earlier studies found that problematic Internet use was negatively correlated with age and positively with recency of exposure to the Internet [26, 27]. A simple reading of these results would imply that younger Internet users are therefore more vulnerable. More recent studies with general Internet user

samples, and with student samples, would suggest that the correlation with age and recency of exposure to the Internet is less robust [14, 19, 21]. The second reason cited is that schools and Universities usually provide good access to the Internet. Stable and cheap access to the Internet is almost a prerequisite for PIU. The third reason is that for many students this is the first time that they move out of their parent's home and away from the control that they might exert over their Internet use. The final reason is that, in many cases, student and school children samples tend to be convenience samples. General surveys of Internet users [4, 7, 13, 19, 28, 29] are probably the best to identify which groups of Internet users are most vulnerable to PIU. However, the general surveys of Internet users have not specifically identified students or high school children as being at greater risk than other portions of the population. In general surveys, the best predictors of PIU have been identified as Internet usage behaviours such as time spent online, the functions of the Internet such as online gaming or online chatting [4, 7, 19], and personal factors such as personality [13, 29] or mood [28]. In this study we recommend that research needs to investigate other possible vulnerable groups that have stable and cheap access to the Internet. This study specifically targets employees in the information technology (IT) sector as a potential vulnerable group within the South African context. IT employees are a group that is highly skilled within the South African labour market, who work with computers, and who are highly likely to have access to the Internet at their place of work (and may even require the use of the Internet in executing their work duties). Within the context of low Internet penetration rates that we find in South Africa [15], we propose that people with access to computer technology are more vulnerable to problematic Internet use than those with less access to computer technology and the Internet.

1.3 Correlates of PIU

A whole host of variables have been considered as predictors of problematic Internet use. These range from biographical variables (age and gender), Internet usage behaviours (length of time spent online, recency of exposure, online gaming and gambling, and online chatting), and psychological variables (depression, loneliness, solitariness, impulsivity and procrastination). Li and Chung [30], Morahan-Martin and Schumacher [21], Niemi et al. [10], and others, have found that PIU was more likely in males than females. In PIU studies, younger users have also been found to be more likely to experience problems with their Internet use than older users [13, 14]. However, Leung [14] found that PIU was more prevalent with females than males and with students rather than scholars or people in formal employment. Yuen and Lavin [8] found no significant differences between males and females on PIU symptoms. Some studies have found that problematic Internet use is most likely to occur with people who have just started to use the Internet [13]. In contrast, Leung [14] found that there was no relationship between problematic Internet use and recency of exposure to the Internet.

The most obvious correlate of problematic Internet use is the length of time that a user spends online [5, 8, 14, 22, 31]. The length of time spent online is particularly important to investigate with IT workers as some, if not all, of these people's jobs might entail being online at least some of the time. One must be careful not to simply

equate problematic Internet use with length of time involved with online activities, particularly in a sample of IT workers. A person whose work centres on being online (e.g. a website developer or network manager) might spend a large proportion of their working day on the Internet in the productive pursuit of their work duties. It is interesting that some studies have found that the length of time spent online is unrelated to PIU [13].

Various functions of the Internet have been found to be more or less conducive towards the development of PIU. In general, interactive functions such as online chatting, online shopping, online games, and erotica tend to cause more problems than information functions such as information-seeking and email [4, 7, 14, 30]. However, Widyanto and McMurren [13] found no significant relationship between the interactive functions of the Internet and problematic Internet use.

The studies investigating psychological predispositions have investigated a plethora of personality and mood dimensions. The most consistent relationship has been found between PIU and depression [11, 20, 22, 29] or sadness [4]. These studies have been correlational in design making it difficult to determine whether depression leads to PIU or whether PIU makes a person depressed. Davis et al. [11] argued that depression was the precursor causing a person to seek out the social/interactive qualities of the Internet. On the other hand, Campbell et al. [1] found no relationship between mood (stress, anxiety, and depression) and time spent online. Various personality traits have been related to PIU including introversion [29], dependence [5], loneliness [21, 28], shyness/anxiety [8, 28], compulsiveness [4], sensation-seeking [31], low self-esteem [5, 10, 32], external locus of control [28], and social disinhibition [10, 21, 31]. However, Campbell, et al. [1] found no relationship between time spent online and depression, anxiety, or social fearfulness (neuroticism, introversion, or psychoticism). Perhaps this is because time spent online is not necessarily directly related to PIU.

Finally, Davis et al. [11] have argued that some individuals use the Internet to avoid certain stressful or demanding situations. Procrastination online (Davis et al., 2002), also referred to as cyberslacking [33] or cyberloafing [34], has been found to be strongly related to PIU and is therefore also important to consider, especially with IT workers. Even when an IT worker is required to be online as part of their job, they might use features of the Internet to avoid doing work-related tasks. In a student sample, Nalwa and Anand [20] found that PIU dependents were more likely to use the Internet to delay completing other work commitments. No research has investigated whether the same is true of IT workers.

2 Methodology

A total of 1399 responses were returned from an online survey placed on the website of a prominent South African IT magazine. The survey consisted of a biographical section (9 items), an Internet usage section (6 items), Thatcher and Goolam's [19] Problematic Internet Use Questionnaire (PIUQ) (20 items), and Davis et al.'s [11] distraction subscale (7 items) of the Online Cognition Scale (OCS) to assess procrastination. The scales demonstrated good internal reliability (Cronbach alphas of .92 and .89 respectively) and appropriate factorial validity with this sample. Due to

the large sample size, statistical significance was considered at $p < .01$ level in the analyses. The respondents included 1065 males and 334 females, mostly in the age groups 24 to 29 years old ($N=378$) and 30-35 years old ($N=314$), with a Diploma ($N=403$) or Bachelor's degree ($N=259$). The majority of respondents had access to the Internet from work ($N=1311$) and/or home ($N=1039$), usually from both locations. Most respondents had been using the Internet for longer than 5 years ($N=1196$) and usually connected to the Internet in sessions of fewer than 2 hours ($N=703$) or shorter than 5 hours ($N=393$) at a time per day. A total of 563 respondents accessed the Internet every day with 495 of the respondents only accessing the Internet every work day. Nearly all respondents use the Internet for email ($N=1325$) although a large proportion of respondents also used other online communication facilities such as online chatting ($N=239$), Instant Messaging (593), and Online telephony ($N=597$).

3 Results

3.1 PIU Prevalence in South African IT Workers

Using cut-offs established by Thatcher and Goolam [19], 45 respondents (3.22%) were identified as at high risk of problematic Internet use (scores on the PIUQ of 70+). A further 522 respondents (37.31%) were identified as at moderate risk (scores on the PIUQ between 40 and 69).

3.2 PIU Correlates in South African IT Workers

The correlations of the various Internet use dimensions with the PIUQ score were statistically significant at $p < .01$ for number of days per week online, length of time online per session, the number of different uses of the Internet (negative correlation), the number of different access points to the Internet, and online procrastination. The PIU score was not significantly correlated with the length of time since starting to use the Internet. The correlations are given in Table 1.

Table 1. Internet use variables correlated with the PIUQ score

	Days per week	Time online per session	N uses of the Internet	N access points	Online procrastination	Time since starting to use the Internet
PIUQ score	.27 *	.26 *	-.13 *	.25 *	.67 *	.01

The analyses of the biographical descriptors revealed that the PIUQ score was significantly higher in males ($t=4.61$, $p < .01$) and PIU was negatively correlated with age ($r = -.13$, $p < .01$).

T-tests comparing the PIUQ score on the different uses of the Internet indicated that IT workers who used the Internet for online chatting, instant messaging, online telephony, blogging, peer-2-peer file transfers, and FTP file transfers were likely to have significantly higher PIU scores. There were no statistically significant differences for the use of email or web browsing as shown in Table 2.

Table 2. The PIUQ score with different uses of the Internet

Internet use	PIUQ used	Mean if not PIUQ mean if used	t
Online chatting	37.28	49.11	13.37 *
Web browsing	33.94	39.45	2.47 (NS)
Email	36.54	39.46	1.63 (NS)
FTP	38.05	41.01	4.17 *
Instant messaging	37.02	42.41	7.68 *
Online telephony	37.87	43.18	6.77 *
Peer-2-peer file transfers	37.63	44.68	8.73 *
Blogging	48.08	46.53	8.62 *

3.3 Relative Contributory Factors Towards PIU in South African IT Workers

A stepwise multiple linear regression resulted in 4 variables explaining a significant proportion of the variance (54% of the variance). The variables of procrastination, length of time online in a session, using online chat, and number of days per week online, were found to be the most important variables in explaining the greatest proportion of the variance in problematic Internet use within this sample (see Table 3). While the regression model was statistically significant ($p<.05$) with the addition of 10 other variables, these variables explained less than 1% additional variance each which was deemed a negligible amount. It was likely that statistical significance in a number of these instances might be an artifact of the large sample size.

Table 3. Multiple linear regression showing significant predictors of the PIUQ score in IT workers

Variable entered	Total R ²	ΔR^2	F
Procrastination	.45		1024.79 *
Length of time online per session	.50	.05	629.42 *
Use of online chat	.52	.02	453.06 *
Days/week online	.54	.015	358.16 *

4 Discussion

4.1 PIU Prevalence Amongst South African IT Workers

Using the same cut-off criteria as Thatcher and Goolam [19] on the same instrument (the PIUQ) the prevalence of PIU in this sample was 3.22%. This is double the prevalence rate of 1.67% obtained by Thatcher and Goolam's [19], but still relatively low. Due to the comparatively small number of respondents with PIU (N=30 from a total sample of 1795 respondents in Thatcher and Goolam's [19] study and N=45 from 1399 respondents in this study) this may be an artefact of the different samples. The small increase in the prevalence rate may also be a result of the increased access to the Internet [15] or the reducing costs associated with Internet access. This prevalence rate is quite similar to the South Korean sample of 4% [4]. The prevalence

rate in this South African sample is substantially lower than students in Pakistan [9], high school pupils in India [20], British students [10, 21], the general population of Czech users [3], US college students [8], and Taiwanese high school pupils [5, 24, 31]. These differences may also be a result of different sampling methods and criteria for “diagnosing” PIU adopted in the different studies.

4.2 PIU Correlates in South African IT Workers

This study found that males were statistically more likely to display PIU symptoms than females; a result supported by Li and Chung [30], Morahan-Martin and Schumacher [21], and Niemz et al. [10], but contrary to Yuen and Lavin [8] who found no differences between males and females in a sample of students. In this study we found that age was negatively correlated with age suggesting that younger IT workers were more likely to display PIU symptoms than older IT workers. This result is supported by Leung [14] and Widyanto and McMurrin [13]. The correlation, while statistically significant, was not particularly strong ($r = -.13$) suggesting that this statistical significance is largely due to the large sample size. This result is unsurprising given that the South African IT worker sample in this study was dominated by males (76% males).

There were stronger correlations between PIU and indicators of the amount of time spent online (i.e. time spent online per session, the days per week spent online, and the number of access points). These results are consistent with the vast majority of research on PIU [5, 8, 14, 22, 31]. What was quite interesting was the negative correlation between the number of different uses of the Internet and PIU symptoms. This would suggest that a user who engages in fewer types of activities with the Internet is more likely to display PIU symptoms. This is consistent with the notion of specific pathological Internet use as opposed to generalized pathological Internet use [35]. The results also demonstrated that PIU was more likely when the IT workers engaged in interactive online activities such as online chatting, blogging, instant messaging, online telephony and file transfers than with more functional activities such as email and web browsing. This result was consistent with the majority of research looking at PIU and the use of the Internet [4, 7, 14, 30]. Consistent with Leung [14], this study also found no relationship between recency in starting to use the Internet and PIU.

The strongest relationship was between online procrastination and PIU. This was consistent with past research that has looked at PIU and procrastination [11, 20]. This would suggest that with IT workers, PIU is most likely to occur when they are using the Internet to avoid work-related tasks.

4.3 Relative Contributory Factors Towards PIU in South African IT Workers

Significantly, the amount of time spent online in a single session (and other variables used to assess the gross amount of time spent online) was not the variable that contributed most to predicting PIU in IT workers. Online procrastination was the single biggest contributor towards predicting PIU (explaining 45% of the variance in PIU on its own). The length of time that an IT worker spent online in a single session and the number of days per week that an IT worker went online were also statistically

significant predictors, but did not explain a great deal of the variance in PIU (5% and 1.5% respectively). In fact, using online chatting explained slightly more of the variance in PIU (2%) than the number of days per week that an IT worker went online. These results imply that using the Internet to avoid work-related tasks is the best predictor of PIU. However, Davis et al. [11] used the distraction subscale of their Online Cognition Scale (OCS) to assess PIU. The use of the distraction subscale of the OCS to measure Internet procrastination in this study may have exaggerated the strength of the correlation between PIU and Internet procrastination and consequently the strength of the regression.

4.4 Concluding Comments

In many aspects, PIU in South African IT workers displays many of the same signs as PIU in other populations. IT workers who are young and male are more likely to display PIU symptoms than those who are older or female. An IT worker is more likely to suffer from PIU if they spend excessive periods of time online and particularly if the time spent online is for non-work-related activities such as online chatting, blogging, instant messaging, and peer-2-peer file transfers. Where South African IT workers differ from other studies is in the dominance of procrastination in predicting PIU. Spending a large amount of time online is not necessarily an indication of a problem in an IT worker's use of the Internet. After all, some IT workers will spend most of their working day online while actively completing work-related tasks.

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A Novel Design for an Ultra-Large Screen Display for Industrial Process Control

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Abstract. While large screen display technology has been used in process control rooms for many years, it still remains an immature area where there are few examples of successful utilization of its potential benefits in providing essential support to control room crews. We present a solution claimed to represent a major breakthrough in the transfer of modern Human System Interface concepts for process control from the research community to large-scale industrial application. The design principles and approaches that have emerged from this interaction between research and real-life problems are presented, including the novel design challenges imposed by the use of a new type of ultra-large screen technology.

Keywords: Human-computer interface display design, large screen, industrial applications, human-centered design, visual constraints, information design, ecological interface design.

1 Introduction

This paper presents the foundations, rationale and novel features of a new design of an ultra-large screen display for the control room of a new process plant built by Statoil in Norway. This work is claimed to represent a major breakthrough in the transfer of modern Human System Interface (HSI) concepts for process control from the research community to large-scale industrial application, and opens important opportunities for further study of the impact on operator satisfaction and behavior as well as performance effects from introducing such solutions to real-life operational settings.

The authors' perspective has been formed by our experiences in working at the intersection between practically oriented design approaches used in industry and the more formally defined approaches derived from cognitive systems engineering and similar theory. Our purpose is to bring to the attention of HSI research community a large joint effort by Norwegian industry and researchers focusing on the utilization of large screen display technology to improve safety, efficiency and work environment in control rooms. The design project described in this paper is typical for an industry project in that it tackles "ill-defined" problems under constraints very different from

those found in most academically oriented HSI design work that is published. The main contributions of this paper is thus to report challenges, issues, principles and lessons learned that have emerged from this project that we believe to have general relevance and interest for HSI research community and industry users.

It is beyond the scope of this paper to describe all relevant HSI issues that are involved in such a project. Highlighted here are the challenges of the design phase, which included the creation of a novel, relevant, efficient, and usable dynamic visualizations of the plant state. Conducting a user-centered design process on a highly innovative concept is also described. And finally we discuss how the display design faced novel challenges due to the combination of a new type of large screen technology and spatial layout. The “ultra-large screen” (ULS) concept leads to a breakdown of the previously sharp boundaries between room layout design and layout of information within displays.

2 Motivation for the Development of the New Design

The Snøhvit plant is a novel plant design for producing LNG (Liquefied Natural Gas). It is designed for a low staffing level, and Statoil has put much effort into the development and application of advanced technologies to meet the high efficiency, safety and environmental standards. One of the challenges such a new plant presents to HSI designers is that there is no plant operation or user experience available. The basic HSI system consists of four operator workstations for individual use with four screens each, with approximately 1000 detailed displays and 20 system-oriented overview displays.

Numerous challenges face control room operators responsible for monitoring and controlling this highly complex plant. For providing an information source for plant-wide overview, the control room design featured an exceptionally large 16 m x 1.5 m large screen display that created a continuous display surface on a curved wall enclosing the crew.

While large screen display (LSD) technology has been used in process control rooms for many years, it still remains an immature area where there are few examples of successful utilization of its potential benefits in providing essential support to control room crews. Based on traditional piping and instrumentation diagrams, alarm lists, etc.; the principles of process control HSIs in industry have remained basically unchanged for decades, despite their well-documented limitations in supporting abnormal situation management and other operational challenges. And while large screens may be considered a new type of presentation medium in the control room, they are typically used merely to show displays based on the traditional principles.

Both Statoil and the HSI design research community at the Institute of Energy Technology (IFE) in Norway recognized that Snøhvit represented a unique window of opportunity to advance the state-of-the-art in display design in industry towards solutions that improve situation awareness and crew collaboration while reducing workload and human error.

3 Design Rationale, Approach, Features and Review

The overall challenge presented to the Snøhvit design team by Statoil was to use advanced concepts from research to turn the “ultra-large screen” into a highly useful and usable tool to supplement and overcome the shortcomings found in other parts of the total HSI. The solution should significantly improve operators ability to monitor and handle the safety, production and environmental issues in this complex plant. While the use of novel concepts from the research frontier were highly welcome, it was also necessary to consider the issue of user acceptance in a real-life operating environment. This is discussed in section 3.1.

The so-called “Information-Rich Design” (IRD) concept [4], [1] is an alternative HSI concept developed to supplement and potentially replace traditional displays used for process control and monitoring. The concept has emerged from IFE’s interaction with a broad range of industry problems and users over a decade, and the Snøhvit solution represents the most extensive application of this concept.

Section 3.2 describes the principles and features of the IRD and its application and development for the Snøhvit solution in terms of selection and structuring of information content and visual form of information presented. Layout design and physical ergonomic issues are discussed in the next chapter.

Section 3.3 presents a brief review of a key visual element, the *ControlStar*.

3.1 Design Approach and User Involvement Process

Active involvement of users and other domain experts was essential to establish the clear understanding of work domain constraints and operator tasks required to tailor the display design to the target plant and user group. A user-centered (not user-driven) involvement process in accordance with ISO 13407 [8] was conducted, and a permanent multi-disciplinary working group including operators, process and automation personnel and vendor representatives was formed for this purpose. In a series of iterations of different design solutions the design team used its multi-disciplinary background comprising interface design, human factors and process domain expertise to cooperate closely with this working group in creating an appropriate and acceptable solution.

The design team had broad experience with development and evaluation of different HSI solutions for process control applications in the nuclear and petroleum domains. This work has also included the use of different theory-based frameworks that assume that systematic methods based on formal analyses are essential for handling a complex design task. However, a more appropriate model for characterizing the approach used by the IFE design team in projects such as Snøhvit is the “Reflecting Practitioner” model proposed by Schön [9]. This model aims to capture the principles underlying the actual work approaches used by a diverse range of professions dealing with ill-defined problems (such as design) in real-world settings. The model is fundamentally different from the idealized approaches and methods often taught academically in many professions, including interface design, and we find it a fitting description of how experienced practitioners in interface design engage in a rapid cycle of prototyping, “micro-experiments”, reflection, problem reframing and idea generation. IFE’s design group has applied this approach

across different research and industry projects to pursue the two-fold goals of supplying innovative, yet practical large screen design solutions to plants, and to identify and formulate the concepts and principles described in the next section.

The design team had substantial experience using the Ecological Interface Design framework [16], [2], and the Snøhvit design borrows several goals and principles from EID. This includes the recognition that interface design is able to form users' mental models of their work domain and shapes their mental strategies, a clear conceptual separation of information content and visual form, and the principle that information requirements are derived from understanding work domain characteristics and constraints rather than task analysis or iteration on existing designs. Information is also provided at various levels of abstraction, and novel visual forms are used to utilize human perceptual capabilities through extensive use of analog and configural display formats that aim to facilitate direct perceptual processing. However, several of the guiding principles in the Snøhvit design cannot be attributed to EID, which does not address many of the primary issues involved in designing large screen overview displays; the selection of an optimal sub-set of the total information for presentation, choosing efficient visual forms for overview purposes, and ensuring user acceptance. While the Abstraction Hierarchy concept was used to find relevant abstractions levels and constraints to include in the design, the sort of complete and formal Work Domain Analysis that forms the basis of a "formal" EID was deliberately not performed. Therefore, while the visual design aims to create an environment for facilitating ecological interaction [5], the Snøhvit solution does not have the characteristics required to adapt the claim made by the EID theory that knowledge-based problem solving behavior in unanticipated situations is explicitly supported.

3.2 The "Information-Rich Design" Concept for Large Screen Displays

The set of principles that constitute IRD have been created to facilitate certain changes in operators' strategies for monitoring and control that are believed to be beneficial. The design should exploit instinctive behavior by making key information available in fixed locations. It should serve as the preferred source for overview information in important operational situations by supporting early detection and initial diagnosing. Both alarm-based and pre-alarm detection strategies should be supported to be flexible and support users in adapting more proactive monitoring strategies. It is aimed to provide a high data density in the display without causing information overloading. The usability of the display must be explicitly considered for different operational situations.

Information Content – Rationale, Selection and Prioritization. The starting point for an Information-Rich Design solution is an effective set of principles for guiding the selection, structuring and prioritization of the information content to be presented. The target users must be defined clearly, as well as the range of operational modes that the display should be explicitly designed to support (this typically includes normal and disturbed operation as well as process shutdowns and emergency handling).

In the selection of key information for inclusion in a large screen overview several dimensions must be considered. The first is to ensure acceptable situation awareness in terms of providing efficient monitoring of relevant safety and production data which are guided by the nature and severity of *consequences* of failing to detect or interpret plant deviations. Including key performance indicators (KPIs) based on product quality and quantity, efficiency, and environmental parameters is important for maintaining the overall view of the plant performance, and integrating the *key alarm concept* as defined by the EEMUA Alarm Guide [10] is another way to support the alarm handling and total system usability in upset conditions. Information should also be selected based on its ability to support monitoring anticipated process bottlenecks and pay special attention to supporting collaboration and coordination of tasks within the crew.

The other type of criteria for information selection aims to reduce the physical and cognitive workloads of operators by providing direct visual access to *frequently used* data.

Plant and process expertise including work domain knowledge and task requirements must be obtained by the design group. The Snøhvit project was presented with particular challenges in this phase since at the time of design there were no operating experiences, procedures or experienced users available. Instead the requirements had to be extracted from basic plant documentation and dialogues with domain-experts and users from other types of existing plants.

Visual Form of the Information Presented. The visual forms used in IRD are designed to be perceived and interpreted by users with minimum effort by utilizing their powerful human perceptual capabilities. The main influence on the graphical features of the IRD approach has been the principles of Information Design by Tufte [11], [12], [13] which advocate the use of mature graphical design principles for de-cluttering to achieve information-dense displays. Unlike the digital coding of data widely used in current process control displays, IRD uses analog coding extensively to allow processing with little effort and large parallel capacity. Visual elements are designed so that multiple reading strategies are supported; a brief glance should be enough for quick detection of problems or reassurance that no major problems exist, while closer inspection of details within the display should also be possible in other situations. This is supported by the use of multiple visual layers created by careful use of colors and other graphical means to achieve layering and separation effects. The salience of each layer reflects the importance, so the display may be quickly scanned for abnormal states by scanning only the most easily visible features of the total display.

Basic usability principles regarding font sizes and legibility must be respected in all display design work. An additional guiding principle in IRD is that making the design aesthetically attractive also contributes to its efficiency, inspired by the “emotional design” concept by Norman [7].

A typical feature in IRD is the use of mini-trends that are aligned and normalized to facilitate rapid visual scanning for anomalies, as shown in Fig. 1. More complex configurational formats have also been developed for visualizing multivariate data in a way that utilizes emergent features. One example of such a display is shown in Fig. 2.

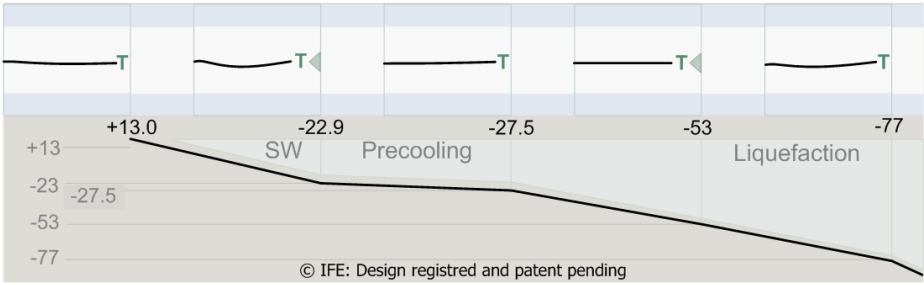


Fig. 1. This temperature profile with five minitrend elements creates a visual scanning band that makes it easier for the operator to monitor 5 key variables in the plant. When the temperature is normal and stable the different trends will be aligned. Note that the alarm areas of each minitrend together form a band. Below, the temperature profile shows the same parameters in relation to each other in a common scale to give the operators information about the relative performance of each subsystem.

The two fundamental IRD principles for optimizing the total layout of visual elements are: 1) Provide a very simple visual structure to allow easy scanning, orientation and reading of data-dense displays, and 2) the layout should also provide a sufficiently correct picture of the plant system topology. Finding a solution that satisfies these different and often competing constraints is one of the major efforts involved in designing an IRD display. For the Snøhvit project the special ergonomic requirements from the ULS solution added significantly to this design challenge; this is elaborated in chapter four.

3.3 Design Guideline Review

We argue that the element shown in Fig. 2 complies with the review guideline NUREG 0700 section 1.2.10 [14] regarding configural formats. The ControlStar element provides a rapid transition between high-level functional information and low-level information as detailed parameter values through emergent features. The high-level functional view informs the user at a glance about the overall situation of the whole sub-system. A closer view gives information about the specific variables. The normalizing and the regular shape functions as a reference aid for the operators in recognizing abnormalities for the whole sub-system. The polygon representing actual set of measurements should be in the middle covering the dashed (ideal) line in a normal situation. Thus, the deviation will emerge when a deviation increase. The use of color and line thickness in the two polar diagrams makes these two dynamic polygons appropriately salient for the basic visual inspection task. Additionally, the deformation of the polar diagrams in case of deviation is another visually salient property. Finally, the display element gives an intuitive presentation of the situation (aggregates a substantial amount of data from a meaningful unit of plant operation for quick inspection of controller performance and bottlenecks) without being too complex.

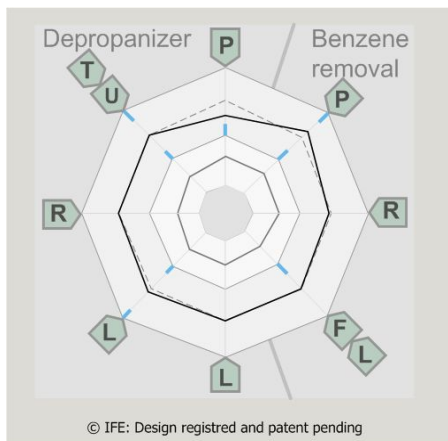


Fig. 2. The ControlStar is based on the well-known Polar Star displays [3]. The outer layer shows the mode of the control structures (single or cascade controllers in auto, manual or cascade). The middle layer is a normalized polar star showing the controlled measurements (of the outer/master controller in case of a cascade) relative to set point and high/low range limits. This layer also shows the H/L alarm configuration as lines along the spokes. The inner layer is a non-normalized polar diagram of the controller output of the controller (the inner loop in the case of a cascade structure).

4 Total Display Layout and Ergonomical Challenges

A fundamental principle is that the large screen display solution together with the rest of the HSI must interact as a whole with the entire crew. When developing the total solution the design team had to form a visual display design for the extremely large surface and huge amounts of information. The Snøhvit ultra-large screen display solution posed special design challenges to help users orientate and correctly recognize information sources within the total display. A single operator cannot manage to get a complete overview or attend to the whole process, but the layout of the total display is carefully chosen, and allows each operator to attend to all sub-systems for which he/she has control and supervision responsibility. One major goal was to minimize the operators' viewing difficulties when monitoring and controlling his or her process part. The design team had to find the balance between giving complete or much information and making all the information visible while minimizing head and eye movement for the responsible operator. Therefore the design has included careful consideration about where to locate the visualization of the different systems. This process was done in close co-operation with the end-users – the operators and the process domain experts.

For evaluation of the total interaction environment it was necessary to develop a 3D VR-model of the control room including the ultra-large screen solution. During the design process different visualization proposals were evaluated in the 3D-model supporting the iterative design process.

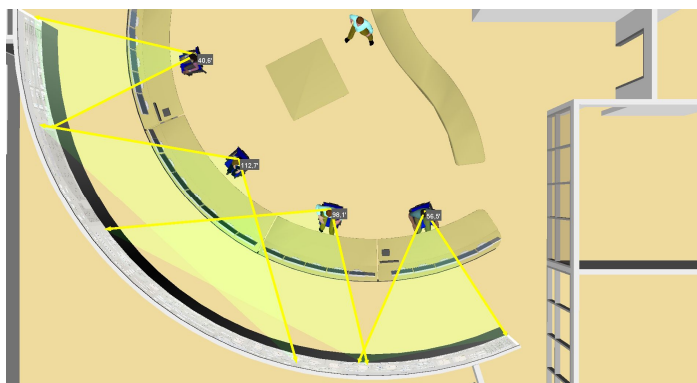


Fig. 3. A birds-eye view of the control room shows the four operators, each marked with the distribution angle for the systems responsible to monitor and control: From upper-left: The loading/storing operator (40°), the utility operator (115°), the main process operator (100°), and the subsea operator (56°). The distance from each of these four operators to the screen is about 3.5 meters. A standing operator is placed in a distance of about 8 meters to the front of the screen. The review guideline [14], stating that the operator should not be closer than half the width of the screen in order to be capable to view all, is satisfactory fulfilled for viewing the primary information areas.

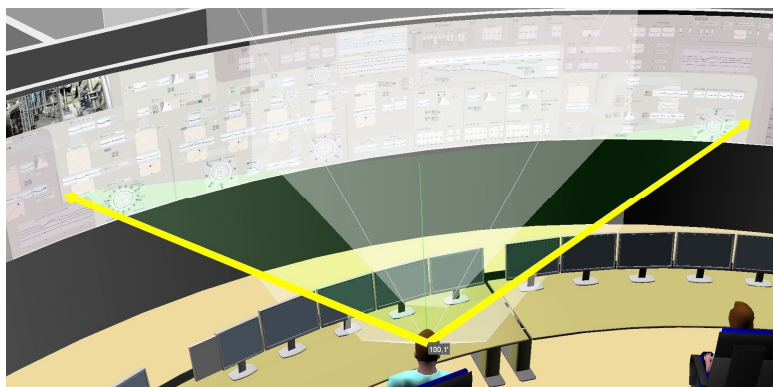


Fig. 4. This snapshot illustrates the layout for the main process operator. The semitransparent view-cone illustrates the limited screen area that the operator can fully attend at one moment during a specific task. Information to be monitored and controlled by the main process operator is distributed across a much wider display area shown between the two thick angle measures, corresponding to a total viewing-angle of 100° . In this illustration the dimmed areas to the left and right indicate information defined to be of secondary or no interest to this operator. The final design include 130 IRD mini-trends, 61 controllers shown in six ControlStars (showing six to 16 controllers in each), non-trended analog coding of 80 measurements, 30 temperature measurements shown as detailed profiles for key units, about 50 temperatures in ten long temperature profiles, and about 150 temperatures in ten short temperature profiles, and four user customizable long-term trends, each of four variables.

5 Remaining Issues and Planned Further Work

Training has not been an issue in the design project, but a complex product such as the Snøhvit solution clearly requires a comprehensive training program. The learning curve for operators and the process by which they adopt the use of this kind of display are highly relevant research issues related to training. Key issues in further studies will be to observe how individual cognitive and teamwork strategies are made possible and are shaped by different features in the new large screen displays, and further analyze how these strategies may affect operator and plant performance [6]. Results from EID research indicate that users' holistic vs. serialist cognitive styles may be a factor that influence how successfully users adopt the use of visually complex displays in their work strategies [15]. This is potentially relevant also for the type of display designs presented here.

A large, joint-industry funded research project is currently being established to evaluate and document experiences with this and other designs based on similar new ideas that are currently being introduced in a number of control rooms in Norwegian oil and gas industry. Data will be collected from different control rooms in the form of field observations, interviews, questionnaires, and plant and alarm system performance data. In addition to addressing the research issues outline here, this project also aims to establish better design guidelines based on what emerges as best practices.

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Methodology to Apply a Usability Testing by Non Specialized People: Evaluation of the European Platform "e-Exhibitions"

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Abstract. This paper presents a methodology developed to the Usability analysis of a platform to create and publish virtual exhibitions (e-Exhibitions Platform). This methodology was developed considering its application by anybody without large experience in usability testing. The methodology was applied with success in Portugal, Italy and Germany with a sample of 18 subjects. This methodology intends to fill the gap related to the long-distance usability testing applied by people without experience in this kind of test.

Keywords: Usability Testing, Methodology, Usability tools, Protocol.

1 Introduction

Nowadays a great variety of material and sources are available: recorded interviews, artefacts, documents, films, pictures and paintings, etc. found in different institutions like archives and libraries, museums and private collections, outdoor exhibitions and heritage monuments. Although distributed all over the world in their regional peculiarities with worldwide links, yet they form part of a Mundial cultural heritage, which is part of the identity of all citizens.

Cultural heritage and art are of primary importance in European tradition and for its future orientation. Many cities have projects, collections and exhibitions which stand for the continuity of cultural themes in European history. Former industrial areas close to the city centre have been redeveloped or are in this process. There are world-wide examples, which in one or the other way are linked to a cultural identity which incorporates change: from old warehouses to recreational areas and service centres. The identification of the citizens with regional issues in a globalising economic pattern is one way to conserve motivation and promote cultural diversity and economic initiative at local level. The themes referred to are e.g.: seafaring history, brewing techniques, the history of migration, trade and commerce, regional development environmental conditions and changes together with future direction in art.

According Nascimento et al [1] in a first moment the museums were only the guardians of the memory and culture, however now they have more than this preventive function. Nowadays, the museums have also a pedagogic mission of knowledge transfer. Therefore the actual tendency is an interactive museum or another way to present an exhibition. They must be able to do the knowledge synthesis in order discuss this knowledge with the public. In this way, the visitor is not considered as a knowledge receiver but also the creator of new knowledge. The visitor is now the actor in a process of enlargement of the culture: scientific, technical and business-related.

Innovative concepts for new museums integrating multimedia presentations have been developed seeking the interactivity and the knowledge exchange. According to Wazlawick et al [2] at museums the use of the new information and communication technologies to support co-operative work has already achieved very interesting and promising results, including environments that allow communication in several media and the shared construction of particular objects. However, at least three deficits can be noted in this context:

- Although there are many cross-cultural links in the history of migration, sailing, shipbuilding, fishing, etc., there is not adequate presentation of this common heritage;
- The differences in the approach to virtual presentations are stunning: for instance the participating museums have their websites online, but they differ considerably in the information given on the museum and its environment. Whilst some only contain basic information on location and opening hours, others offer multilingual access and virtual tours. Some only possess basic experience in the digitalization of artefacts and use of modern ICTs, whereas others have experts employed and some also use ATM broadband links. Almost all name e-commerce as a priority. Many of the regional approaches suffer from a lack of resources and, as a consequence, necessary work is done piecemeal;
- Up to now, co-operation is mainly performed on a bi-lateral level following mostly arbitrary patterns. Co-operation amongst the museums auction houses and art galleries and with industrial actors on a pan-European level can both contribute to find a novel way of presenting a common heritage and secondly enable with economies of scale in a systematic process of networking to identify affordable and feasible solutions.

A more systematic way in identifying user needs, in defining technical, artistic and commercial requirements can be achieved with a user-centred adaptation embedded in a well structured network. In this context, a platform and a portal to create and to publish online virtual exhibitions, called e-Exhibitions Platform, were developed. It shall not only provide service and common approaches to collate interactive web-exhibitions available, but also inaugurate a culture of choosing, between technical and socio-economic scenarios in concert with others, considering the usability as one of the main issue.

According Nielsen [3] usability is a quality attribute that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease of use during the design process.

Usability depends on a number of factors including how well the functionality fits user needs, how well the flow through the application fits user tasks, and how well the response of the application fits user expectations.

In order to evaluate how usable is this platform to create and publish virtual exhibitions, a usability test was developed to this specific system. This usability test should be applied in three European countries by non-experts in Usability testing. Therefore a methodology to apply a usability testing by non-specialized people was developed.

Considering the importance of Usability in systems products, the e-Exhibitions Platform was tested by users. This test was developed by the Ergonomics Lab in the Technical University of Lisbon – UTL using the version 1.0 of the e-Exhibitions Platform.

2 Objectives

The main goal of this methodology is to make possible to non experts in Ergonomics and Usability applying usability tests. It could be possible through the development of an application protocol based in a systems prototype in order to provide to these non- specialists a pre-established guide. This proposed methodology intends to fill the gap related to the Usability Testing applied by people without experience in this kind of test, mainly when the experts have to organize the Usability tests in long-distance.

2.1 Specific Objectives

- Develop an easy application protocol considering a user- centred perspective;
- Analyze the results of the tests in order to identify a homogeneous tendency among the protocol application in different countries.

3 Methodology

The methodology was developed by a multidisciplinary team composed by ergonomist, designer, architect and specialists in usability. This development team organized a brainstorming meeting to define the main features of the usability test for the specific system (the platform to create and publish virtual exhibitions called e-Exhibitions Platform). In this meeting were defined the concepts and the potential solutions for the problem related to the application of an Usability test by non specialized people who is located in a long-distance from the expert team, due the e-Exhibitions usability tests must be performed in three countries (Portugal, Italy and Germany) by moderator without any experience in usability testing.

In this meeting was established a development of a model to lead usability test with the following elements:

- i. A simplified prototype of the system;
- ii. An application protocol;
- iii. A training program to people non-specialized in usability testing application.

3.1 Simplified Prototype

The tested system, as already mentioned, is a platform to create virtual exhibitions, called e-Exhibitions Platform, which will be used by everybody who wants to create and publish their own virtual exhibition. This platform was in the development phase, so there was a functional prototype available (e-Exhibitions Platform v. 1.0.0).

There are some different targets in the e-Exhibitions platform, some people (mainly the management team) are only responsible for create projects and exhibitions; others are responsible to insert information or edit the exhibitions created previously. Some people are also responsible only for the media files or exhibits and there are some who are responsible only for publish the created exhibition. In another hand, only one person can do all these tasks by himself/herself.

In this way, five main tasks were identified in the e-Exhibitions platform creation and publishing process:

1. Create a project and an Exhibition – related to the management target which is responsible only for these subjects;
2. Change the layout, Insert text, Create theme and Add rooms – related to the creation team, the responsible for the information's insertion;
3. Import and Insert a Media File – related to those targets responsible by the design or by the media information;
4. Create an exhibit – related to the creation of exhibits that can be done by a responsible only for this issue;
5. Publish the Exhibition – related to the responsible for publishing the created exhibitions.

Considering these tasks a simplified prototype was developed based in the version of the e-Exhibition Platform already available (v.1.0.0). This simplified prototype was made with only the correct links necessities to accomplish the task available. Each task had a corresponding simplified prototype with only correct links available. As correct links were considered those corresponding to the smallest way that the users must select to continue and accomplish the task.

This prototype was created to establish a controlled scenario facilitating to lead the usability tests. Using a prototype the users can not distract themselves with wrong ways during the interaction once only the available links were clickable. This users' access was done because many times during the usability tests the users make random clicks and get lost. Thus, the access control through the links' availability makes the usability test application by non specialized moderators easier. This simplified prototype allows the moderator to pay attention only in the users' behaviour and verbalizations.

The methodology for the e-Exhibitions Usability tests was developed in order to take advantage of the usability experts knowledge that take part in the e-Exhibitions project as well as the users' opinion and main difficulties.

There are several usability evaluation techniques that can be used in a usability test [4-7]. This methodology was developed considering some of these usability evaluation techniques: thinking aloud method, cognitive walking through and questionnaires. Each one of these techniques used for the e-Exhibitions usability tests require specific tools and methods.

The five main tasks were also used for the cognitive walking through and thinking aloud methods, where the users interacted with the simplified prototype saying what were their feelings, impressions, wishes and frustrations about every step the accomplish each task.

3.2 Application Protocol

An application protocol was also developed in order to systematize the usability test. It was divided into three components:

- An application manual;
- An evaluation guide;
- Results-sheets.

Application Manual. An application manual was created to systematize the usability tests in the three countries (Portugal, Germany and Italy) facilitating the application of usability tests by non-experts moderators.

This manual defines:

- How to apply the usability tests;
- Where to apply;
- How long it takes;
- Application's conditions;
- How to collect the data;
- How to process the collected data.

Evaluation Guide. An evaluation guide was also developed with the purpose of systematize and organize the usability tests once it will be applied by inexperienced moderators. This way the moderators will be able to lead the usability test with the users with this evaluation guide while apply the tests using the defined techniques (cognitive walking through and thinking aloud).

This guide is composed by analysis forms made in way to turn easier the usability test application. In this guide the moderators can find information about the task, information about the correct links available in the simplified prototype that the user can select to go ahead in the test and questions that the moderator has to ask the users during the test. The evaluation guides also allows the moderator to register the user's emotion or felling during the test through some "smile icons" (Figure 1).

Task 1

Usability Test



!

You have to create your own virtual exhibition using the e-Exhibitions Platform.
In this task you have to create a project called "The Italian talent" and inside this project you have to create an exhibition called "Leonardo Da Vinci"

1.6 - Projects page (4_projectsB.htm)

?

Did you already create your project? Yes No

How do you know? _____

What do you think about the process that brings you here? _____

Now you have to create an exhibition called "Leonardo Da Vinci"



Go to: 1.7 - 4_projectsC.htm (page 7)

Go to: 1.8 - 6_title.htm (page 8)

MODERATOR: Check user reaction to this page:

No Reaction

Satisfied

Disappointed

Confused

Surprised

Irrited

Comments: _____

From this page, what link do you select in order to continue the task? (Stop after the 1st correct link)

Click	Place	Comments	gave up
1st			
2nd			
3rd			

What are you expecting to find in the next page? (after 1st correct link)

MODERATOR Comments:



Create a project and an exhibition

7

Fig. 1. An example of the evaluation guide’s sheet

This evaluation guide was developed specifically for the Usability tests with users of the e-Exhibitions Platform and they should not be used to lead another Usability testing.

Three questionnaires were also applied:

- 1. Identification questionnaire – the main objective is to know the users experience using the internet. It was filled out at the beginning of the session;

2. Perception and emotion questionnaires – the objective of this questionnaire is analyze the users perception through the emotion. It was filled out by the users at the end of the session;
3. After-task questionnaire – wants to know the users main impressions about the navigation, design, difficulties and others. It was filled out by the users after the accomplishment of the tasks.

Results-Sheets. An Excel document was elaborated by the development team in order to standardize the results delivery. Thus, all data collected in the evaluation guide during the usability test must be inserted in the specific excel file. The excel file was used to turn the fulfillment simpler.

This process allowed the result analysis in a systematic way, turning this process easier and more efficient.

All verbalization, expectations and improvement suggestions were considered in the results analysis sheet.

3.3 Training Programs

In order to apply the usability test in Portugal, Italy and Germany, the usability experts prepared a training workshop.

The Usability training Workshops were training sessions with the partners of Germany, Italy and Portugal with the intention of teaching them how to lead a usability test and how to apply the developed tools for the e-Exhibitions Platform usability testing. The partners invited to these sessions were those who are responsible for the application of the Usability testing in their respective countries (moderators).

The Usability Training workshop was developed considering two main parts, a theoretical part and a practical one. The aspects related to the usability main concepts and an introduction to the main features of a usability test were considered in the theoretical part of the training. Thus, in this first part were discussed topics as:

- What is usability;
- The advantage of usability;
- The objective of usability;
- What are the main usability techniques;
- How to lead an usability test;

Besides topics related to the Usability theories, the Evaluation Guide of the e-Exhibitions Platform was presented and the participants learnt how to use this tool and how to apply it during the Usability test. Some considerations about the moderator's behaviours during the tests application were also made.

In the second part of the Usability Training workshop a practical exercise was made. In this exercise the participants leaded a usability test using the evaluation guide and following the developed application protocol. The comments about the moderator's questions and behaviours and some doubts were highlighted at the end of the practical exercise.

4 Final Comments

Nowadays, usability is an important issue in a system centered in the user's perspective. A methodology to apply usability tests by moderators without experience is a real profit in this field.

In this way, the developed methodology figures as a helpful tool to lead usability tests by non-specialist moderators located far from the experts and development team.

This methodology was applied in three countries, Portugal, Germany and Italy and the usability tests were lead by moderators without any experience in these countries. All moderators participated in the usability training workshop received the simplified prototype and the application protocol. The results obtained at these countries were homogeneous once they showed the same tendency in the aspects evaluated by the e-Exhibitions Usability test.

The moderators that leaded the usability tests had success in understanding and applying the developed tool. They had success in leading the usability tests in an acceptable period of time (between 60 and 90 minutes for each test) and they applied the usability test for the e-Exhibitions Platform without necessity of complementary training. In this way, the usability tests in these countries occurred without problems.

The developed tool can be considered efficient once the moderators reached the delineated expectations in the beginning of the project. The results collected by non-experts moderators were similar to those collected by experts. It corroborates with the reliability of this methodology.

The final results, after all usability tests, were very important to improve the e-Exhibitions Platform. These suggested modifications were based in the users experience interacting with the system and they cover their wishes, expectation and many other points, mainly those that were not considered without a usability test.

Another point to consider is that even with different cultures (due it was applied in Portugal, Germany and Italy) the results did not present big differences.

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Evaluation of Guiard's Theory of Bimanual Control for Navigation and Selection

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Abstract. Two-handed interaction is a very common paradigm that is gaining popularity in the fields of medical tele-operation, gaming, and large-scale design. In this paper, we validate Guiard's theory of bimanual control for the tasks of navigation and selection. We present the related literature and the theoretical models that motivate the research, in particular Guiard's theory of bimanual control. Two experiments are designed to verify and establish the relationship between navigation and selection in bimanual interaction based on Guiard's theory. The contributions assist interaction designers in developing adequate tools for bimanual operation.

Keywords: Unimanual, Bimanual, Navigation, Selection, Dominant Hand, Non-dominant Hand, Guiard's model.

1 Introduction

Humans use both hands frequently to perform everyday actions. We naturally use our hands to perform tasks such as picking up an item, washing dishes or in more precise tasks such as hammering a nail to the wall. Typically, our manual operations can be divided into two types: unimanual (one-handed) and bimanual (two-handed). The bimanual operations can be further categorized into symmetric, where both hands perform similar tasks and have the same level of importance; and asymmetric, in which the two hands have different roles at the same time. In bimanual situations, people tend to use one hand for fine operations while the other hand provides a rough guide for the first hand [6]. Researchers have termed these two hands as Dominant Hand (DH) and Non-Dominant Hand (NDH). To a right-handed person, the DH refers to their right hand, and the NDH refers to their left hand.

As a natural way of functioning, two-handed interactions take place in everyday tasks, and with minimal training. In addition, using two hands can reduce the task switching time in one-handed operations. Generally, bimanual interaction, with regards to computing related navigation and selection, is designed to have two input devices and two corresponding cursors. However, people are limited to using their dominant hand to operate the computer in current interfaces. In this paper, we intend to investigate the efficiency of applying theories of bimanual control to tasks that involve navigation in a virtual environment and selection of objects.

2 Background and Related Work

Many studies have examined the nature of bimanual operation and have compared the efficiency between unimanual and bimanual operations, or between symmetric and asymmetric bimanual interactions. Based on a number of theories, researchers have also introduced new bimanual interaction techniques. We present a survey of the literature pertinent to bimanual interaction and the literature that is related to the research proposed here. In this section, we describe the major results that relate to the work carried out here.

2.1 Bimanual Versus Unimanual Operation

A number of experiments have been carried out to compare input efficiency between two-handed and one-handed interactions. Similarly, with bimanual interaction, several results describe the nature of symmetric and asymmetric tasks. In one classic study, Buxton and Myers [3] compared the distribution and efficiency of labour with unimanual to bimanual interactions. The participants in their study were grouped into experts and novices. In the first experiment, all the subjects were provided with a graphical drawing interface. Their task consisted of positioning a square in a target place, and to scale it to an expected size. The participants did the experiment with one hand and with two hands. The results of this experiment showed that subjects perform better when they use both hands for simultaneously positioning and scaling an object. In the second experiment, the subjects were required to scroll a word processing document until they found a target word. Buxton and Myers found that, both experts and novices improved in efficiency after changing from one hand to two hands. Furthermore, their results show that the improvement is better for novices than experts. The conclusion of their study suggests that two-handed interaction, for the specific tasks, were more efficient than one-handed operation.

Kabbash et al. [9] examined a one-handed technique and three different types of two-handed techniques. In their experiments, the subjects selected a color from a movable menu and drew lines between displayed vertices. The three bimanual techniques were: i) each hand controls a different cursor with same functionality; ii) the left hand is only responsible for moving the menu, while the right hand is responsible for all the other functions; iii) uses a technique called Toolglass [2], where the colour selection menu is transparent, so that the users can see through the menu. They captured the amount of visual diversion, motor operation and the time for completing the tasks. Their results show that, Toolglass has the least number of motor operations. In addition, only the Toolglass technique out-performs the unimanual technique, while the other two techniques take more time than the unimanual operation. Kabbash et al. concluded that, the method in which the bimanual technique is designed is critical to its efficiency, and "if designed improperly, two hands can be worse than one" [9].

Leganchuk et al. [12] compared two bimanual techniques with traditional unimanual approach. In their research, two experiments were carried out. In the first experiment, the subjects were required to position and resize either an ellipse or a rectangle to minimally cover a given figure in one of six predefined shapes. This experiment compared the traditional unimanual technique (U), a symmetric bimanual

technique (SB), and a bimanual Toolglass technique (BT). Their results show that, the bimanual techniques outperform the unimanual technique by 17%, while there was no significant difference between the two bimanual techniques. In the second experiment, the users were able to practice before starting the experiment. This time, only U and BT were compared. Their results show that BT outperformed U by 39%. Leganchuk et al. concluded that, cognitive ability is important for performance results, and the mental representation of an ongoing action is important for bimanual interaction performance [12].

In a follow-up to Leganchuk et al. [12], Owen et al. [14] proposed that because the two hands would provide more feedback, manipulation capability, and help to evaluate the data, using both hands are more expressive than using one hand. They investigated the time of completing a unimanual operation and that of completing two bimanual operations with an integrated device for both hands or two separated input devices for each hand. The task in their experiments consisted of manipulating a curve to match a given curve. The authors hypothesized that the one hand task would take longer to complete than the two-hands completion time. They conjectured that part of the overhead would result from a certain amount of cognitive effort. Their results show that the two-handed conditions were approximately 40% faster than the one-handed conditions. When the task is more complicated, both hands are more efficient. In this study, Owen et al. [14] emphasized integrating bimanual interaction in one input device. However, there is no evidence that shows that an integrated device will outperform a non-integrated setup.

Latulipe et al. [10, 11] compared the efficiency between unimanual (UNI), symmetric bimanual (SYM) and asymmetric bimanual (ASYM) actions using a one-mouse interface for unimanual and two-mice interface for bimanual. In their experiments, the users are required to perform an image rotation and scale task. The researchers measured the completion time of performing a task; the response time after the image was shown until the mouse starts to move; the accumulative switch time of the period between the change from one mouse to the other; and the movement time which is the completion time minus the other two. Their results show that the mean completion time of SYM is 87% faster than UNI, and ASYM is 42% faster than UNI. Latulipe et al. [11] concluded that, asymmetric bimanual outperforms unimanual actions, while symmetric bimanual technique is the best among the three designs.

In another study, Hinckley et al. [7, 8] designed a task in which the subjects were asked to align virtual objects using one hand and two hands. They provided two tools to control two separate virtual objects. The object would move and rotate according to the operation allowed by the tool. Users could only pickup one tool at a time for the unimanual situation; and would pickup both tools in the bimanual condition. The degree of angle separation between the two objects and the distance between the two objects were recorded. The results show that when subjects use both hands they perform the task more accurately than using one hand only.

The studies above examined the benefits of bimanual interaction in comparison to unimanual operation. The results generally indicate that bimanual interaction, based on a given task, can outperform unimanual interaction. None of the studies, to the best of my knowledge, have investigated the distribution of labour between both hands for the tasks of navigation and selection. In particular, the central question in this study

inquires as to whether it is better to perform navigation tasks with the NDH and the task of selection with the DH, or the opposite. To resolve this question we first provide a description of Guiard's Kinematic Chain model that motivates my investigation.

2.2 Guiard's Kinematics Chain Model

Many bimanual interactive designs have been proposed for various industrial or real-world applications [4, 5, 8, 9, 10, 11]. However, most studies show that, bimanual interaction can be designed in different ways. In particular, the designers are faced with the question of how to distribute the tasks between both hands. To determine the method in which to split the tasks between the left and right hands, it is important to first determine the role of each hand, and to distinguish the tasks that each hand is better at.

To get an answer to the question of the role of each hand, and how to distribute the various tasks between the two hands, we turn to Guiard's theory of bimanual interaction, which is also referred to as Guiard's kinematic chain model. Guiard [6, 13] developed a model to demonstrate the relationship between the roles of both hands in a bimanual application. He defines human hands as two motors as they can make movements, regardless of the internal mechanism of the motion. The movement of such a motor is described in Figure 1. The motor is controlled by an information processing system (IPS), which is analogous to the human brain when the motor represents a human hand. A reference position (RP) generates an input to the motor, and the output of the motor produces a variable position (VP).

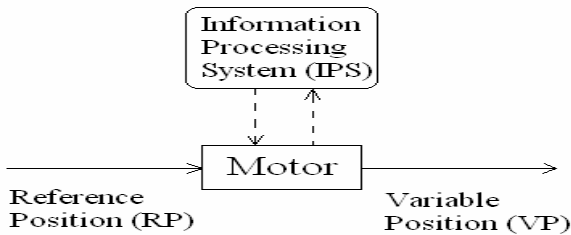


Fig. 1. Representation of a typical motor [8]

Guiard first identified three categories of bimanual actions: orthogonal, where the task of each hand are not related; parallel, where the two hands perform the same task to achieve the same goal; and serial, where the output of one hand is the input of the other hand. In contrast to the first two conditions, the third type of interaction is more natural. Therefore, to take advantage of bimanual interaction, it is best that two hands perform different tasks. This generally often leads to a serial method of processing such that the output from one hand is the input of the other hand. This serialized model is called the *kinematic chain model* or *Guiard's model of bimanual control* [6]. In Guiard's model, the non-dominant hand (NDH) acts before the dominant hand (DH), and typically performs a coarse action. The NDH also provides a frame or reference to the DH. The DH then performs a finer action, which requires the most

significant cognitive effort from the user. This relation is depicted in Figure 2. The RP for the non-dominant hand (NDH) is the input to the NDH motor. After the movement of the NDH motor, the NDH produces a VP, which together with the RP of the dominant hand (DH) becomes the input of the DH motor. The motion of the DH will then generate a VP for the DH. This chain may contain many motors in a serial manner, and the VP for the DH can then become part of the input for the next NDH motor. According to Guiard’s model, the chain should always start from the non-dominant hand motor (NDH), and usually end at the dominant hand motor (DH).

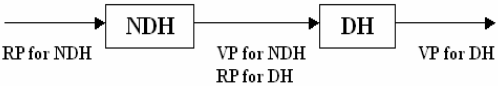


Fig. 2. Guiard’s kinematic chain model [8]

Guiard’s model is purely descriptive and is summarized in Table 1 below. The actions in this model can be explained by means of a drawing application designed to take advantage of both hands to draw images. The painter is given a template and a pencil. The template will be used by the non-dominant hand (NDH) and the pencil is manipulated by the dominant hand (DH). For simplicity, let us assume that the painter is right-handed and so the NDH is the left hand, and the DH is the right hand. To draw figures, the painter will first take the template in the left hand. The template is moved in the drawing space until the painter has a good place to start. In this way the left-hand is setting the spatial frame of reference for the right hand. In handling the template the painter will typically perform coarse movements. Additionally, in this way the movement of the left hand leads the dominant hand, or right hand. Once the position of the template is fixed, the painter works within the established frame of reference set by the left-hand. In this way it has followed the left hand. Finally, to get an image the painter has to perform fine movements. This set of actions is properly encapsulated in Guiard’s theory of bimanual control.

Table 1. The roles of both hands in Guiard’s Model [4]

Hand	Role and Action
Non-Dominant (NDH)	- Leads the dominant hand - Sets the spatial frame of reference for the dominant hand - Performs coarse movements
Dominant (DH)	- Follows the non-dominant hand - Works within the established frame of reference set by the non-dominant hand - Performs fine movements

As described above a significant number of studies have investigated the applicability or effectiveness of Guiard’s theory for bimanual control. The results vary with the different interface designs, the different experimental conditions, tasks, and design. One area that has not been investigated is the use of bimanual interaction for navigation and selection tasks. Navigation and selection are common tasks that are

carried out in a variety of applications. Navigation is primarily significant in virtual environments, in 3D interfaces, and in applications that requires visual searching and browsing. Selection is common in most graphical user interfaces. More specifically, bimanual interaction with navigation and selection has been applied to medical tele-learning (the trainee will navigate in a virtual environment using one hand and perform selections with another), in tele-surgery (the surgeon will navigate in the environment the represents the patients body and use the other hand to perform precise stitching or picking), and in video games.

In this paper we are concerned with finding out how we assign the different tasks of navigation and selection to the different hand. More specifically, do we assign the task of navigation to the DH and selection to the NDH or do we do the reverse? The objective of this study is to verify the implication of Guiard's theory of bimanual interaction for the tasks of navigation and selection.

3 Study

To determine how to assign tasks to the non-dominant hand and to the dominant hand we first describe the nature of navigation and selection. Bimanual navigation and selection requires continuous and asymmetric behavior. Navigation may not require very precise movements, but rather it can be coarse, and it typically sets the frame of reference. Selection is precise, requires attention to detail, and will typically be working in a frame of reference that has already been instantiated. Based on Guiard's theory of bimanual control and the results of prior work, we expect that users will perform better when navigation is relegated to the non-dominant hand and selection to the dominant hand (primary hypothesis). In the following section we describe the experimental set-up that will be designed to test the hypothesis.

3.1 Design

To verify the hypothesis we conducted two separate experiments. In the first experiment, the users navigated and selected objects in an environment where the targets are static. In the second experiment, the targets are dynamic. In both experiments, we test the effect of using the dominant and non-dominant hand as suggested by Guiard's model

Experiment 1: Static objects. The objective of this experiment is to validate Guiard's theory for the tasks of selection and navigation with static targets.

Materials. The experiment will be implemented on an Intel Pentium 4 CPU and 19" 1280x1024 resolution display monitor. The operating system will be Windows XP. The input devices for navigation and selection are two Logitech Extreme 3D joysticks.

Implementation. The implementation is carried out using the Microsoft .NET C# environment.

Description of the task. To validate Guiard’s theory of bimanual control we designed a task that necessitates navigation and selection. The system presents the users a maze in which they navigate and select specific objects. Both navigation and selection is performed using two joysticks. The task is performed under different conditions as described below. The following figure depicts a possible scenario.

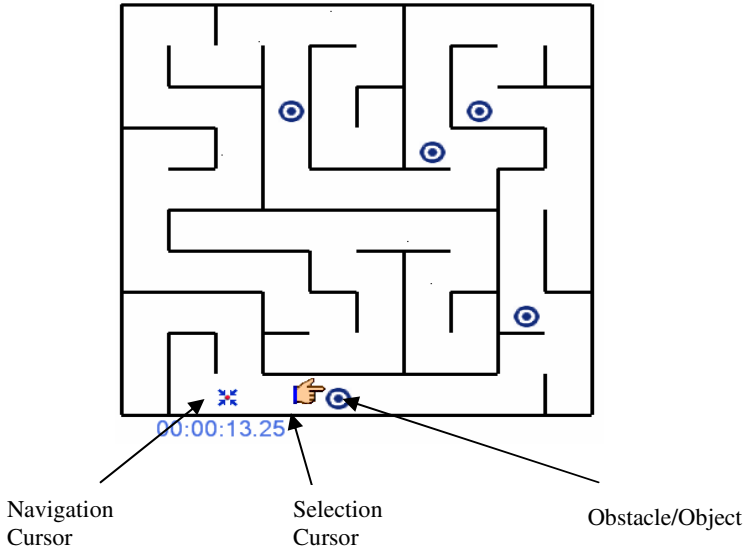


Fig. 3. Interface of the maze for the experiment

Both joysticks’ cursors are positioned at the start location which will be the left bottom of the maze at the beginning of each trial. The objective is to exit from the maze by navigating throughout the maze removing obstructions by selecting them. With the navigation joystick the user starts to navigate along the route. The participant has to eliminate every object that appears on the route using both joysticks. This task is representative of tasks that require some form of navigation toward the objects and then some selection. We record the time to complete the task.

Design. The experiment uses a 2x2x2 within-subject design. The main factors for this experiment are task division (2 levels) and maze complexity which is composed of number of turns (few and many) and the width of paths (small and large). Each of these factors is described in some detail below.

Task Division. To verify the application of Guiard’s theory for bimanual operation, the experiment assigns two types of task division to the dominant hand and non-dominant hand. In the first condition the navigation joystick is set to the DH and the selection joystick to the NDH. In the second condition we reverse the control of each joystick.

Number of turns. One level of complexity is the different number of turns along the route from the start point to the end point. There are two levels of turns for this experiment with 10 and 20 turns for each trial.

Width of paths. To add additional complexity, the experiment varies the different widths of paths from the start to the end. This will be set according to the Steering Law [1]. This factor has two levels, one of 5 pixels and the other of 10 pixels wide.

Experiment 2: Dynamic Objects. Experiment 2 is identical to Experiment 1 with the difference that objects are dynamic and the user has to navigate toward the dynamic objects and select them. The methodology is similar and so we report the results of both experiments together.

4 Results and Analysis

For each trial the system records the time it takes the user to navigate and select objects in the entire maze. We analyze the results by means of a $2 \times 2 \times 2$ (Task Division $\times$ Number of Turns $\times$ Path Width) repeated measures analysis of variance (ANOVA) with Task Division, Number of Turns, and Path Width serving as repeated measures. The experiment collects the completion time for each trial. Through both experiments, we expect to validate Guiard's theory. Namely, the results will validate whether Guiard's theory applies to the tasks of navigation and selection in virtual environments.

4.1 Results for Static Experiment

In experiment 1, we obtained the following results:

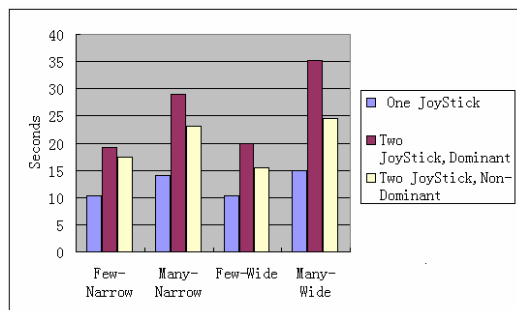


Fig. 4. Chart of experimental results

The preliminary results (figure 4) with twelve participants show that navigation and selection can be assigned to the two different hands based on Guiard's model, i.e. navigation can be relegated to the non-dominant hand and selection to the dominant hand.

The results are consistent across all participants. In summary we see that:

1. Unimanual is faster than bimanual operation.
2. In bimanual experiments, non-dominant hand (NDH) for navigation is faster than dominant hand (DH) for navigation.

4.2 Results for Dynamic Experiments

Similar to static experiments, the dynamic experiments produced consistent results that show same features as static experiments, namely:

1. Unimanual is faster than bimanual operation.
2. In the bimanual condition, non-dominant hand (NDH) for navigation is faster than dominant hand (DH) for navigation.

The overall results for static and dynamic experiments are similar and so we combine the discussion for these two experiments.

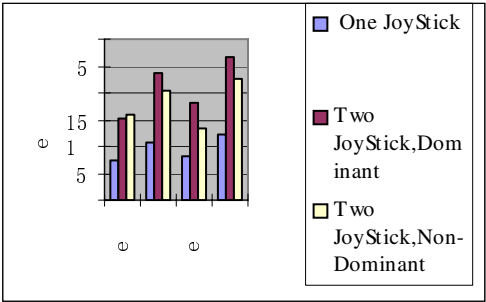


Fig. 5. Chart of experimental results

4.3 Analysis

In our experiments we found that unimanual operation performs better than when navigation is given to both the dominant hand and the non-dominant hand in bimanual experiments. This result seems contrary to the Guiard’s Kinematics Chain Model. However, based on investigation of testers’ feedback and extensive study, we find the task design of this experiment is not very typical for bimanual operation. In general the design of navigation and selection may have been improved if the operation was performed in a symmetric manner. In this case, our task did not require symmetric operation and for that reason it is not clear whether there are any benefits to bimanual operation under such conditions.

In both experiments, the results show that navigation to the non-dominant hand outperforms navigation in the dominant hand. One reason for this is that users found it difficult to perform the selection operation. In this case, selection required that the user follow the navigation hand and then perform a precise selection of the target. This can be difficult given the complexity of the space users are required to navigate and select objects.

5 Conclusions and Contributions

According to the analyses above, we conclude that:

- bimanual interaction does not perform better than unimanual interaction for tasks that are asymmetric;
- definition of dominant and non-dominant hand depends on the workload of the tasks assigned to each hand.

Buxton and Myers's contribution [7] is that they tested bimanual interaction in very simple navigation and selection environments using the mouse, which is only 1DOF navigation device. This device is limited in terms of navigation for many tasks, such as those seen in games. In this research, we tested bimanual interaction under real-time navigation and selection environment using two joystick input device. This work has not been carried out previously. Furthermore, there is very little work in bimanual interaction with a 2D navigation device such as joysticks.

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Evaluation Approach for Post-stroke Rehabilitation Via Virtual Reality Aided Motor Training

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Abstract. This paper introduces an evaluation approach that was applied to clinical data collected from a virtual reality aided motor training program for post-stroke rehabilitation. The goal of the proposed evaluation approach is to diagnose the patient's current status (performance) and detect change in status over time (progression). Three measures, *performance time*, *movement efficiency*, and *movement speed*, were defined to represent kinematic features of reaching. 3-D performance maps and progression maps were generated based on each kinematic measure to visualize a single patient's behavior. The case study revealed the patient's current status as to direction and range of upper extremity reach ability, composed of pitch, yaw and arm length. Further, progression was found and visualized quantitatively over a series of practice sessions.

Keywords: Virtual reality, rehabilitation, evaluation approach, human computer interaction.

1 Introduction

1.1 Background

In the US, more than 700,000 people annually suffer a stroke, an event that is a leading cause of long-term disability [1]. This disability can manifest itself as difficulty in performing activities of daily living such as dressing, preparing and eating a meal, bathing, or work related tasks. As such, quality of life may be severely impacted by stroke [2][3] and more effective methods for rehabilitating lost functioning are a high priority. Fortunately, loss of upper extremity (UE) function can be improved via task-oriented motor training which promotes practice of relevant movements, is highly repetitive, and increases in intensity based on patient progress. A good motor training task should be designed to target a specific functional deficit (i.e., pointing, grasping, reaching) and the intensity of exercise should be based on both ongoing status and desired therapeutic goals such as increased movement speed,

accuracy, efficiency, and range.. However, motor-training tasks used in conventional therapy are limited in their capacity to systematically control stimulus presentation and precisely capture motor performance in real time. Problems with the controlled manipulation of physical exercise objects limit the ability to vary intensity level in a flexible and dynamic way. Moreover, data collected during conventional therapy process is often too limited in type and extent to reliably evaluate the status or performance of the patient. Finally, one possible factor in the mixed outcomes found in rehabilitation research may be in part due to the inability to maintain a patient's motivation and engagement when presenting him with a repetitive series of training challenges. Hence, the integration of gaming features in virtual reality (VR)-based rehabilitation systems to enhance client motivation is viewed as an important direction to explore. Patient motivation may be minimal when there is little immediate meaningful real time feedback from the physical environment after a long exercise session.

A VR interactive system provides numerous assets for rehabilitation beyond what is currently available with traditional methods [4][5]. One of the cardinal benefits of this form of advanced simulation technology involves the capacity for systematic delivery and control of stimuli. In this regard, an ideal match exists between the stimulus delivery assets of VR simulation approaches and rehabilitation requirements for progressive and variable practice. This "Ultimate Skinner Box" asset can provide value across the spectrum of rehabilitation approaches, from analysis and training at an analog level targeting component cognitive and physical processes (i.e., selective attention, grip strength, etc.) to the complex orchestration of more complex integrated functional behaviors (e.g., planning, initiating and physically performing the steps required to prepare a meal in a distracting setting). This asset can also be seen to allow for the hierarchical delivery of stimulus challenges across a range of difficulty levels. In this way an individual's rehabilitation can be customized to begin at a stimulus challenge level most attainable and comfortable for him, with gradual progression to higher functional difficulty levels based on the individual's performance. Another strength of VR for rehabilitation is that it allows the creation of simulated realistic environments within which performance can be tested and trained in a systematic fashion. By designing virtual environments that not only "look like" the real world, but actually incorporate challenges that require real world functional behaviors, the ecological validity of rehabilitation methods could be enhanced. As well, within a virtual environment (VE), the experimental control required for rigorous scientific analysis and replication can still be maintained within simulated contexts that embody the complex challenges found in naturalistic settings. Thus VR derived results may have predictive validity and clinical relevance for the challenges that clients face in the real world. Further, with the use of advanced sensing systems in VR, a large quantity and wide variety of high quality data can be captured to assist in the rehabilitation process. Finally, VR-oriented tasks can be equipped with game features that provide real-time visual, auditory and haptic feedback not only to motivate the patient but also to make the patient feel present within the virtual world. Thus far, early research suggests that the use of VR technology is valuable in improving motor skills for post-stroke rehabilitation of functional deficits including reaching [6], hand function [7] and walking [8] [9].

1.2 Previous Work

We developed a virtual reality aided motor training task, static reaching, for post-stroke rehabilitation of functional upper extremity (UE) reaching. The interactive system was designed to allow individualized practice based on level of ability and allow therapist driven progression to achieve therapeutic goals. Within the VE, the patient reaches to multiple targets with synchronized arm and hand movements of the paretic side as shown in Fig. 1. The work space for each patient was defined in relation to individual shoulder position and arm length. Targets were specified in 3-D space by defining pitch, yaw, and percentage of arm-length as shown in Fig. 2. A more detailed description of this task has been reported previously (Stewart et al, Luke – did you previously report the system?).



Fig. 1. Virtual reality aided motor training task: static reaching

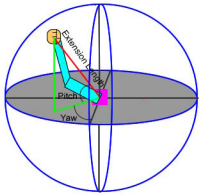


Fig. 2. Determination of target location

A clinical test using this VR task (along with 3 others) was conducted with five patients post-stroke. Volunteers were screened to see if they meet the inclusion criteria: 1) stroke at least one month prior to the pilot trial; 2) over the age of 18 years; 3) able to attend 12 training sessions at the Motor Behavior and Neurorehabilitation Laboratory at the University of Southern California. Subjects are excluded if they had a Mini-Mental Status Exam score below 24, significant limitations in passive range of motion, or no active movement in the hemiparetic UE. Five subjects passed the screening and participated in the trial. According to their initial UE Fugl-Meyer motor scores, the severity of their motor impairment was classified as severe or moderate as shown in Table 1.

Table 1. Severity of disability of subjects

ID	101	102	103	105	106
Severity	Severe	Severe	Moderate	Moderate	Moderate

1.3 Overview

One of the challenges in applying such a system to stroke rehabilitation is developing a method to detect and quantify a patient’s status and progress over time using the collected motion data. In this paper, we first define three kinematic measures to indicate movement performance. Then, we represent each measure with a 2-D pitch-yaw grid map that indicates performance based on target location within the

workspace. Next, we integrate the kinematic measures with the pitch-yaw map to generate a 3-D performance map that allows visualization of the patient's current status and development of methodologies to evaluate progress over sessions. A case study is presented with the data collected from one subject post-stroke who practiced this VR task for 12 sessions over 3 weeks.

2 Evaluation Approach

2.1 Kinematic Measures

Three types of kinematic measures, performance time, movement efficiency and movement speed, were used to quantify reaching performance. All measures were derived from the continuous position and orientation data of an electromagnetic tracker placed on the hand at a data acquisition rate ranging from 60Hz to 80 Hz.

Performance time (PT) was defined as the period between the time when the virtual hand left the start position and the time the virtual hand collided with a target in 3-D space. It provides an index of movement time without regard to the length of the movement path. A lower value indicates faster trial performance. Movement efficiency (ME) was defined as the ratio of the actual movement path over the shortest possible movement path, the linear distance between the start position and the position of the virtual target. ME is an index of how efficiently the patient achieves the target. A lower value of ME indicates better reach efficiency.

Movement speed (MS) was defined as the ratio of the actual movement path over performance time.

2.2 2-D Pitch-Yaw Grid Map

We developed a method to represent workspace location defined by pitch, yaw and arm length with a series of 2-D pitch maps as below in Fig. 3. For each arm length ratio (from 10% to 120%), the zone for each combination of pitch and yaw angle was projected onto a plane diagram. Each grid on the 2-D map represents a certain location in the reaching workspace. Also, each grid indicates a certain 3-D position in space.

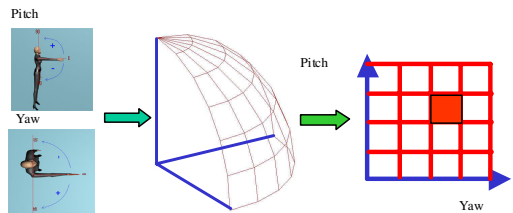


Fig. 3. Translation of target location at a given arm length to workspace location and projected onto a 2-D pitch yaw grid map

2.3 Average Chart and Slope Chart

Average chart and slope charts were built via a two-step classifying process. Data for all test trials were grouped into multiple datasets where each dataset included the data belonging to a specific grid on the pitch yaw map. Each dataset was further classified

into multiple sub-datasets according to session number of completion. Kinematic measures were derived for each sub-dataset. Then, for each kinematic measure, an average value and slope value of multiple sub-datasets belonging to each dataset were calculated. Average and slope values were placed into separate charts that specified grid location. The same procedure was repeated for each grid location on both the average and slope charts. This procedure is summarized in Fig. 4.

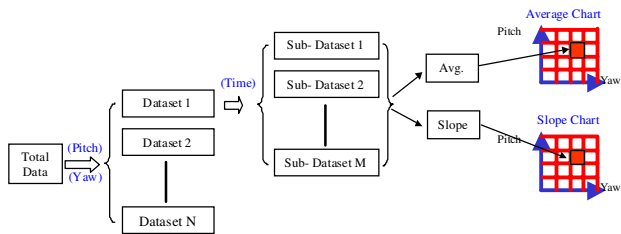


Fig. 4. Development of average chart and slope chart

2.4 Performance Map

A 3-D performance map was built by extracting the value from each grid of the average chart as shown in Fig. 5. Current status could then be visualized and compared from grid to grid via the 3-D performance map. For PT and ME, the lower the height of the bar, the better the performance. For MS, the higher the height of the bar, the better the performance.

2.5 Progression Map

A 3-D progression map was built by extracting the value from each grid of the slope chart as shown in Fig. 6. A positive slope represents a positive trend on progression for MS (improving performance) but represents a negative trend on progression for PT and ME (decreasing performance). In order to simply analysis and comparison, the sign of the slope was reversed for PT and ME so that a positive slope equated to a positive progression trend for all three measures. All negative slopes were then reset to zero and classified as showing no progression based on the assumption that a subject’s performance could not become worse over practice. Further, change of status was visualized and compared from grid to grid via a 3-D progression map.

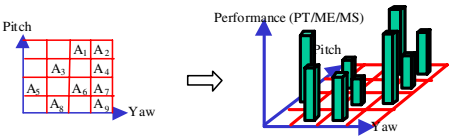


Fig. 5. Creation of the 3-D performance map

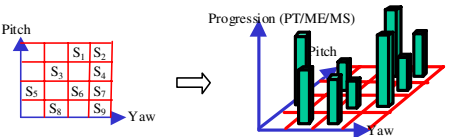


Fig. 6. 3D progression map

2.6 Level Classification

Both performance and progression were classified into three levels and labeled in different colors on the 3-D map. Thus, the user can quickly perceive and locate current status or change of status.

Performance was classified as “Excellent”, “Good” or “Fair”. All performance data was sorted by its value from better to worse. The mean of the first half of each data set was established as the cutting point between “Excellent” and “Good”. Then, the mean of the second half of each data set was established as the cutting point between “Good” and “Fair”.

Progression was classified as “Significant”, “Minor” or “None”. After all signs were made positive as mentioned above, negative data sets were labeled as “None” indicating no progress. The mean of the remaining data was established as the cutting point between “Significant” and “Minor”.

3 Case Study

Due to the large amount of data collected for the 5 patients, subject 103 was selected for case presentation and to demonstrate the described evaluative approach.

3.1 Visualization of Performance: Arm Length Ratio 60%

For each kinematic measure (ME, MS or PT), the performance chart was built using all extracted data sets. The cut-off values used to classify the status levels for this subject are shown in Table 2. The 3-D performance map is shown in Fig. 7 and labeled with different colors to indicate the level of current status: red stands for “Excellent”, blue stands for “Good” and green stands for “Fair”.

At an arm length ratio of 60%, the results show that the subject’s best PT fell within the zone defined by pitch from 15 to 60 degrees and yaw from -40 to 60 degrees. Poorer performance in PT appears mostly with pitch values higher than 60 degrees. With respect to ME, the subject performed better when pitch was lower than 75 degrees and yaw lower than 60 degrees. With respect to MS, the subject moved at slower speed when pitch was higher than 90 degrees or lower than 15 degrees.

Table 2. Performance level classification

<i>Performance</i>	PT (sec)	ME	MS
Excellent	$PT < 2.49$	$ME < 1.41$	$MS < 33.42$
Good	$2.49 < PT < 10.77$	$1.41 < ME < 3.24$	$19.27 < MS < 33.42$
Fair	$PT > 10.77$	$ME > 3.24$	$MS > 19.27$

Table 3. Progression level classification

<i>Progression</i>	$-S_{PT}$	$-S_{ME}$	S_{MS}
Significant	$-S_{PT} > 2.46$	$-S_{ME} > 0.56$	$S_{MS} > 5.36$
Minor	$0 < -S_{PT} < 2.46$	$0 < -S_{ME} < 0.56$	$0 < S_{MS} < 5.36$
None	$-S_{PT} < 0$	$-S_{ME} < 0$	$S_{MS} < 0$

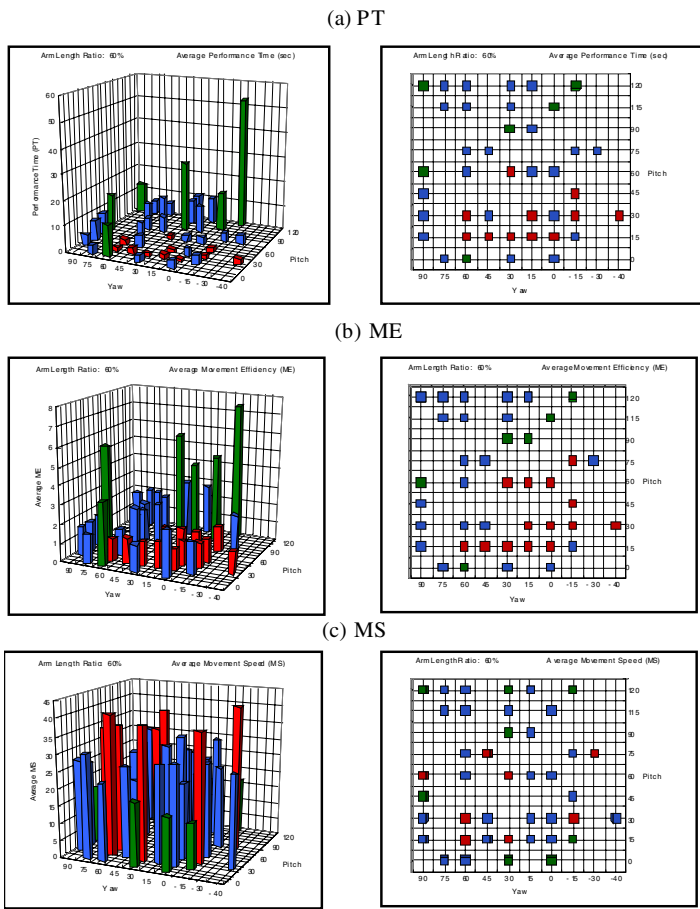


Fig. 7. Performance map of each kinematic measure

3.2 Visualization of Progression: Arm Length Ratio 60%

A progression chart was built for each performance measure. The cut-off values for each level of progression for this subject are shown in Table 3. Also, a 3-D progression map for each kinematic measure is shown in Fig. 8, with different colors indicating the level of progression, where red stands for “Significant”, blue stands for “Minor” and green stands for “None”.

“Significant” progression for PT was found primarily at pitch values of 120 degrees while no progression was found predominantly in the zone defined by pitch values below 90 degrees and yaw values below 45 degrees. “Significant” progression on ME occurred in a zone with either pitch higher than 90 degrees or yaw higher than 45 degrees. For MS, significant progress was only seen in a zone with yaw values higher than 60 degrees.

3.3 Overview of Performance Versus Arm Length Ratio

The mean of each kinematic measure for all zones was calculated for each arm length ratio. (Fig. 9) It indicates that PT increased gradually with increased arm length ratio. However, ME showed no significant change until the arm length ratio reached 100%. At arm length ratios greater than 100%, ME increased rapidly.

3.4 Overview of Progression Versus Arm Length Ratio

At each arm length ratio, the percentage of zones that fell within each progression level was calculated. (Fig. 10) At an arm length ratio equal to or higher than 85%, the percentage of zones in progression on PT and ME is obviously higher than for other arm length ratios. However, MS has the highest percentage of zones in progression at two extremes of the arm length ratio: 25% and 120%.

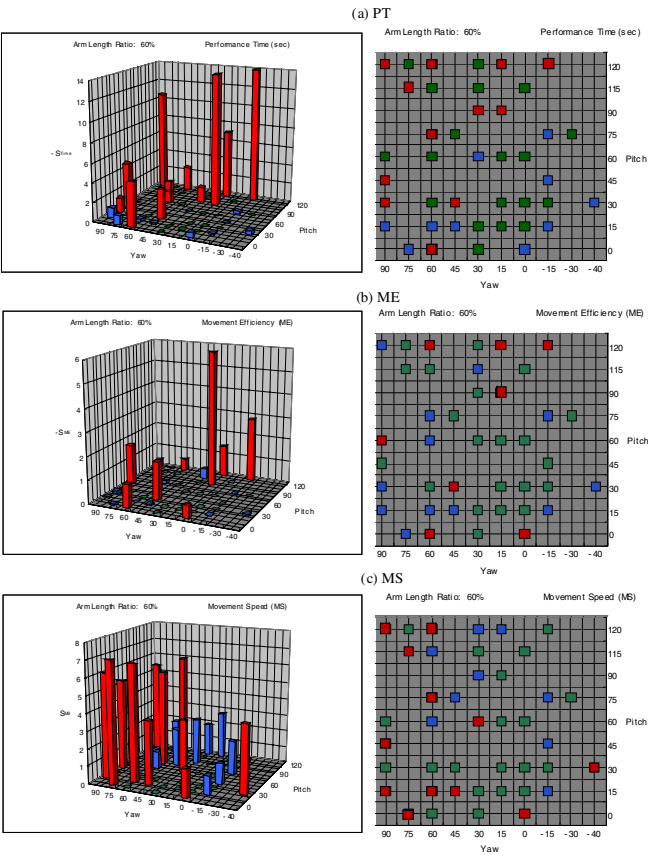


Fig. 8. Progression map of kinematic measures

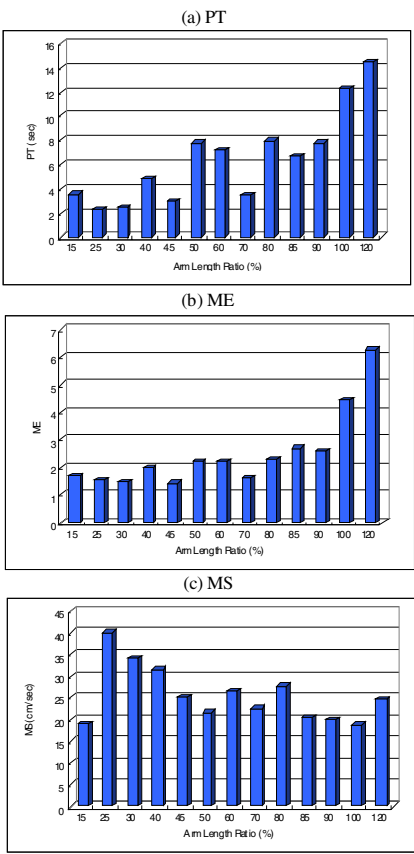


Fig. 9. Performance versus arm length

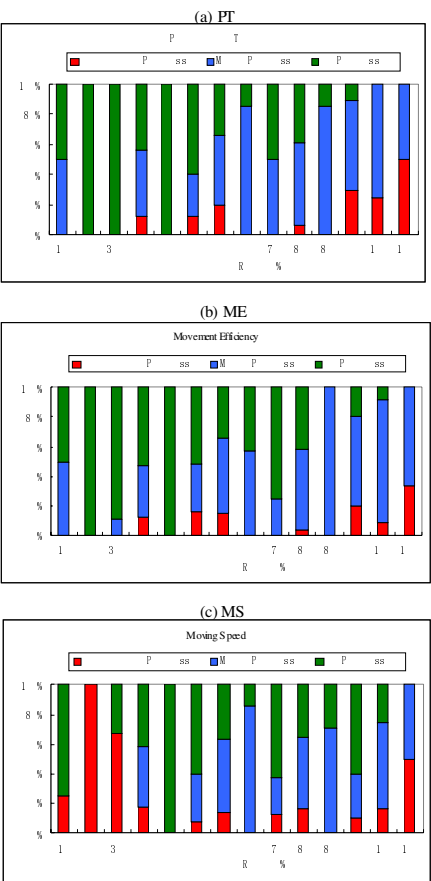


Fig. 10. Performance versus arm length

4 Conclusion and Future Work

4.1 Conclusion

A VR aided upper extremity motor training system was designed to meet the needs of both patients and therapists. Representative measures, PT, ME and MS were defined to represent kinematic features of performance. An evaluation approach was developed to generate performance and progression maps that allowed visualization of the current status (performance) and the change in status over sessions (progression) of kinematics measures.

The presented case study of subject 103 reveals the patient's current status with respect to his/her range of reach ability composed of pitch, yaw and arm length. Further, progression of movement ability was found and visualized over a series of practice sessions for this individual. Progression occurred predominantly in zones with lower initial performance levels.

4.2 Future Work

Analysis of the remaining subjects' data will be completed to further investigate the statistical model. A larger scale clinical trial including both patients' post-stroke and healthy controls is needed to provide a more robust data set for further study. Advanced learning-based algorithms will be developed to allow systematic analysis of large amounts of data across multiple dimensions of movement. Further, an easy-to-use tool for evaluation of a patient's current status and progress over sessions needs to be developed to assist the clinician in decision making and treatment planning.

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