Michelle M. Robertson (Ed.)

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Ergonomics and Health Aspects of Work with Computers

International Conference, EHAWC 2011
Held as Part of HCI International 2011
Orlando, FL, USA, July 2011, Proceedings

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Foreword

The 14th International Conference on Human–Computer Interaction, HCI International 2011, was held in Orlando, Florida, USA, July 9–14, 2011, jointly with the Symposium on Human Interface (Japan) 2011, the 9th International Conference on Engineering Psychology and Cognitive Ergonomics, the 6th International Conference on Universal Access in Human–Computer Interaction, the 4th International Conference on Virtual and Mixed Reality, the 4th International Conference on Internationalization, Design and Global Development, the 4th International Conference on Online Communities and Social Computing, the 6th International Conference on Augmented Cognition, the Third International Conference on Digital Human Modeling, the Second International Conference on Human-Centered Design, and the First International Conference on Design, User Experience, and Usability.

A total of 4,039 individuals from academia, research institutes, industry and governmental agencies from 67 countries submitted contributions, and 1,318 papers that were 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 Michelle M. Robertson, contains papers in the thematic area of ergonomics and health aspects of work with computers (EHAWC), addressing the following major topics:

- Quality of working life
- Health and well-being
- Interactive devices and interfaces

The remaining volumes of the HCI International 2011 Proceedings are:

- Volume 1, LNCS 6761, Human–Computer Interaction—Design and Development Approaches (Part I), edited by Julie A. Jacko
- Volume 2, LNCS 6762, Human–Computer Interaction—Interaction Techniques and Environments (Part II), edited by Julie A. Jacko
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- Volume 21, LNAI 6781, Engineering Psychology and Cognitive Ergonomics, edited by Don Harris
- Volume 22, CCIS 173, HCI International 2011 Posters Proceedings (Part I), edited by Constantine Stephanidis
- Volume 23, CCIS 174, HCI International 2011 Posters Proceedings (Part II), edited by Constantine Stephanidis

I would like to thank the Program Chairs and the members of the Program Boards of all Thematic Areas, listed herein, for their contribution to the highest scientific quality and the overall success of the HCI International 2011 Conference.

In addition to the members of the Program Boards, I also wish to thank the following volunteer external reviewers: Roman Vilimek from Germany, Ramalingam Ponnusamy from India, Si Jung "Jun" Kim from the USA, and Ilia Adami, Iosif Klironomos, Vassilis Kouroumalis, George Margetis, and Stavroula Ntoa from Greece.

This conference would not have been possible without the continuous support and advice of the Conference Scientific Advisor, Gavriel Salvendy, as well as the dedicated work and outstanding efforts of the Communications and Exhibition Chair and Editor of HCI International News, Abbas Moallem.

I would also like to thank for their contribution toward the organization of the HCI International 2011 Conference the members of the Human–Computer Interaction Laboratory of ICS-FORTH, and in particular Margherita Antona, George Paparoulis, Maria Pitsoulaki, Stavroula Ntoa, Maria Bouhli and George Kapnas.

July 2011 Constantine Stephanidis

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HCI International 2013

The 15th International Conference on Human–Computer Interaction, HCI International 2013, will be held jointly with the affiliated conferences in the summer of 2013. It will cover a broad spectrum of themes related to human–computer interaction (HCI), 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. More information about the topics, as well as the venue and dates of the conference, will be announced through the HCI International Conference series website: http://www.hci-international.org/

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New Ways of Working: A Proposed Framework and Literature Review

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Abstract. The drive towards new ways of working is of great relevance to our modern world. Many companies and organizations have introduced aspects of this new approach in recent years, while many others are on the verge of doing so. The new way of working consists of a large variety of measures enabling flexibility in time and place Expectations are often high: those who embrace such innovations aim to reduce operating costs and create more productive employees. However, it is worth asking whether these expectations are realistic. To date, very little research has been done on how the introduction of new ways of working affects operational objectives. This article is aimed to provide an overview of the available knowledge of the effects of the new way of working concept through scientific research and by developing a clearly defined framework. Some of the most important findings are outlined.

Keywords: New way of working; flexible working, telecommuting, teleworking, home working, activity related work, social ICT, flexible office environment.

1 Introduction

The current economy is fundamentally changing at some point. In the past decade we have changed towards a knowledge driven economy and information society. Organizations need to respond more rapidly to customer needs, and the pressure to become more customer centered is increasing. The value of customers and employees is becoming more prominent. And information and communication technologies are developed in a way that digital information is available at any time at many places. Parallel to this the hierarchical structures are gradually replaced by more flexible network models, and we increasingly rely on knowledge and good ideas rather than physical labor. As a result, we see that the way we work is drastically changing [1]. For example WorldatWork [2] estimated that 12.4 million American employees worked from home or remote at least one day per month in 2006, which increased up to 17.2 million in 2008. In the UK the number of teleworkers is estimated to more than double in popularity in eight years to 2.4 million workers [3], indicating that telecommuting continues to become an omnipresent work arrangement [4].

Many organizations see potential opportunities in the transition to new ways of working (NWW) and in Western Europe the number of organizations that have

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implemented a form of NWW is rapidly increasing. The majority of the changes are made because they have a certain benefit in mind, without having a clear understanding of the overall effects. Assumed benefit of this new ways of working is an increase in employee productivity by better facilitating the work task with ICT and workplace design, and by providing employees with more autonomy in where or when to work. It is assumed that the employees will experience a greater flexibility in the way they work with colleagues, experience more balance in the personal work situation, and increased mobility in work hours [5]. On firm level a reduction of commuter traffic and thereby CO_2 emission is reported, while also contributing by solving the mobility problems. Another beneficial aspect is a more efficiently use of the available number of square meters office buildings [6].

Even though expectations of the NWW are high, there is a lacking of good (quantitative) and multi factorial scientific research that clarify the effects [5, 7]. Organizations adopting the new way of working have ensured that there is an arising need to measure, map and interpret the business objectives in such way that it better suit the new work situation. For example increase their focus on result outcome and impact on customer's satisfaction instead of focus on face time. Gaining knowledge on this topic can provide organizations with a better understanding and (at forehand) insight in the effects of their NWW investment or policy decisions regarding the implementation.

The magnitude of the new way of working, especially in relation to business goals is large and complex. First of all there are a brought variety of definitions on NWW, and the term New Ways of Working is often used inappropriately to refer to less far-reaching changes in office measures and working methods. At this moment no framework exists concerning the measures that should be included in the definition (i.e. teleworking, home working, internet access, management trough trust). Secondly, besides the missing framework on NWW measures, it seems like organizations use NWW arrangement to reach a broad variety of business objectives (i.e reducing cost, attracting talented employees, increase productivity). Supplementary to that, the different companies and organizations also differ in the way they monitor business objectives. For instance, productivity, especially which of knowledge workers, is very difficult to assess, since it includes qualitative factors as well as many relevant factors that are of a quantitative nature [10].

Setting a defined framework on NWW measures as well as on business objectives is necessary to frame the topic and in order to study the scientific literature. In order to investigate the effect of NWW measures the framework needs to include relationship between measures and different business objectives. This article is aimed to provide an overview of the available knowledge of the effects of the NWW measures through scientific research and by developing a clearly defined framework. The research question is: "What is the scientific proof of the relationships between different NWW measures in relation to business goals, and can we use this information in order to compose a NWW framework?" In this paper we will outline some of the main results on the effect of NWW measures in relation to productivity and present the framework of the NWW.

2 Method

The first step to study the NWW measures in relation to business goals was conducting a literature review. The objective of the review study is to provide insight on what is known about the relationships between NWW measures and the business goals. This review was based on an electronic literature search in Dutch- and English-language databases (Web of Science, Science Direct, Scopus and TNO database) and by the references of the articles that were found. Because of the currency of the topic we made a selection of recent studies (published between 2000 - 2010), or the research should be adequate enough to generalize the content to the present situation. Based on literature findings a first framework is created.

The focuses of this literature study is in knowledge-intensive organizations, defined as “Companies where most work can be said to be of an intellectual nature and where well-qualified employees form the major part of the workforce” [11]. For the NWW arrangement we used the following definition: “New Ways of Working is an outlook of ways of working that corresponds as closely as possible to the needs of the knowledge worker”. It leads to the creation of a productive, sustainable, inspiring working environment that promotes the performance of both the team and the individual by means of technological and social innovation”.

Keywords to search on the NWW topic were selected by the use of several expert opinions and based on the topics referred to in the available general NWW literature. Combinations of keywords on group 1: NWW measures as well as group 2: business objectives were used. The search terms consisted of the following keywords: flextime, flexible measures, telecommuting, teleworker, ways of working, mobile work, computing, telecommuting, spatial flexibility, distributed organization, remote work arrangement, flexible work, task related office environment, flexibility office, desk-sharing, online collaboration, video conference, internet access, workplace flexibility, workplace concepts management on trust(group 1), employee health, sickness absence, knowledge sharing, organization attractiveness, employee engagement, effectiveness, performance, team effectiveness, team performance, work satisfaction, work life balance, work family balance, work family benefits, work family enrichment, work family interaction, work home interference (group 2).

The articles were selected by the following inclusion criteria: First, the study should be published in the English or Dutch language in a peer-reviewed journal. Or it is a description of a well founded theoretical framework published in a peer-reviewed article. Secondly, the population studied should be sufficiently representative for a knowledge or information workers, so that research generic interpretable is possible. Thirdly, central to the article should be an NWW aspect, and / or a mediator and / or a business objective. Fourthly the article should properly describe the research set-up, the type of research methods, inclusion of a representative group of subjects, and measurement instruments used.

From all papers that resulted from the search strategy in the electronic databases, the abstracts were analyzed by TNO experts. Papers that appeared not to meet our inclusion criteria were excluded. In case the abstract did not provide sufficient information, the full paper text was screened. Next, the reference lists in the remaining papers that met our inclusion criteria, were analyzed to search for more relevant papers.

The second step is to fill the 'gaps' in literature results with experts' values. This is done in meetings with both experts in social or behavioral science and experts from the field where NWW are implemented. The meetings are set up and guided according to a protocol that provokes a balanced valuing of experts opinion called MARVEL. MARVEL is a Method to Analyse Relations between Variables using Enriched Loops (MARVEL). The method is developed in order to obtain insight into the effects of interventions. It is designed as a tool for conducting a first policy intervention analysis for problems with a limited availability of quantitative data. Since this is the case with the literature on NWW, the use of the MARVEL tool will be examined in order to get a better understanding of the complex effects of NWW.

3 Results

The literature review revealed some interesting relationships between NWW measures and business objectives. The quantity as well as the quantity of the relevant studies were however somewhat disappointing. A total of 176 articles were selected. After the screening this resulted in 44 articles with useful information to underpin the theoretical framework. Based on the results a framework of definitions and principles on HNW measures were made. The results presented here outline the definitions and principals and show some of the most important findings of this review in relation to the business goal productivity.

3.1 Definitions and Principles

A selection of NWW measures is made to focus on the most common and more important most potential measures for successful implementation of NWW. The measures for the framework are selected together with representatives of four different companies (KPN, Rabobank, Philips Real Estate, and Veldhoen + Company) that apply NWW in different forms of execution. The following measures were selected:

- Working from home
- Activity-related working: the use of work locations within their organization that correspond most effectively with the specific task they are carrying out at a particular moment. Ideally, employees should use a different workspace for each distinct task.
- Satellite offices: the use of offices outside of their own organization to carry out their tasks, for instance at the customer's premises.
- Mobile working: carry out work tasks while travelling (e.g. commuting or on business trips).
- Flexible working hours: carry out the work tasks inside and outside standard working hours.
- Using internet access.
- Use of social network services for example LinkedIn or Facebook.
- Use of video conferencing for communication and/or activities (e.g. meetings) with internal and external people working at other locations.

- Use of collaborative tools to carry out joint activities/tasks that involve internal and/or external collaborators (e.g. Wikis, social text, document sharing).
- Management based on trust: To achieve a working relationship between employer and employee that centers on mutual trust and commitment, rather than rules and workers' rights. This new kind of working relationship creates space for employees to be enterprising, thereby leading to a general rise in the achievements and boosting the competitive position of the organization as a whole. The employees are self-motivating and take initiatives while the managers give space and offer autonomy, as well as providing clarity about duties, frames of reference and levels of authority.

3.2 Relationship between Flexible Working and Productivity

The found studies on the relationship between flexible working and productivity, 7 studies in total, are difficult to compare since they differ in objective, definitions and use different measurement methods. Even though some evidence is found, we did not find strong convincing evidence on the effects of flexible work on productivity.

One of the found studies consisted of a review study of 80 academic articles concerning flexible work [12]. Their study showed little clear evidence that telework increase satisfaction and productivity. In 2007 a meta analysis was conducted on telecommuting [13]. They suggest that telecommuting is likely more good than bad for individuals and found small but favorable effects on perceived autonomy, work–family conflict, job satisfaction, performance, turnover intent, and stress. On the contrary, they found that telecommuting also had no straightforward, damaging effects on the quality of workplace relationships or perceived career prospects. Inconsistent results are also found in the study of Beauregard and Henry [14]. Some studies found no effect of teleworking on productivity [8] or even negative effect [14]. One studies reported that telework is more likely to cause an increase of work overtime, which should not be defined as an increase of productivity, but as a risk factor for health [15].

Another interesting study that was found focuses at productivity on business level [17].and tried to explore the relationship between teleworking adoption, workplace flexibility and firm performance by studying 479 small and medium sized firms. They concluded that the contribution of teleworking to firm performance is very significant and suggests that teleworking can increase organizational flexibility and generate sustainable competitive advantage.

3.3 Relationship between Flexible Office Environment and Productivity

According to De Croon et al, [18] there is a lack of consistent evidence for the effect of flexible office environment on the productivity of employees. The exact implementation of the physical office environment and the match between workspaces and work tasks or activities of the employees mainly account for the success. Employees report an increase in communication as being one of the biggest benefits of the flexible office environment compared to traditional owned workplaces [19]. It is unknown whether an increase in communication will result in an increase of job performance [20] and it is assumable that this relies on function type. The study of

Robertson and Huang [21] suggest that when an office work environment is ergonomically designed and coupled with training, it provides employees with a high degree of environmental control and knowledge, which may positively influence individual performance, group collaboration and effectiveness. Results of the study revealed that satisfaction with workstation layout had a significant relationship with individual performance, group collaboration and effectiveness. These results are underpinned by the results of 2008, where the effect of workspace design was studied. Optimizing the workspace design in order to support group and individual work, in combination with providing ergonomic training and information to employees significantly reduced the business process time [22].

3.4 Relationship between Flexible Work Times and Productivity

A review of Beauregard and Henry [14] reveals that there is no conclusive evidence for the existence of a relationship between working on flexible hours and productivity. Some studies show that self rated productivity is higher when employees experience more flexibility in work times. Other studies show that with minimal flexibility, (e.g. agreement on the specific hours at forehand), an optimum of productivity was achieved. At firm level flexible work hours seem to result in positive productivity effects. A few explanations for the increase in productivity is that employees choose the best moment to perform the job, have better balanced work and privet lives causing less interference and reduce traveling time [14].

3.5 Relationship between Collaborative Tools and Productivity

The European commission [23] has conducted a study on the effects of ICT on firm productivity, measured in terms of turnover growth. They report a growing consensus that ICT does have positive effects on labour and total factor productivity. For a long period of time it was unclear what the relationship was between ICT investments and the productivity of a company. The conclusion of the study states that there is limited evidence for the existence of the relationship, although the causality remains unclear [23]. In the study of Kratzer et al, [24] an increase in creative productivity is seen when team members have autonomy on which communication tools they are able to use (face-to-face or collaborative tools). Productivity (expressed by creativity) of the team was lowest when team members constantly were space dependent (face-to-face) or constantly place independent (collaborative tools). However, other study report otherwise [25]. For meetings where decision making plays an important role, it is suggested to use face-to-face meetings in stead of ICT systems. Although the quality of the results is similar, the face-to-face groups were more efficient [26].

3.6 A First NWW Framework

Based on the literature and expert opinions a framework, and definition of NWW measures could be made (figure 1). This framework shows the NWW measures on the one side and the business objectives on the other side and the effects found in the literature review are displayed using black dotted lines. Only productivity effects are presented in this paper.

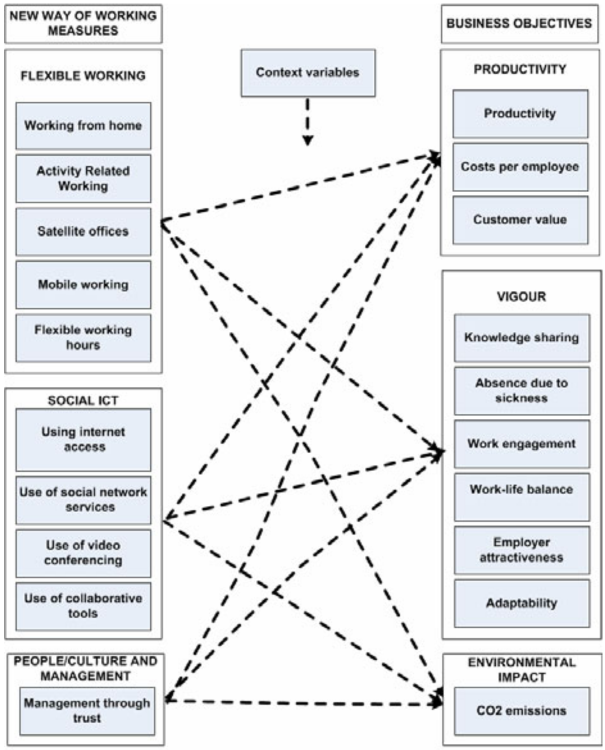

Fig. 1. Simplified framework of the relationships between NWW measures and business objectives

This framework is input for the experts meeting and MARVEL method. The MARVEL results are not available at the time of publication of this paper.

4 Discussion

From the literature review we gained inside in the effect of some critical factors that influence the extent in which NWW measures affect business goals. The lack of a coherent framework, no standardized definitions and the brought variety of scientific research found, caused a great difficulty to compare and interpret the research findings. For the business objective productivity, a wide variety of different measures were found, and almost no objective measures. For knowledge intensive work it is of great importance to focus on quantity as well as quality productivity outcomes. We suggest using the definition defined by the Q2 model of Rhijn et al. [10], in which productivity is defined as a function of the ratio between outputs and inputs both in terms of quantity and quality. They define quantity as an aspect related to efficiency, 'doing things right', whereas quality is associated with effectiveness, 'doing the right things' [27].

The framework that is presented provides us with a first outline of the relationships between NWW measures and business objectives. An important factor that is not included in this framework and might affect the relationships between NWW and business objectives is the interaction effect between NWW measures. The success of NWW appears to be associated with the correct interaction of the implementation of NWW measures. For instance a good combination between the use of ICT resources, establishment of the physical environment and management style is of great importance for the success and actual outcome on business objectives.

A second factor that might affect the relationships in the NWW framework is the way in which the NWW programs are implemented in organizations. Researchers suggest that this is of great relevance for the success outcome, but how involvement affects the business objectives remains unclear [28]. This is partially confirmed by study of Lee and Brand, who showed that higher group cohesiveness is perceived when employees experienced more personal control over the physical workspace [29] and it might increase productivity as well. A third factor that influences the effect of NWW and should be taken into account is the differences in individual characteristics. The individual characteristics such as need for autonomy [30], age [31] and privet family situation [14]. might effect on the relationships shown in the framework.

The above discussed interfering factors (referred to as context variables) show the complexity of the framework. We see the NWW framework as a base which needs further research in order to gain more scientific insight. MARVEL is a first attempt to fill the framework, but is expected to lead to a priority of hypothesis that should be researched in the coming years.

5 Conclusion

The objective of this research study was to investigate whether it is possible to establish relationships between HNW measures and business objectives in an integrated theoretical framework. All together the literature research increased the understanding of the existence of relationships between the NWW measures and business objectives and has resulted in an initial outline and scoping of the NWW framework. For a small number of the hypothetical connections, the scientific literature provided conclusive information on the effect of a particular NWW measure on business objectives. However, this still left a large number of hypothetical relationships in the model for which there is no or relatively little scientific evidence. The advantage of the framework is that it concretizes the aspects of NWW in a set of measures and relates these to operational objectives, expressed as business objectives. It also defines the gaps in knowledge and highlights the particularly complex nature of the issue.

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References

1. Manoochehri, G., Pinkerton, T.: Managing Telecommuters: Opportunities and Challenges. American Business Review 21(1), 9–16 (2003)
2. WorldatWork Telework trendlines (2009), http://www.workingfromanywhere.org/news/Trendlines_2009.pdf
3. Office of National Statistics. Labor market trends (October 2005), http://www.statistics.gov.uk/StatBase/Product.asp?vlnk=550 (September 27, 2006)
4. Golden, T.D.: Avoiding depletion in virtual work: Telework and the intervening impact of work exhaustion on commitment and turnover intentions. Journal of Vocational Behavior 69, 176–187 (2006)
5. Virick, M., Da Silva, N., Arrington, K.: Moderators of the curvilinear relation between extent of telecommuting and job and life satisfaction: The role of performance outcome orientation and worker type. Human Relations 63(1), 137–154 (2010)
6. Vink, P.: Aangetoonde effecten van het kantoorinterieur: Naar comfortabele, innovatieve, productieve en duurzame kantoren (Proofed effects of office environment). Kluwer, Alphen aan den Rijn (2009)
7. Knight, C., Haslan, A.: Your place or mine? Organizational identification and comfort as mediators of relationships between the managerial control of workspace and employees' satisfaction and well-being. British Journal of Management 21, 717–735 (2010)
8. Hill, E.J., Ferris, M., Märtinson, V.: Does it matter where you work? A comparison of how three work venues (traditional office, virtual office, and home office) influence aspects of work and personal/family life. Journal of Vocational Behavior 63, 220–241 (2003)
9. Helminen, V., Ristimäki, M.: Relationships between commuting distance, frequency and telework in Finland. Journal of Transport Geography 5, 331–342 (2007)
10. Rhijn, G., van, H.K., ten, K.-E.L., Oeij, P.: Productivity assessment and improvement in knowledge intensive organizations and work processes: The Q2 model. In: 16th World Productivity Congress and European Productivity Conference, "Productivity at the Crossroads: Creating a Socially, Economically and Environmentally Responsible World", Antalya, Turkey, November 2-5 (2010)
11. Alversson, M.: Knowledge work and knowledge-intensive firms. Oxford University Press, Oxford (2004)
12. Bailey, D.E., Kurland, N.B.: A review of telework research: findings, new directions, and lessons for the study of modern work. Journal of Organizational Behavior 23, 383–400 (2002)
13. Gajendran, R.S., Harrison, D.A.: The Good, the Bad, and the Unknown About Telecommuting: Meta-Analysis of Psychological Mediators and Individual Consequences. Journal of Applied Psychology 92(6), 1524–1541 (2007)
14. Beauregard, T.A., Henry, L.C.: Making the link between work-life balance practices and organizational performance. Human Resource Management Review 19, 9–22 (2009)
15. van Echtelt, P.E.: Time-greedy employment relationships. Four studies on the time claims of Post-Fordist work. Gildeprint, Enschede (2007), http://dissertations.ub.rug.nl/faculties/ppsw/2007/p.e.van.echtelt/?pLanguage=en&pFullItemRecord=ON
16. Butler, E.S., Aasheim, C., Williams, S.: Does Telecommuting Improve Productivity? Communications of the ACM 50(4), 101–103 (2007)

17. Sánchez, A.M., Pérez, M., De Luis Carnicer, P., Vela Jiménez, M.J.: Teleworking and workplace flexibility: a study of impact on firm performance. Personnel Review 36(1), 42–64 (2007)
18. Croon, E.M., de, S.J.K., Kuijer, P., Kuijer, F.M., Frings-Dresen, M.H.W.: The effect of office concepts on worker health and performance: a systematic review of the literature. Ergonomics 48(2), 119–134 (2005)
19. Blok, M., Groenesteijn, L., Formanoy, F., De Korte, E., Vink, P.: Innovative Ways of Working: A Comparison of a Traditional and a Flexible Office Environment on Office Space Use, Performance, Privacy and Satisfaction. In: Vink, P., Kantola, J. (eds.) Advances in Occupational, Social and Organizational Ergonomics, pp. 218–227. CRC Press, Boca Raton (2010)
20. van der Voordt, D.J.M.: Winst en risico's van flexibele werkplekken. Delft/Naarden: Center for People and Buildings/Centrum Facility Management. (2002)
21. Robertson, M.M., Huang, Y.-H.: Effect of a workplace design and training intervention on individual performance, group effectiveness and collaboration: The role of environmental control. Work 27, 3–12 (2006)
22. Robertson, M.M., Huang, Y.-H., O'Neill, M.J., Schleifer, L.M.: Flexible workspace design and ergonomics training: Impacts on the psychosocial work environment, musculoskeletal health, and work effectiveness among knowledge workers. Applied Ergonomics 39, 482–494 (2008)
23. Koellinger, P.: Impact of ICT on Corporate Performance, Productivity and Employment European Commission, DG Enterprise & Industry. Dynamics. e-Business W@tch. Special Report No. 01 (December 2006)
24. Kratzer, J., Leenders, R.T.A.J., van Engelen, J.M.L.: Managing creative team performance in virtual environments: an empirical study in 44 R&D teams. Technovation 26, 42–49 (2009)
25. Lira, E., Ripoll, P., Peiró, J.M., González, P.: The roles of group potency and information and communication technologies in the relationship between task conflict and team effectiveness: A longitudinal study. Computers in Human Behavior 23, 2888–2903 (2007)
26. Cappel, J.J., Windsdor, J.C.: Ethical Decision Making: A Comparison of Computer-Supported and Face-to-Face Group. Journal of Business Ethics 28, 95–107 (2000)
27. Tangen, S.: Understanding the concept of productivity. In: Proceedings of the 7th Asia Pacific Industrial Engineering and Management Systems Conference, APIEMS 2002, Taipei, Taiwan (2002)
28. Becker, F.: Workplace planning, design, and management. In: Zube, E.H., Moore, G.T. (eds.) Advances in Environment, Behavior and Design, vol. 3, pp. 115–151. Plenum Press, New York (1991)
29. Lee, S.Y., Brand, J.L.: Effects of control over office workspace on perceptions of the work environment and work outcomes. Journal of Environmental Psychology 25, 323–333 (2005)
30. O'Neill, T.A., Hambley, L.A., Greidanus, N.S., MacDonnell, R., Kline, T.J.B.: Predicting teleworker success: an exploration of personality, motivational, situational, and job characteristics. New Technology, Work and Employment 24(2), 144–162 (2009)
31. Armour, S.: GenerationY: They've arrived at work with a new attitude. USA Today (2005)

Beyond the Technology Acceptance Model: Elements to Validate the Human-Technology Symbiosis Model

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Abstract. This chapter forms part of an area of research on the Human-Technology-Organisation relationship. This research has emphasised the emergence of closely linked, intense and symbiotic forms of activity in workplaces and at home. Despite the relevance of the « Technology Acceptance Model », the use of technology doesn't always depend on « perceived usefulness » and « perceived usability », but on the level to which a process of human-machine symbiosis has developed. Based on a survey of 482 respondents we examine this technosymbiosis on three dimensions: (a) a sense of control; (b) the benefit of human- machine mutual adaptation; and (c) the perception of utility. We show that the use of a new technology is correlated with a high level of technosymbiosis, i.e. correlated with these three elements. Finally, the link between these dimensions and the use of technology is established. This validation is based on the correlation between the average score of the rating of attitudes in a questionnaire and the number of technologies the respondents reported using ($r = .597$, $p < .0001$). In addition, these three dimensions explain for 35% of the variance (adjusted $R^2 = .355$) in the use of technology.

Keywords: Technosymbiosis, Neosymbiosis, Technology Acceptance, Human-technology relationship.

1 Introduction

A large number of theories try to explain the phenomena behind the use of new technologies. Globally, models of the human-technology-organisation relationship have been put forward which can be fitted into three categories [8, 9]:

- Models focused on operative acceptance emphasize that human-machine interaction must be ergonomically optimised to facilitate communication, to make it usable, convivial, simple, effective, efficient, and enjoyable… [4]. In this approach the interaction between humans and technology is often decontextualised from socio-economic and organisational processes which, however, give evidence about the context of use. The main objective is to design and develop technologies adapted to humans, aiming to guarantee a software operative acceptance leading to technology usage.

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- Social acceptance models address the problem of the introduction of new technologies into socio-organizational situations, highlighting the disrupting effect of the forms of regulation imposed by new usages which primarily depend on social factors. From this point of view, the impact of the technology depends on social acceptance, which is on the one hand an interpretation of the determinant variables of user acceptance (e.g.: perceived usefulness and perceived usability) [10] and on the other hand determined by the disruptive effect of factors involving social regulations (socio-economic organizational, and cultural changes…) [1].
- In symbiotic models, technology is considered as neither unknown nor distant, and nor foreign to us, which would justify our accepting or rejecting it, but it is regarded as an extension of ourselves, we live with it, humans and technology cohabit. Furthermore, technology is man-made: It appears as if humans have entered into a sort of technosymbiosis where they transfer what is programmable in themselves to technology, at the same time these technologies become symbiotic agents which transform human beings.

The aim of this paper is to highlight the importance of three variables in the characterization of the symbiotic relationship between humans, technology, and contexts. We will show that technosymbiosis is based on (a) a sense of mastery of technological uses, (b) a representation of the benefits of a mutual adaptation between human beings and technologies, and (c) a usefulness perception, all of which reinforce and augment technology usage. In order to do this we will return to the key points of the theory of human-technology-organization symbiosis, followed by the results obtained from our questionnaire of 14 items given to 482 respondents, these results fitting in with our model.

2 Human-Technology Symbiosis

2.1 Theoretical Reminder

Seeing the computer as a symbiont created by humans is a thesis developed by Licklider [17]. At that time, the famous American psychologist, who was greatly instrumental in giving the computer its present day form, had envisaged the emergence of an era of interdependence between human beings and computers, where the interaction between the two would become tightly linked: symbiosis. In this way users would be able to « dialogue »with the machine as they do with their fellow human beings enabling the provision of a real conversation. Since Licklider's first article, symbiosis, a notion originating from the Natural Sciences defined as « living together», is no longer reserved for relationships in nature, but also describes the relationship between human beings and their artefacts.

Today Licklider's ideas have never been more topical [11, 12, 13]. Technological evolution has proved him right: technologies are becoming more and more embedded, complex, miniaturised, robust, and autonomous... They have become invisible, yet they have an enormous impact on our lives whether we use them or not. The idea of the human-technology relationship in terms of symbiosis, hybridization, fusion or coupling, is of increasing relevance. In this sense, the interdependency formed between humans and their symbiont, the technological artefact is made explicit in the symbiotic approach.

More than 40 years later, the human-technology-organisation symbiosis model [2, 3, 4, 5, 6, 7, 8, 9]; postulates that human beings and technologies coexist so well that human beings shape technology just as technology shapes human beings. Without referring back to the theoretical elements, this symbiosis between humans and technologies produces permanent interactive loops enabling technology and the human psyche to develop in parallel. To summarize, the human-technology symbiosis theory can be synthesized into the following four ideas:

- **Co-extension**: Technology becomes a human extension. It stretches human skills, aptitudes, capacities and properties. Humans transfer what can be done by machines from themselves to their symbionts. Once this is achieved, the technosymbionts become a part of ourselves, possessing similar and expanded human properties (augmented intelligence, greater perceptivity, error management resilience, user empowerment…).
- **Co-evolution** defines the transformations occurring during the evolution of the two elements: Human beings benefit from their relationship with technology, which in turn (via inventors, designers and engineers) benefits from successive improvements. In the living world, co-evolution is often observed in the relationship between natural symbionts and their living hosts. In the technological world, technologies' features are integrated into an evolutionary process as part of sustainable and mutual interactions with human beings, this creating technosymbiosis. Interactions between natural and artificial organisms lead to competition driven evolution making adaptation necessary.
- **Co-action**. This is the state of permanent feedback of one element to the other elements. Human beings and technology act together following complex and continuous cycles. They have an effect on each other. Humans bring about changes in technology as the latter enables humans to bring about change in their own activities.
- **Co-dependence**. Humans have confidence in their technology and often use it to think, to act, to work, to expand their feelings, to communicate, to play, to buy… Humans rely on their technosymbiont to the extent that daily activities carried out in the past, have disappeared or have been forgotten. Sometimes humans cannot carry out certain activities without their techno-symbiont.

The metaphorical use of the biological term "symbiosis", has no other purpose than to describe an interdependent relationship between two living or non living entities who each benefit from cohabitation. But if the notion of human-techno-symbiosis is relevant in this respect, one needs to define the psychological factors which are required to demonstrate that humans engage his/her mind to live in a symbiotic relationship with technology.

2.2 The Human Perception of Technosymbiosis

By emphasizing that humans and machines are connected by strongly dependent links, the human-technology symbiosis theory assumes first of all that certain human beings have developed a high level of mastery of these technologies, more specifically, that they are confident in their capacity to use them.

Hence with this mastery, human beings have developed a strong **sense of control**. Experiencing a sense of mastery, means experiencing a sense of control of the technology that will enable them to understand it better, to define its limits, to understand how it functions, and even to develop the capacity to make repairs. The notion of technosymbiosis implies therefore that humans have developed sufficient mastery to enable them to interact with the technology.

However, a sense of control isn't enough to explain technosymbiosis, humans also perceive the benefits derived from **mutual adaptations** established with technologies, as for example, exchanging information, and knowledge transfer, developing forms of delegation, or sharing resources. This is what characterizes the notion of technosymbiosis: The existence of mutual adaptation where humans and machines gain new benefits through mutual adjustment.

Finally, symbiosis fosters a **perception of self performance**: The technology is perceived as useful and efficient, and hence it increases our sense of accomplishment.

3 Problem and Method

3.1 Main Questions

Our general research question is to investigate whether human behaviour, when facing technological systems can be assessed effectively according to a symbiotic framework which highlights the existence of technosymbiosis based on (figure 1):

- The benefit perceived through mutual adaptation: Humans and technology mutually adapt via the redesigning processes to upgrade the technology. It is the degree to which a person believes that mutual adaptations, from humans to technology and technology to humans, would give more benefits to upgrade interaction quality.

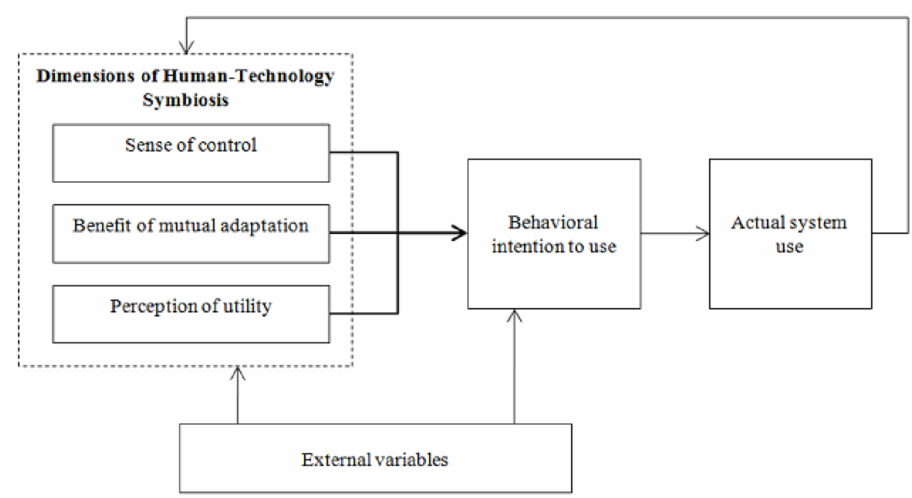

Fig. 1. Basic model of technosymbiosis

- Sense of mastery of the technology: Self perceived efficiency in the use of technology enhances the level of human technosymbiosis; that is the degree to which a person believes using a technology would enhance his or her sense of control of the technological world.
- Perceived utility related to the technology and perceived usefulness; that is the degree to which a person believes using a technology would empower their interaction or enhance their performance.

3.2 From Interviews to Questionnaires

The quantitative assessment was made in five stages:

- Setting out the questions. As well as the considerable bibliography on the subject, unstructured interviews were conducted with 4 interviewees. The aim was first, to verify the appropriateness of the themes used in conversation with the interviewees, and second, to check that the vocabulary used to design the questionnaire was generally easy to understand. On this basis 54 questions were constructed.
- Semi-structured interviews. These 54 questions were then given to 10 people with differing profiles. They responded to the questions as well as giving their opinions on the design of the questions and their understanding of them.
- Pre-test. The instrument was then given its first real examination through a pre-test on a sample of 172 people [6, 7]. This pre-test showed how well the instrument had been put together as well as indicating where the instrument did not work, particularly in certain items.
- Correction of parts which did not work well. The problems encountered in the deficiencies were taken into account in the current validated version of “questionnaire on human-technology symbiosis”. The items are shown in the table below (table 1).
- Final interviews. The items were again given to 10 people, as in stage 2. Finally, the questionnaire was self-administered to 482 people. The participants had to rate their agreement with the set of items on a Lickert type scale ranging from 0 (completely disagree) to 6 (completely agree). A high score for an item denotes a high degree of symbiosis, conversely a low score denotes a low degree of symbiosis

3.3 The Content of the Questionnaire

The questionnaire is split into two parts. The first part deals with collecting information about the participants, (age, profession, gender…) and their use of technologies (time spent using it, types of hardware/equipment/software used…). The second part comprises 14 questions on technosymbiosis (table 1). The statistical analysis seeks to validate the quality of the instrument and to describe its use (measured by how much technologies have been used) through a series of set attitude statements.

Table 1. List of items used to assess the hypothetical dimensions of technosymbiosis

Sense of control(6 items)	
Feeling of simplicity	*I find Information and Communication Technologies simple to use. (ICT).*
Sense of ease	*I feel at ease when handling ICT's.*
Operative agility	*I know how to obtain what I need from ICT's.*
Maintenance skills	*I think I am able to make repairs to ICT breakdowns.*
Control of change	*I know how to handle changes imposed by ICT's.*
High level of mastery of use	*I never have any problems with ICT's .*
Benefit of mutual adaptation (6 items)	
Adaptation to expectations	*Changes in ICT's increasingly meet my expectations.*
Adaptation to changes	*In the workplace or at home, I think ICT's generate changes that are easy to deal with.*
Preferential Adaptation	*For everyday activities I prefer using ICT's to more traditional methods.*
Belief in technological adaptation	*I feel that ICT's will meet my future needs.*
Benefit of inventiveness	*Social changes brought about by ICT's are beneficial as they enable me to be inventive.*
Benefit of fun and pleasure.	*Activities using ICT's become more enjoyable and fun to do.*
Perception of utility (2 items)	
Usefulness	*ICT's offer useful functionalities.*
Effectiveness	*ICT's offer functions which enable me to be more efficient.*

3.4 Sampling

The participants in the study have an average age of 39.7 (σ = 18.9). The sample (n = 482) is made up of French adults divided into three groups: students (167), employees (161) and senior citizens (154). Within these three subsamples, the proportion of women and men was split (47% women and 53% men. There was an equal distribution of participants by socioeconomic status in the sample.

4 Results

In order to validate our grouping of the attitude statements into conceptual meaningful sets, we conducted a principal components analysis. The matrix of partial correlations is shown in (table 2). The Eigenvalues for the three factors were 5.35, 2.15, 1.16 respectively. The first factor explains 38.25% of the variance, the second explains 15.39% and the last 8.31% (Cronbach's α = 0.88). From the component matrix, we can confirm that the distribution generally corresponds to our hypothesis, even though we would have thought that the benefits of adaptation would have had a greater weight.

Table 2. Results of the factor analyses and Cronbach's α

	Items / Factors	1	2	3	*α*
Sense of control	Feeling of simplicity	***.837***	.134	-	**.852**
	Sense of ease	***.882***	.107	-	
	Operative agility	***.665***	.308	.124	
	Maintenance skills	***.747***	-	.128	
	Control of change	***.733***	.187	-	
	High level of mastery of use	***.572***	.218	.200	
Benefit of mutual adaptation	Adaptation to expectations	.257	***.755***	.296	**.855**
	Adaptation to changes	.263	***.645***	-	
	Preferential adaptation	.446	***.589***	-	
	Benefit of inventiveness	.115	***.741***	.145	
	Belief in technological adaptation	.142	***.715***	.244	
	Benefit of fun and pleasure	.135	***.786***	-	
Perception of utility	Utility	.176	.156	***.859***	**.787**
	Efficiency	.118	.262	***.827***	

The first factor corresponds well to the theme of sense of control of technologies. We find once more, the configuration of the items linked to the need for people to control their technological environment, to feel at ease, and to master it as well as possible.

The second factor relates to the benefits of adaptation, which is that people perceive the benefit from adapting to technologies and technologies adapting to them.

Finally, the third factor which is made up of two items clearly refers to perceived usefulness as Davis [10] envisaged it; i.e. it refers to utility and perceived efficiency.

This analysis also highlights the relative weight of each factor: firstly the sense of control, followed by benefit of mutual adaptation and finally perceived usefulness. Whilst perceived usefulness is effectively a classic factor which is often identified [14, 15, 16], nonetheless, a sense of control and benefit of adaptation, add to our knowledge base in order to allow us to explain the use of technology. These two factors are essential for us to identify the technosymbiotic effects:

- Having the feeling of mastering the technology, i.e. controlling technology to develop a highly developed relationship between human and technology;
- Taking into account the benefits of the mutual adaptation of human and technology.

Finally, validating the link between measurements and the use of technology was made, based on the correlation between the average score of respondents to the questionnaire and the number of technologies they reported using ($r = .597$, $p < .0001$). In addition, the measured dimensions explain for 35% of the variance (adjusted $R^2 = .355$) in the use of technology.

5 Discussion – Conclusion

These results give weight to the notion of symbiosis which introduces the awareness of technological feedback on the user as being an important point in the use of technologies. On the fringe of the technological acceptance theories [14, 16], it appears therefore, that a successful human-technology relationship is not based, (not sufficiently, or not only,) on perceived usability and perceived usefulness, leading the user to develop intention to use, then actual use of the system, as believed in the social acceptance of technology theories. It lies in establishing a durable partnership based on interactions which will enable the development of a sense of technological control, the impression of a benefit of mutual adaptation, and perceived utility.

Today human beings draw the benefit of being connected to technology, which carries out certain tasks, leaving them free to do other activities, which sometimes, unfortunately, give little satisfaction. In any case, technosymbiosis is a form of relationship with technology, in the sense that its main aim is to help, facilitate, or give pleasure to the user in a given activity. It's about assisting the user in improving their degree of efficiency and quality of life. Technosymbiosis is also a process generating behaviour patterns which (a) reflect a process of technological mastery, (b) generate a benefit of mutual adaptation and (c) confer a perceived usefulness. No doubt, these three dimensions represent new leverage to a better understanding of human behavior in relation to technical systems and most of all to facilitate the integration of technology into the work place and at home.

References

1. Bobillier-Chaumon, M.-E., Bessière, C., Brangier, E.: Les effets du changement technologique sur le travail collaboratif. Revue d'Interaction Humain-Machine 4(1), 37–58 (2003)
2. Brangier, E.: L'assistance technique comme forme de symbiose entre l'homme et la technologie. Esquisse d'un modèle de la symbiose homme-technologie-organisation. Revue d'Interaction Humain-Machine 3(2), 19–34 (2002)
3. Brangier, E.: La notion de « symbiose homme-technologie-organisation ». In: Delobbe, N., Karnas, G., Vandenberg, C. (eds.) Evaluation et Développement des Compétences au Travail, pp. 413–422. Presses Universitaires de Louvain, Louvain (2003)
4. Brangier, E., Barcenilla, J.: Concevoir un produit facile à utiliser: Adapter les technologies à l'homme. Éditions d'Organisation, Paris (2003)
5. Brangier, E., Dufresne, A., Hammes-Adelé, S.: Approche symbiotique de la relation humain-technologie : perspectives pour l'ergonomie informatique. Le Travail Humain. Tome 72(4), 333–353 (2009)
6. Brangier, E., Hammes, S.: Élaboration et validation d'un questionnaire de mesure de l'acceptation des technologies de l'information et de la communication basée sur le modèle de la symbiose humain-technologie-organisation. In: Brangier, E., Kolski, C., Ruault, J.-R. (eds.) Actes de la Conférence Ergo'IA 2006, pp. 71–78. Estia, Biarritz (2006)
7. Brangier, E., Hammes, S.: Comment mesurer la relation humain - technologies – organisation ? Élaboration d'un questionnaire de mesure de la relation humain-technologie-organisation basée sur le modèle de la symbiose. PISTES 9(2) (2007a), http://www.pistes.uqam.ca/v9n2/articles/v9n2a1s.htm

8. Brangier, E., Hammes, S.: Les approches psychosociales du management des technologies de l'information et de la communication. In: Trognon, A., Bromberg, M. (eds.) Psychologie Sociale et Ressources Humaines, pp. 463–478. Presses Universitaires de France, Paris (2007b)
9. Brangier, E., Hammes-Adelé, S., Bastien, J.M.C.: Analyse critique des approches de l'acceptation des technologies : de l'utilisabilité à la symbiose humain-technologie-organisation. European Revue of Applied Psychology 60, 129–146 (2010)
10. Davis, F.D.: Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13, 319–339 (1989)
11. Griffith, D.: Neo-symbiosis: a system design philosophy for diversity and enrichment. International Journal of Industrial Ergonomics 36(12), 1075–1079 (2006)
12. Griffith, D., Greitzer, F.L.: Neo-Symbiosis: The Next Stage in the Evolution of Human Information Interaction. International Journal of Cognitive Informatics and Natural Intelligence 1(1), 39–52 (2007)
13. Hancock, P.A.: Man, machine and Morality: toward a philosophy of human-technology symbiosis. Ashgate, 184p (2009)
14. King, W.R., He, J.: A meta-analysis of the technology acceptance model. Information & Management 43, 740–755 (2006)
15. Lee, Y., Kozar, K.A., Larsen, K.R.T.: The technology acceptance model: Past, present, and future. Communications of the Association for Information Systems 12, 752–780 (2003)
16. Legris, P., Ingham, J., Collerette, P.: Why do people use information technology? A critical review of the technology acceptance model. Information & Management 40, 191–204 (2003)
17. Licklider, J.C.R.: Man-Computer Symbiosis. IRE Transactions on Human Factors in Electronics HFE-1, 4–11 (1960)

The Interaction Effect of Posture and Psychological Stress on Neck-Shoulder Muscle Activity in Typing: A Pilot Study

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Abstract. Work-related musculoskeletal disorders are common among computer users, especially involving the neck and shoulder region. Previous studies showed subjects with neck pain had altered muscle recruitment patterns that persisted throughout the sustained computing task. Moreover, some studies reported that working posture and psychological stress also influence muscle recruitment. Therefore the aim of this study was to investigate the interaction effect of working posture and psychological stress on muscle activity. Fourteen subjects (7 neck pain subjects and 7 healthy subjects) were recruited in this study. This study designated two working postures (upright sitting posture/ backward sitting posture) and two levels of psychological stress (standard typing task/ stressful typing task), and used surface EMG to collect the muscle activity of the upper trapezius and cervical erector spinae during a10-min typing process. Results showed psychological stress trends to increase the muscle activity, while a backward sitting posture trends to decrease muscle activity. Considering the busy and stressful life in modern lifestyle, this study suggests subjects with neck pain should maintain a backward sitting posture during computer use.

Keywords: Neck pain, Typing task, EMG, Working posture, Psychological stress.

1 Introduction

Work-related musculoskeletal disorders are common among computer users, with the neck and shoulder region being most often affected [1-2]. Many studies demonstrated increased neck-shoulder muscle activities in neck pain subjects [3-7]. Hall and Quintner [5] found increased upper trapezius (UT) activity with sensitized neural tissue in patients with painful cervical radiculopathy. Szeto et al. [8] demonstrated increased activity in the cervical erector spinae (CES) and UT muscles in neck pain subjects during typing tasks. Falla et al. [4] also reported subjects with neck pain

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demonstrated greater activation of accessory neck muscles during a repetitive upper limb task compared to healthy subjects. The gartering of neck-shoulder muscle activation may represent an altered pattern of muscle recruitment which compensates for reduced activation of painful muscles [4, 7]. On the other hand, psychological stress is thought to increase the risk of developing a musculoskeletal disorder in the neck-shoulder region [9]. Johnston et al. [10] reported the normalized EMG amplitudes of neck-shoulder muscles were increased during stressful typing tasks. These findings suggest an altered muscle recruitment pattern in neck-shoulder muscles during stressful situations.

Working posture also has an important effect on the muscle recruitment pattern. Many studies reported a significant association between forward head posture during computer processing and neck pain [7, 11-13]. Weon et al. [14] reported increased neck flexion angles were associated with significantly higher activity in the UT muscle. Szeto et al. [13] suggested the altered muscle recruitment have a relationship with the altered kinematics.

Some studies showed a marked reduction of the level of neck and shoulder muscle activity when a posture with the thoraco-lumbar spine slightly inclined backward was used [15-16], suggesting the backward sitting posture may be beneficial to the muscle recruitment pattern. However, the interaction effect of working posture and psychological stress on the neck pain subjects has not been studied.

2 Methods

2.1 Subjects

Fourteen subjects were recruited for this investigation (7 female and 7 males, age range=19–24 years). An interview questionnaire modified from the Standard Nordic Questionnaire [17] was used to collect information about musculoskeletal symptoms in the neck-shoulder region, including the right/left neck and shoulders. The inclusion criteria of case group were the subjects perform a minimum of 6 h of computer work daily, with moderate to severe discomfort in the right/left neck and shoulder regions (summed discomfort scores 5/40) for at least 3 of the past 12 months. The subjects with no complaint of neck and shoulder discomfort for less than 3 months and no present complaints (summed discomfort scores=0/40) were assigned to the control group.

2.2 Experimental Procedure

The experimental tasks were four typing tasks, each one lasted 10 min. This study involved four typing conditions, including: upright sitting-standard typing task (upright-standard), backward sitting-standard typing task (backward-standard), upright sitting-stressful typing task (upright-stressful), and backward sitting-stressful typing task (backward-stressful). The orders of the four typing conditions were randomly determined. Subjects were required to copy a text that appeared on their computer screen, by typing the text in another window. Subjects were not allowed to use the computer mouse. The definitions of working postures and workload conditions are:

1. Upright sitting posture (upright). In this condition, subjects were asked to maintain erect posture.
2. Backward sitting posture (backward). In this condition, subjects sit on chair in which the back support was angled backward 10°.
3. Standard typing task (standard). The subjects were requested to type at a comfortable pace.
4. Stressful typing task (stressful). Subjects were verbally encouraged to work faster and informed of the number of typing errors.

2.3 The Workstation

A chair with adjustable height was used. In each condition, the height of seat was adjusted to the fit the subjects' knees. The upper edge of the screen was 5–10° below the horizontal plane of eyes. The viewing distance was 400 mm. Table space in front of the keyboard was broad enough to support hands or forearms. The angle of elbow during typing was almost 90° [18].

2.4 Measurements

Muscle activity was measured by surface-EMG. Electrodes were placed over the right CES and UT muscles. For CES, the distal electrode was placed 10 mm lateral to C5 spinous process, and the proximal electrode was placed 20 mm above the distal electrode. For UT, the midpoint of the two electrodes were level with the midpoint between the acromion and the C7 spinous process [7]. The signals were amplified by a preamplifier placed close to the electrodes and then sent to the data acquisition unit of the NeXus-10 System (Mind Media B.V., Netherlands) that amplified and sampled the EMG inputs at 2048 Hz. All the EMG signals were processed in BioTrace+ (Mind Media B.V., Netherlands) program with a band-pass filtered at 20–500 Hz. Then the signals were down-sampled to 10 Hz RMS (root-mean-square). The EMG amplitude was normalized to maximum voluntary contraction (MVC, see Table 1) [7].

Subjects verbally rated their typing-related discomfort in four body regions (left / right neck and shoulder) on a numerical scales of 0-10 with 0 = no discomfort, 1 = minimal discomfort and 10 = extreme / intolerable discomfort. These four body regions were adapted from the Standardized Nordic Questionnaire [17].

2.5 Data Analysis

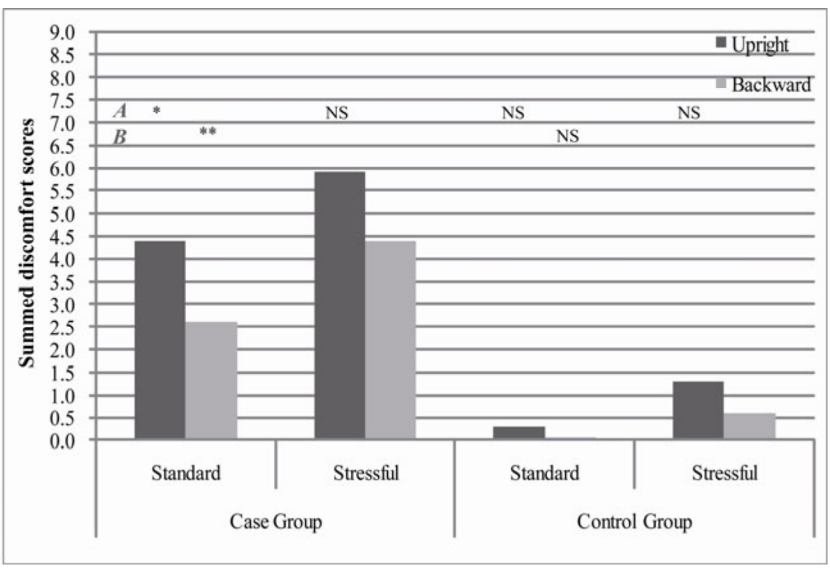
Paired t-test (SPSS 16.0 for Windows, 2008) was used to examine the difference of normalized EMG amplitudes and summed discomfort scores within the four typing conditions. Statistical significance was set at a probability level of 0.1.

Table 1. Maximum voluntary contraction tested in normalization for CES and UT muscles

Muscle	Starting position	Muscle action and application of load
Cervical erector spinae (CES)	Head in upright position	Neck extension- against resistant force at the posterior occiput
Upper trapezius (UT)	Arm in 0° flexion and abduction Scapula at neutral elevation	Scapular elevation- against adjustable strap on the acromioclavicular joint

3 Results

Fig.1. showed the mean values of summed discomfort scores. There were significant differences between the case group and control group in all four typing conditions (all p 0.05). Both subject groups have decreased summed discomfort scores in the backward sitting posture, although only the case group showed a significant difference (p 0.1) under the standard typing condition. Comparing the upright-stressful condition with the backward-standard condition, there was a significant difference in the case group; however, there was still no significant difference with the control group.



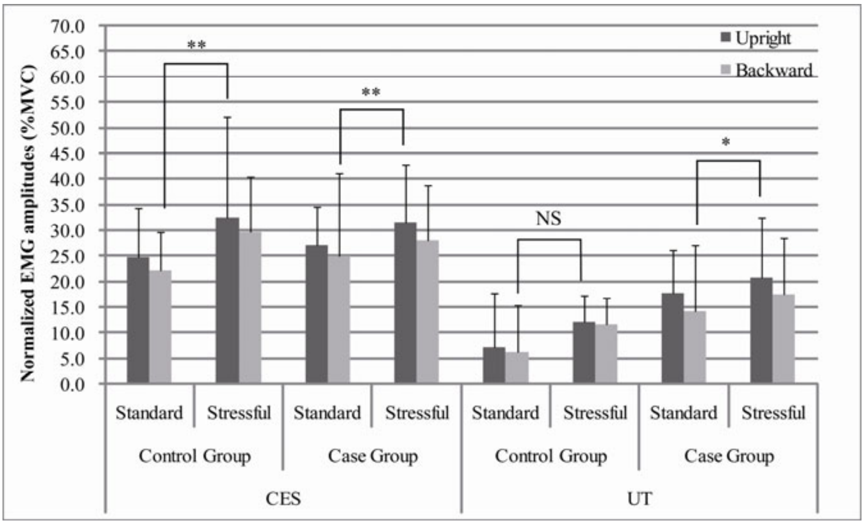
NS: no significant difference; *: significant difference with p 0.1; **: significant difference with p 0.05

A: Compared upright-standard with backward-standard; compared upright-stressful with backward-stressful (posture effect).

B: Compared upright-stressful with backward-standard (stress × posture effect).

Fig. 1. The mean values of summed discomfort scores

Fig.2 summarized the normalized EMG data of the CES and UT. Although no significant difference was found, these results show the UT muscle activity in the case group was higher than the control group; compared with the standard typing condition, both of these two groups showed increased muscle activity of CES and UT under stressful typing conditions; compared with upright sitting posture, both subjects groups have deceased muscle activity of CES and UT in the backward sitting posture. When comparing the backward-standard condition with the upright-stressful condition, there were significant differences in CES and UT muscle activities of case group (all p 0.05); however, significant difference were only demonstrated in CES muscle activities of the control group (p 0.1).



NS: no significant difference; *: significant difference with p 0.1; **: significant difference with p 0.05.

Fig. 2. The normalized EMG amplitudes of CES and UT

4 Discussion

This study compared four typing conditions to investigate the interaction effect of sitting posture and psychological stress on neck-shoulder muscle activities and summed discomfort scores. The results showed the backward sitting posture tends to decrease the muscle activities of neck-shoulder muscles, and the stressful typing condition tends to increase muscle activities. When comparing the upright-stressful with backward-standard, significant differences were found in the summed discomfort scores and normalized EMG amplitudes in case group.

Previous studies reported the symptom of pain, psychological stress and working posture all have significant effects on the muscle recruitment pattern [6-7, 10, 12-14, 19]. This study focused on the interaction of these factors. The order of summed discomfort scores was: upright-stressful backward-stressful = upright- standard backward-standard, showing that the subjects felt less discomfort when using the backward-standard condition, and reported most discomfort in the upright-stressful condition. Fall et al [20] reported that subjects with chronic neck pain had a reduced ability to maintain an upright sitting posture. O'Leary et al. [21] demonstrated decreased endurance of the craniocervical flexor muscles in neck pain subjects at 20% MVC. Since it is difficult to maintain an upright sitting posture, neck pain subjects were reported a forward head posture during computer use [13, 22]. The forward head posture has been associated with increased cervical compressive loading [23], and a significant association with neck pain [11]. Although the posture effect of summed discomfort scores in case group only showed significant different in standard typing tasks, the scores show a trend toward decreased discomfort in the backward sitting posture. When combining the stress and posture effects, the case group have significantly increased discomfort scores, however, there still no significant influence on the control group. An interesting finding there was no significant difference in any of the tests of summed discomfort scores of control group, means of most of the subjects in control group revealed no difference of discomfort during the four typing tasks, and that the muscle recruitment pattern was altered by the psychological stress and working posture.

The order of normalized EMG amplitudes of the two subjects groups was: upright-stressful backward-stressful upright-standard backward-standard, showing the upright sitting posture and stressful typing task tended to have increase the muscle activity, and conversely, the backward sitting posture and standard typing task were reported to reveal a trend towards decrease in muscle activity. When investigating the interaction of stress and posture (comparing the upright-stressful condition with the backward-standard condition), this study demonstrated significant differences of UT and CES muscle activities in the case group, revealing that stressful psychological conditions have a significant effect when combined with the upright sitting posture. Considering the busy and stressful life in modern society, maintaining a backward sitting posture is a good strategy for the neck pain subjects.

In conclusion, this study suggested the backward sitting posture is the prefer working posture for neck pain subjects during typing task, especially in psychologically stressful situations. The interaction effect of posture and stress also significant changed the muscle activities of CES in healthy subjects. However, no significant influences were found on subjective discomfort in the healthy subjects.

References

1. Gerr, F., Marcus, M., Ensor, C., Kleinbaum, D., Cohen, S., Edwards, A., Gentry, E., Ortiz, D.J., Monteilh, C.: A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. American Journal of Industrial Medicine 41, 221–235 (2002)
2. Klussmann, A., Gebhardt, H., Liebers, F., Rieger, M.: Musculoskeletal symptoms of the upper extremities and the neck: A cross-sectional study on prevalence and symptom-predicting factors at visual display terminal (VDT) workstations. BMC Musculoskeletal Disorders 9, 96 (2008)

3. Bansevicius, D., Sjaastad, O.: Cervicogenic headache: The influence of mental load on pain level and EMG of shoulder-neck and facial muscles. Headache 36, 372–378 (1996)
4. Falla, D., Bilenkij, G., Jull, G.: Patients with chronic neck pain demonstrate altered patterns of muscle activation during performance of a functional upper limb task. Spine 29, 1436–1440 (2004)
5. Hall, T.M., Quintner, J.L.: Responses to mechanical stimulation of the upper limb in painful cervical radiculopathy. Australian Journal of Physiotherapy 42, 277–285 (1996)
6. Straker, L., Skoss, R., Burnett, A., Burgess-Limerick, R.: Effect of visual display height on modelled upper and lower cervical gravitational moment, muscle capacity and relative strain. Ergonomics 52, 204–221 (2009)
7. Szeto, G., Straker, L., O'Sullivan, P.: A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work—1: Neck and shoulder muscle recruitment patterns. Manual Therapy 10, 270–280 (2005)
8. Szeto, G.P., Straker, L.M., O'Sullivan, P.B.: During computing tasks symptomatic female office workers demonstrate a trend towards higher cervical postural muscle load than asymptomatic office workers: An experimental study. Australian Journal of Physiotherapy 55, 257–262 (2009)
9. Waersted, M.: Human muscle activity related to non-biomechanical factors in the workplace. European Journal of Applied Physiology 83, 151–158 (2000)
10. Johnston, V., Jull, G., Darnell, R., Jimmieson, N.L., Souvlis, T.: Alterations in cervical muscle activity in functional and stressful tasks in female office workers with neck pain. European Journal of Applied Physiology 103, 253–264 (2008)
11. Chiu, T.T.W., Ku, W.Y., Lee, M.H., Sum, W.K., Wan, M.P., Wong, C.Y., Yuen, C.K.: A study on the prevalence of and risk factors for neck pain among university academic staff in Hong Kong. Journal of Occupational Rehabilitation 12, 77–91 (2002)
12. Yip, C.H.T., Chiu, T.T.W., Poon, A.T.K.: The relationship between head posture and severity and disability of patients with neck pain. Manual Therapy 13, 148–154 (2008)
13. Szeto, G.P.Y., Straker, L.M., O'Sullivan, P.B.: A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work–2: Neck and shoulder kinematics. Manual Therapy 10, 281–291 (2005)
14. Weon, J.H., Oh, J.S., Cynn, H.S., Kim, Y.W., Kwon, O.Y., Yi, C.H.: Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. Journal of Bodywork and Movement Therapies 14, 367–374 (2010)
15. Liao, M.H., Drury, C.G.: Posture, discomfort and performance in a VDT task. Ergonomics 43, 345–359 (2000)
16. Schüldt, K., Ekholm, J., Harms-Ringdahl, K., Arborelius, U.P., Németh, G.: Influence of sitting postures on neck and shoulder e.m.g. during arm-hand work movements. Clinical Biomechanics 2, 126–139 (1987)
17. Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., Andersson, G., Jørgensen, K.: Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics 18, 233–237 (1987)
18. Kroemer, K.H.E., Grandjean, E.: Fitting the task to the human. Taylor & Francis, London (1997)
19. Johnston, V., Jimmieson, N.L., Souvlis, T., Jull, G.: Interaction of psychosocial risk factors explain increased neck problems among female office workers. Pain 129, 311–320 (2007)
20. Falla, D., Jull, G., Russell, T., Vicenzino, B., Hodges, P.: Effect of neck exercise on sitting posture in patients with chronic neck pain. Physical Therapy 87, 408–417 (2007)

21. O'Leary, S., Jull, G., Kim, M., Vicenzino, B.: Cranio-cervical flexor muscle impairment at maximal, moderate, and low loads is a feature of neck pain. Manual Therapy 12, 34–39 (2007)
22. Szeto, G.P.Y., Straker, L., Raine, S.: A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. Applied Ergonomics 33, 75–84 (2002)
23. Harms-Ringdahl, K., Ekholm, J., Schüldt, K., Németh, G., Arborelius, U.P.: Load moments and myoelectric activity when the cervical spine is held in full flexion and extension. Ergonomics 29, 1539–1552 (1986)

Management Standardization Versus Quality of Working Life

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Abstract. In the paper there was defined notion of "quality of working life", starting from the definition included in the ISO90000 norm. The results of employees' satisfaction survey carried out in the following three years in the company having the integrated management system (ISO 9k, ISO 14k, ISO 18k & SA 8000) have been presented. The statistical analysis of the obtained results was carried out and the employees' satisfaction assessment method was proposed. The global assessment coefficients, variance analysis between groups of the employees, assessments correlation analysis and trend coefficient of changes received on the basis of the regression model were taken into account.

Keywords: quality, working life, statistical analysis, management systems.

1 Introduction

Discussion on operations and processes performed by an enterprise and their influence on quality of work environment and working life should start with a definition of the terms "quality" and "quality of working life". In the literature, there are numerous approaches to these terms. Heskett, Sasser and Schlesinger [1] define the term of quality of working life (QWL) as the feelings that employees have towards their jobs, colleagues and organizations that ignite a chain leading to the organizations growth and profitability. Lau, Wong, Chan and Law [2] operationalized QWL as the favorable working environment that supports and promotes satisfaction by providing employees with rewards, job security and career growth opportunities. Serey's [3]definition of QWL is related to meaningful and satisfying work. It includes (i) an opportunity to exercise one's talents and capacities, to face challenges and situations that require independent initiative and self-direction; (ii) an activity thought to be worthwhile by the individuals involved; (iii) an activity in which one understands the role the individual plays in the achievement of some overall goals; and (iv) a sense of taking pride in what one is doing and in doing it well. This issue of meaningful and satisfying work is often merged with discussions of job satisfaction, and believed to be more favorable to QWL. QWL [4] is thus a multi-dimensional construct, made up of a number of interrelated factors that need careful consideration

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to conceptualize and measure. It is associated with job satisfaction, job involvement, motivation, productivity, health, safety and well-being, job security, competence development and balance between work and non work life.

Plato defined quality of an item as a level of excellence it achieves. On the other hand, ISO 9000:2005 standard defines quality as a level of meeting requirements by a set of inherent characteristics. The important aspect of the last definition is referring the idea of quality with requirements – of customers (internal and external), of users and other interested parties.

In case of taking an effort to define quality of working life the parties of such an agreement (requirements – fulfillment of demands) are employees (potential employees) and employers. Thereby, it is necessary to admit that employees are the demanding party and employers are the meeting requirements ones. An employee, accepting negotiated or proposed by an employer working and financial conditions, determines the satisfactory level of quality of working life and requires fulfillment of the contract conditions. Therefore, if quality is defined as a level of meeting requirements, then level of meeting employees' requirements by employers defines their quality of working life.

Certainly, employees' requirements can not be unlimited (then we would deal with Plato's definition of quality). So, fulfillment of employees' requirements by employers consists in by presenting employees a job offer on conditions in compliance with the law of the particular country, customs, good manners, internal regulations concerning work and salary as well as enforced different management standards.

2 Working Life Quality

Thus, precise definition of the term "quality of working life" requires definition of the interested parties, namely employees working in the company, concerning this aspect.

In the course of three year survey done in the years 2007 – 2009, the employees of the same company from the electronics branch were asked the same question on the importance of factors concerning occupational satisfaction. The results have been presented in the fig. 1. It results from the figure that the employees consider decent salary for their work, good atmosphere, supervisors' respect, working conditions, opportunities for self - development and promotion as the most important factors. It is interesting that the hierarchy of the priorities did not change within the space of three years.

The results were confirmed by the experiment carried out by the authors of the paper, who as professional auditors and experts of certifying bodies, during numerous interviews with employees of various companies realized in SA8000, SEDEX and Code of Conducts audits, corporate standards of social responsibility and business ethics were identifying and analyzing the hierarchy of employees' requirements concerning quality of working life.

The conclusion from the research is the following: the most important expectations are:

- Fair salary,
- Occupational satisfaction (I like what I do),

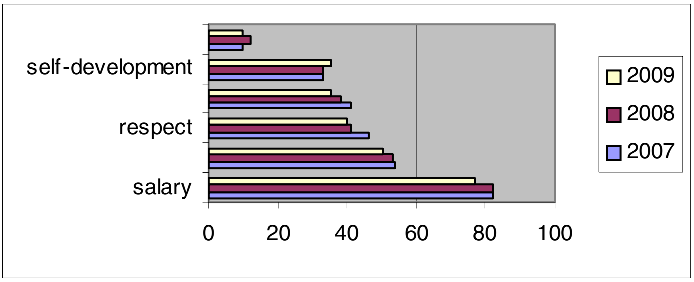

Fig. 1. Importance of factors concerning occupational satisfaction

– Supervisors' respect,
– Good organization of work and workstations,
– Safety, hygiene, ergonomics,
– Opportunity to prove one's independence (strict definition of responsibilities and rights).

Last but not least, the important aspects mentioned by the employees were respect for the natural environment, supporting local societies, enabling freedom of employees' societies.

3 International Standards Versus Life Quality Factors

Most of the requirements presented above are reflected in various management standards. For example, fair salary is directly mentioned in the point 8 of the SA8000 standard, safety and hygiene of work are mentioned both in the SA8000 standard (point 3) and in the OHSAS standard, supervisors' respect is mentioned in points 5 and 6 of the SA8000 standard, definition of the rights and responsibilities is mentioned in point 5.5.1 of the ISO 9001:2008 standard and environmental aspects are discussed in the ISO14001 standard. There are numerous examples of such connections between the employees' requirements and requirements of standards (factor\standard\clause and requirement): Economical demands (salary, working hours, overtime): SA (7. Working Hours, 8. Remuneration); SEDEX (5. Wages and Benefits, 6. Working Hours).

- Civil demands (discrimination, discipline, respect, interpersonal relations): SA8000 (2. Forced and Compulsory Labor, 4. Freedom of Associations & Rights to Collective Bargaining, 5. Discrimination, 6. Disciplinary Practices, 9. Management Systems – Addressing Concerns and Taking Corrective Actions); SEDEX (1. Employment Freely Chosen, 2. Freedom of Association, 4. Child Labor, 7. Discrimination, 9. Harsh or Inhumane Treatment).
- Social demands: SEDEX (announced indirectly).

- Legal and Technical Demands (for example labor code); ISO 9001 (1.1. General ruling), ISO 14001 (entirely), ISO 18001 (entirely), SA8000 (9. Management Systems – Polic); SEDEX (8. Regular employment, A. Entitlement to Work).
- Workstation Organization Demands (efficient procedures on workstations): ISO 9001 (5.5.3. Communication Inside of Organization, 6.3. Infrastructure, 6.4. Working Environment, 7. Execution of Product) [5].
- Safety and Health at Work: SA8000 (3. Health and Safety), ISO 18001 (entirely), SEDEX (3. Safety and Hygienic Conditions).
- Demands concerning environmental protection: ISO 14001 (entirely), SEDEX (B. Environment).
- Demands concerning self – development, competence, responsibility: ISO 9001 (5.5.1. Responsibility and Rights, 6.2.1. General Rules, 6.2.2. Competences, Awareness and Training); SA8000 (9. Management Systems – Planning and Implementation).
- Demands concerning employer's image: SA8000 (9. Management Systems – Outside Communication and Stakeholder Engagement, 9. Management Systems – Control of Suppliers/Subcontractors and Sub - suppliers), SEDEX (0. Management Systems and Code Implementation).

There arises an issue concerning influence of the implementation of these demands on quality of working life by employees.

4 Example of Research of Working Life after Implementation of Quality Integrated Management System

The considered example has been developed on the basis of the data obtained during survey of employees' satisfaction in the company from the electronics branch. The survey was carried out in the three following years (2007 – 2009), beginning with the time of the implementation of the quality integrated management system.

The survey covered three groups of the employees:

– office workers (**monthly**),
– laborers (accounted according to **hourly** rates),
– seasonal workers (**temporarily** employed).

The scope of the survey was very extensive and concerned as much as 24 criteria of working life, which were judged in the scale from 1 to 6 by the respondents. In the report the survey results have been presented in the form of layer charts built with percentages of answers, for the established scale of assessment. The fig. 2 presents the exemplary survey results.

The results concerned mainly identification of aspects assessed the worst by the employees. The results also concerned the recommendations to take actions in order to improve the situation. The results breakdown from the year 2007 was presented in the table 1.

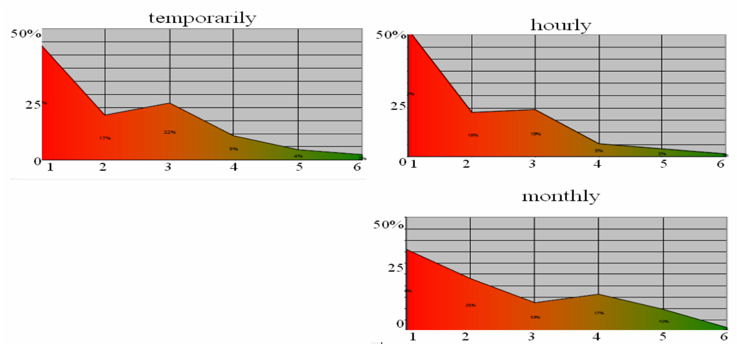

Fig. 2. Example of survey results of employees' treatment assessment in 2007

Table 1. Survey results on employees' satisfaction in 2007

Results following from opinion poll	Recommendations suggested by employees	Recommendations suggested by authors of survey
Especially positive evaluation: - Friendly atmosphere in work, - Salary paid out in due time, **Especially negative evaluation:** - Salary is too low, - Not keeping promises by management, - Treating badly employees by management, - Badly administered social services, - Bad organization of labor and management, - Communication system not effective, - Injustice in giving loans and bonuses.	- Replace production management staff and company board, - Free Saturdays or 100 % rate, - Extend breaks for employees, - Gift certificates for employees, - To put permanent contract of employment, - To shorten accounting period to one month, - Establish motivation rewards,	- Training for company management staff, - Continuation of training series for employees management staff, - Analysis of components of salary system, - Increase of employees' participation in disposal of social services assets, - Adding of new communication channels (company newspaper).

The conclusions from the two following years were very similar. However, on the basis of the results obtained this way, it is impossible to answer the following questions:

- Is it possible to admit, that the evaluation of working life is similar in the particular group of the employees?
- What is the tendency in assessment change after introduction of the quality management system?
- Which assessment categories of working life are statistically similar to each other?
- What is the global assessment of the company?

In order to answer all the above mentioned questions the following analytical and statistical methods were applied: \

- Correlation analysis of evaluation by different groups of employees,
- Analysis of directional coefficients of the regression and linear models (another criterion may be applied for the nonlinear models, on condition of many year's standing of survey),
- Analysis of variance – in order to identify similar categories of assessment of working life.

In the established method of assessment of the employees' satisfaction V was taken as a measure (for each of the criteria):

$$V=L_pR,$$

where: V – assessment measure, L_p – percentage of answers of a given value of assessment, R – value of assessment (1 to 6).

For the purpose of the further analysis 11 criteria were selected:

- Work station equipment,
- Medical care,
- Occupational health and care,
- Relations between employees,
- Working conditions satisfaction,
- Treating by supervisors,
- Communication,
- Information on shape of the company,
- Management,
- Salary,
- Social services.

As the result of the carried out correlation analysis [6,7,8] of the working life assessment given by different groups of the employees, one must say that in the years 2007 – 2008 the assessment does not differ essentially. Thus, the mean values can be assumed in the further evaluation procedure. The results of the correlation analysis were presented in the table 2.

The comparison of the global measure obtained from particular groups of the employees is the acknowledgement of the conclusions resulting from the correlation analysis of the assessment for the categories:

$$G_j = \frac{\sum_{k=1}^{K} V_{j,k}}{K},$$

where: G_j – global measure for j group of employees (j=1-3), $V_{j,k}$ – assessment measure made by j group of employees for k criterion (k=1-11), K – number of criteria.

Table 2. Report on correlation analysis from Winstat computer program (correlation investigation of assessments between employees groups) [7]

Number of observations = 66
Accepted significance level = 0.050

	Name of variable	Mean	Standard Deviation	Variation coefficient
1	X01->Monthly	177.5455	122.395432	68.94%
2	X02->Hourly	163.0909	100.703695	61.75%
3	X03->Temporarily	170.9242	105.217280	61.56%

Matrix of correlation coefficients

	1	2	3
1	1.000000	0.880780	0.827918
2	0.880780	1.000000	0.729480
3	0.827918	0.729480	1.000000

Critical region – two – sided
Critical value of correlation coefficient = 0.242276

The mean value of the global assessment $\overline{G}$ can be determined:

$$\overline{G} = \frac{\sum_{j=1}^{J} G_j}{J}, \; J=3.$$

Fig. 3 shows the distribution of the determined global measures in the particular years of the survey, their mean value and model of the linear regression.

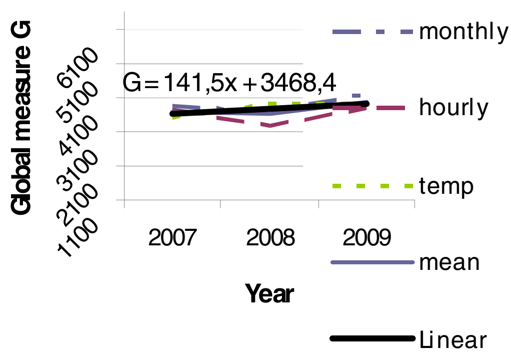

Fig. 3. Graph of global assessment of particular groups of employees and mean value

In the fig. 3 the scale for the values of G within the interval of 1100 – 6600 (tab. 3) was kept on purpose. It is an interval of the possible values of *G* in the considered example. This way of presentation of the calculation results indicates on what level the global assessment is while artificially adjusted scale might lead to false conclusions. It follows from the figure that the general assessment of working life is very similar in the examined groups of the employees and the mean value of that assessment reveals slight uptrend. The determined regression model (linear form) lets find out that at the existing level of the quality improvement of working life the assessment of G will have reached 5101 approximately in 7 years. Therefore, it is not the optimistic prognosis and improving actions must be intensified.

Table 3. Assessment scale of G coefficient

Value of G coefficient	Interpretation
1100 - 2100	Quality of Working Life - very low
2101 - 3100	Quality of Working Life – low
3101 - 5100	Quality of Working Life - average
5101 - 6100	Quality of Working Life – high
6101 - 6600	Quality of Working Life – very high

In order to identify the similarly assessed criteria groups the analysis of variance was applied. On the basis of the analysis the hypothesis of equality of the means of the investigated features in several populations is verified [9].

One made the null hypothesis H_o: mean values from the group are equal (H_0: $\mu_1=\mu_2=..=\mu_k$), i.e. the investigated criteria are assessed similarly, towards the alternative hypothesis H_1: mean values from the group are not equal (the investigated criteria are not assessed similarly) [7].

If the variance analysis does not reveal significance of the differences between the examined groups then no further tests will be carried out. However, if the null hypothesis is rejected in the variance analysis then a question arises, which of the compared populations are responsible for rejection of the null hypothesis. We would like to know, which out of *n* mean values differ between each other and which ones are equal. For that purpose more precise examination of differences between the mean values from particular groups should be carried out. In order to achieve that purpose special *post-hoc tests* (afterwards) will be applied. The test are also called multiple comparisons tests [7]. To evaluate homogenous groups the Duncan's test [9] was

Table 4. Report from Winstat computer program – variance analysis for assessment criteria [7]

```
  Ho: Main effects of coefficient A equal zero.
  H1: Not each of main effects of coefficient A are equal.
  Critical region RIGHT-HAND. Significance level = 0.050
  Calculated value of statistic F = 20.7451
  Number of degree of freedom of numerator = 10
  Number of degrees of freedom of denominator  =  88
  Ho has to be rejected in favor to the alternative hypothesis H1.
  --------------------------------------------------------
           Means arranged in ascending order.
  No of group   Name                     Mean
      6       Treatment                250.1111
     11       Benefits                 254.7778
      7       Communication            294.2222
      8       Information              306.0000
     10       Salary                   306.7778
      2       Medical care             369.1111
      5       Satisfaction             379.6667
      9       Management               385.5556
      1       Equipment                391.3333
      4       Relations                396.2222
      3       Safety and Health        417.6667
  --------------------------------------------------------
Test of homogeneity of groups (Duncan's test). Significance level = 0.05
  Homogenous groups and their means:
  --------------------------------------------------------
  { 2 5 9 1 4 3}:389.93, {7 8 10}: 302.33, {6 11}: 252.44
```

used. The variance analysis results for the assessment criteria of working life have been presented in the tab. 4.

On the basis of the obtained results of the variance analysis it might be assumed that there are three groups of the criteria assessed similarly. The treatment of employees by the employers and social services were assessed the worst. The communication in the company, information on the shape of the company and salary were assessed quite badly, too. The remaining categories were assessed by all the groups of the employees similarly, at the mean value of $\overline{V} = 390$ and the maximal value of $\overline{V}_{\max} = 660$.

In order to answer the question, what is the effectiveness of the introduced actions, the linear regression analysis was applied [9]. Table 5 contains the comparison of the directional coefficients of the regression models and percentage intensity of the realized improving actions.

Table 5. Prognosis assessment of criteria assessment changes of working life

Criterion	Value of directional coefficient of linear regression model	Percentage intensity of changes annually [%]
Benefits	105	21
Treatment	84,5	16,9
Management	76	15,2
Medical care	58,5	11,7
Equipment	48,5	9,7
Satisfaction	46,5	9,3
Communication	44,5	8,9
Information	43	8,6
Safety and health	15	3
Relations	-13	-2,6
Salary	-85	-17

A very good and vivid way to compare current assessments and change tendency is to present the values of these measures in the form of radar chart (fig. 4).

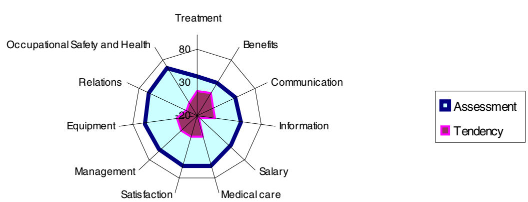

Fig. 4. Radar chart. *Assessment* – standardized mean values of assessment according to the scale 0 – 100. *Tendency* – percentage value of assessment change during year, determined on the basis of linear regression model

5 Conclusions

Implementation of the quality integrated management system does not guarantee the immediate improvement of quality of working life. It is a complicated process and it requires the systematic investigation of the effectiveness and efficiency of the implemented actions. In order to exactly determine the effects and recommendations it is necessary to carry out long – term investigation and monitor the obtained changes trends. In the method of the assessment of quality of working life it is important to consider the following aspects:

- identification of assessment criteria,
- selection of detailed and global measure,
- selection of employees groups and identification of compatibility of their assessments,
- determining criteria groups with similar assessments,
- prognosing assessments changes with determination of the trend coefficient of the changes.

While selecting a measure (coefficient) of the assessment it is important to remember the established scale and link the obtained results to the scale. More natural way and statistically precise is establishing a scale resulting from possible to obtain coefficients (no standardization) values. However, such a scale is difficult to compare with the results obtained from other investigations, for example benchmarking. Then, it is worth of standardizing the obtained results to the most often accepted range 0 – 100.

References

1. Heskett, J., Sasser, W.E., Schlesinger, L.: The Service Profit Chain. The Free Press, New York (1997)
2. Lau, T., Y.H., Wong, K.F., Chan, M.: Law.: Information Technology and the Work Environment-Does it Change the Way People Interact at Work. Human Systems Management 20(3), 267–280 (2001)
3. Serey, T.: Choosing a Robust Quality of Work Life. Business Forum 27(2), 7–10 (2006)
4. Rethinam, G.N., Ismail, M.: Constructs of Quality of Work Life: A Perspective of Information and Technology Professionals. European Journal of Social Sciences 7(1), 58–70 (2008)
5. Drożyner P. Mikołajczak P.: Maintenance of vehicles, machines and equipment in view of the ISO 9001 requirements. Maintenance And Reliability 4(36) (2007)
6. Krysztofiak, M., Urbanek, D.: Metody statystyczne. PWE Warszawa (1981)
7. Mikołajczak, J.: Statystyka matematyczna z pakietem Winstat. Wydawnictwo UWM Olsztyn (2001)
8. Wieczorkowska, G., Kochański, P., Eljaszuk, M.: Statystyka. Wprowadzenie do analizy danych sondażowych i eksperymentalnych. Scholar Warszawa (2003)
9. Stanisz A.: Przystępny kurs statystyki z zastosowaniem STATISTICA PL na przykładach z medycyny. Tom 2. Modele liniowe i nieliniowe, StatSoft Polska, Kraków (2007)

Human-Computer Interaction in Office Work: Evaluation of Interaction Patterns Using Office Equipment and Software during Data Entry and Navigation

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Abstract. This paper presents a study which objective was to investigate the human interaction with the equipment of an office workstation (mouse, keyboard, monitor, paper sheets, pens and calculator) during the activities of reading, writing, data entry and navigation in a computer system for long periods of time and with ecological validation. A sample of 22800 observations, which corresponds to 760 work-hours of 30 office workers, was classified into sixteen Interaction's Categories (IC). The results show that the participants read on the monitor more than on paper and they had a larger use of the mouse instead of the keyboard. Findings of this study allow suggesting what graphical interface designers must seek for new strategies and solutions to reduce the mouse need, exploring other peripherals as keyboard or voice recognition devices; or, at least, diminishing the amplitude of movement with the mouse during the interaction with office's software like the Microsoft® Office 2003.

Keywords: Office workers product interaction, Ergonomics procedures, Observations methods, Video display terminal.

1 Introduction

A rapidly increasing number of people are involved in work with computers for long periods of time. According to Anshel [1], more than 175 million of North Americans frequently use computers at their workplaces. In the beginning of the XXI's century, data from the European Foundation of Living and Working Conditions shown that the percentage of workers who are involved in computer work "all the time" or "almost all the time" is 19% in the European Union [2]. In many of these countries, because of this massification, a constant alert regarding the potential negative effects that the intense use of computers can cause is observed, with many published works in this area [3,4,5]. Most of them indicate that repetitive strain injuries (mainly in the hands,

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shoulders, arms and neck), eye injuries and psychological changes are caused by environmental conditions, excessive workload, and mainly by the several ways of interaction in the workstation of computerized work [6].

In a general way, the data regarding the workers' interaction with the workplace are collected in simulated laboratory conditions or in very controlled real situations. Although this kind of studies interferes with the tasks and with the natural behaviours of the workers, they have some advantage as: an accurate control of variables, a high potential to collect physiological measures and the accuracy of data collected, mainly the quantitative [7,8,9].

Handrick and Kleiner [10] argue that the main element for a good ergonomics analysis of the activity or for the products development is to adopt a systemic approach of activity through the analysis of all interactions possibilities in a real context of work. Thus, the techniques and experimental protocols usually used to evaluate the interaction with Visual Display Terminals (VDTs) fail by: (i) low ecological validity; (ii) lack of systemic evaluation - especially the lack of data-crossing between task, activity and equipment used in the workplace (e.g. keyboard, mouse, monitor); (iii) changing in the study's context due to the need to adapt the environment, the workplace and the individual to the equipment and procedures which are necessary to the data collection; (iv) do not collect all the components of the human behaviour in activity, even when the protocols are done in real work conditions, they use representations (simulation) of the real situation; (v) be very intrusive since they change the environment and even the work task for the studied work requirements.

When objective techniques (e.g. goniometry, pressure maps, electromyography) are used in activities which require the evaluation through long periods of time (as work with VDTs), they have some technological limitations, as they produce too much data and, consequently, there is an overload of the storage system with the impracticability of the statistical treatment of the data (mainly for studies that require periods of time higher than six hours a day).

In order to minimize the difficulty in applying these experimental methods in real context, researchers combine some objective with subjective techniques, which generally are qualitative such as questionnaires, interviews and direct/indirect activity observation. Usually, this approach is related also to the interpretation and evaluation of the comfort or discomfort [11,12,13] that is done through users testimony and the understanding of the real activity through self-report.

IJmker, *et. al.* [14] evaluated studies which made a correlation of muscle-skeletal disorders with the activities of the work with computers between 1967 and 2005. The authors conclude that many studies prefer to classify the interaction activities through the estimates from self-report questionnaires of workers than to do a direct evaluation of these interaction features. IJmker, *et. al.* [14] alerts for the need of studies that aims a better understanding about the computers' use through objective measures of the workers' interaction time with their workstation, namely the use of the main equipment as the mouse and keyboard.

In this context, the main objective of this study apply a systematic observations of the activities at the workstation through digital video recording using a methodology proposed by Rebelo, Filgueiras & Soares [16], to understand the human interaction with the equipment of an office workstation (e.g. mouse, keyboard, files, paper sheets, computer, among others) during the activities of reading, writing, data entry and navigation and using a computer system for long periods of time and with ecological validity. This knowledge will allow to: a) understand the origin and incidence of many work situations and problems; and, b) elaborate more specific recommendations to the products' development. However, for this paper we will present only the results for interaction patterns during the use of a set of specific Interaction Category - IC [16] (Typing, using the mouse and reading).

2 Methodology

This paper presents a part on a larger study and is based on the observation of a group of workers with the same work activity type (works with VDT's), working hours (eight hours/day), accessing to the same group of equipment and using the same model of chair, in order to analyze if there are similar patterns of interaction between users and the devices they use for data entry (mouse and keyboard) and reading (papers and monitor).

2.1 Study Site and Workstation Properties

Data were collected at the offices of a Portuguese company of food distribution. Thirty workstations with workers performing the same activity were selected. The workstations were in an open-space environment and all of them had: a) minimum of eight hours daily of work; b) similar activities, characterized as office work [15]; c) same devices (monitor, keyboard, mouse); d) same furniture and equipment (chair, desktop, cabinets, files, staplers, telephone and calculator); and, e) computers with the same hardware and software. Printer, fax and scanner are collective.

The company did not have software made specifically to address it needs so workers use those available in the market. All administrative activities were made using the pack of software available for all computers (Microsoft® Windows Vista Enterprise OEM, Microsoft® Office 2003 - with Word, Excel, Explorer, Outlook and Powerpoint - Internet Explorer and Mozila® FireFox). The computers did not have hard drive and the software installation was controlled by the main server. Internet Explorer and the Outlook were rarely used according users report in an informal interview.

2.2 The Subjects and Job Tasks

oThirty office workers (28 female and 2 male) were volunteers in this study (mean = 32 years old, SD = 8). The workers were distributed to: Accounting occupations (n = 8), Fleet Control (n = 7), Human Resources Management (n = 7) e Buying/Stock Control (n = 8). In an informal interview, none of the volunteers declared having chronic health problems or special conditions at the workstation. The data collection order was not influenced by the management section and it was decided by the participants.

Participants were informed about the study's objective through a group meeting and an individual approach in the day before of each video recording. All video collection was authorized by the participants through a form of consent.

Finally, participants were instructed to perform their tasks as usual and do not change their work schedule (amount of work using the computer) due to the presence of the cameras.

2.3 Recording Procedure and Features

The participants' interactions with the computer were video recorded on a normal working day and were assessed using: a) two infrared digital cameras (Swann - SW233-H2Y 2,5 GHz – color); b) one multiplexer video recorder (Bosch - DVR-8K with 8 channels 1 TB) and c) one tripod (Philips SBC-5307). All devices' lights were turned off or hidden and participants were informed about the placement of all cameras. However, they did not know the real video recording time.

The digital video cameras turned on automatically and all the workstation was filmed using two different plans (sagittal and superior) considering the best visualization of the participant and activity (Fig. 1).

In order to ensure similar interaction times in the workstation and to not interfere in the workers daily activity, all volunteers were filmed during three days during eight hours continuously (starting at 8:30 a.m.). After the filming period for each participant, a quick analysis of the video was done in order to select the best two days, according the following criteria:

- Longer retention of workers in the workplace (preferred > 6 hours);
- More than 60% of the video was with good visualization of the activities conditions.

If after the video analysis these criteria were not verified for two days of video, a fourth day was video recorded.

Fig. 1. Images of the two different plans (sagittal and superior) of the workstation Observations

The data, collected through video using a methodology proposed by Rebelo, Filgueiras & Soares [16], was analyzed regarding the register of interactions categories and was done using software developed for this purpose. The videos were observed and the ICs were classified by two trained observers in different moments. In this way, two groups of activities were defined: (i) Reading, and (ii) Data Entry and Navigation. The use of the computer was defined as the time attached to the computer with the hands (active use of mouse/keyboard or passive resting on mouse/keyboard) or eyes (viewing the screen).

2.4 Observations Interaction Categories - IC

Sixteen ICs were classified from the activity observation of real situations and from similar situations in the literature [17,18]. Table 1 and Table 2 present the codes and description for ICs "Reading" and "Data Entry/Navigation" groups.

Table 1. Code, IC and description for "Reading" group

Code	Interaction Categories	Description
R1	Reading on a single sheet of paper	Head directed to small amount of paper (<15 sheets) handling or on the table (i.e. single sheet).
R2	Reading on the screen	Head directed to the monitor screen without switching with Reading on paper.
R3	Reading on a volume of paper sheets	Head directed to big amount of paper (>15 sheets) handling or on the table (i.e. books, files).
R4	Reading on a specific support	Head directed to single paper sheets or files (>15 sheets) on a specific support.
R5	Reading on the screen and single sheet of paper	Head direction switching between small amount of paper (<15 sheets) and monitor screen
R6	Reading on the screen and sheets of paper on files	Head direction switching between big amount of paper (>15 sheets) and monitor screen
R7	Reading on panels	Head directed to magnetic boards, that is visible through the images and place in front of the workstation
R8	Others	Any activity that means some kind of specific Reading which were not anticipated.

Table 2. Code, IC and description for "Data Entry and Navigation" group

Code	Interaction Categories	Description
D1	Writing on sheets of paper or similar	Manipulation of writing devices (pen or pencil) and writing on sheets of paper or others.
D2	Typing on PC keyboard	One or two hands are (actively or passively) on the keyboard and no hand on the mouse.
D3	Navigation (using mouse)	One hand is on the mouse (actively or passively).
D4	Using external calculator	One hand is on the calculator (actively or passively).
D5	Using PC keyboard and mouse	One or two hands are (actively or passively) on the keyboard and sometimes with a hand on the mouse.
D6	Writing and typing	One or two hands are (actively or passively) on the keyboard and writing on sheet or others.
D7	Writing and using mouse	One hand is on the mouse (actively or passively) and writing on sheet of paper or others.
D8	Others	Any activity that means some kind of specific Data Entry and Navigation, which were not anticipated.

As mentioned, the analysis was done using software developed for this purpose. It allows classifying the IC (through video analysis) in levels. Despite the system allowing the observation and register of categories in a continuous time, the high number of categories for this analysis represents a cognitive overload to the observer and may contribute to a significant increase in classification errors. Thus, classifications of systematic activity sequences were done using samples controlled by the software (5 seconds of analysis for each 15 seconds of activity). Each one of these activity sequences represents an "event" which remained in looping (5 seconds) until all ICs were registered (Fig. 2).

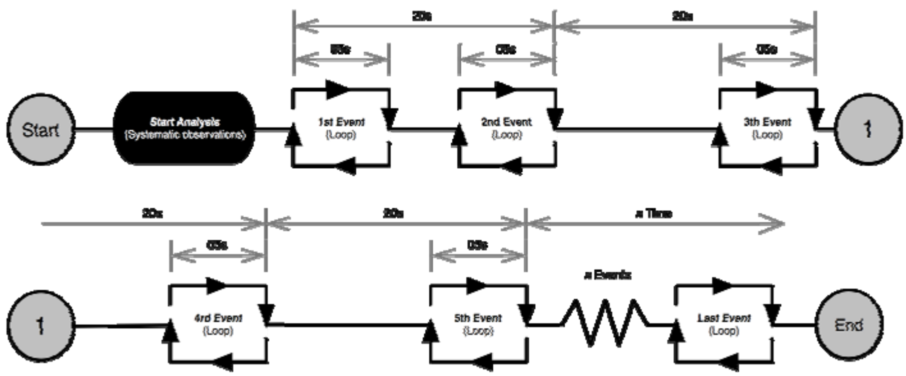

Fig. 2. Flowchart with the systematic observation stages used for the software

3 Results

A sample of 22800 observations, which corresponds to 760 work hours, was classified. The results can be seen on Fig. 3 and Fig. 4.

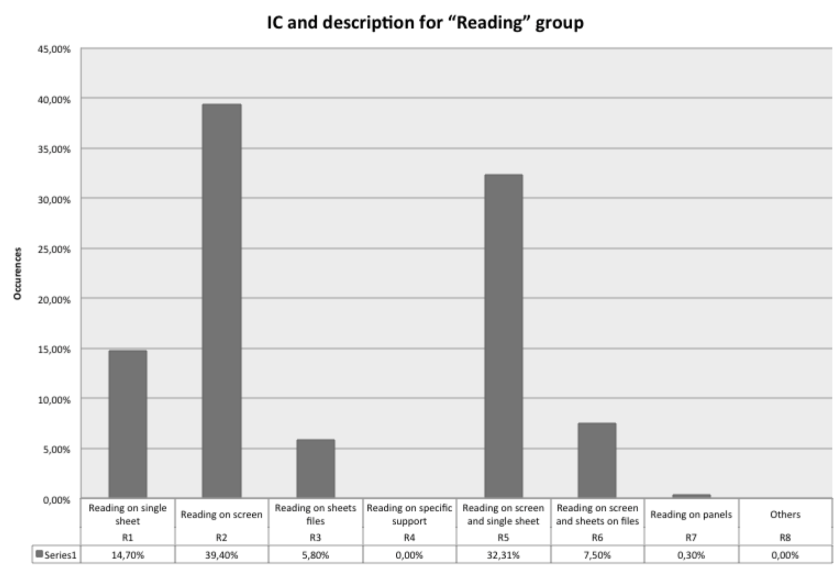

Fig. 3. Results for IC in "Reading" group

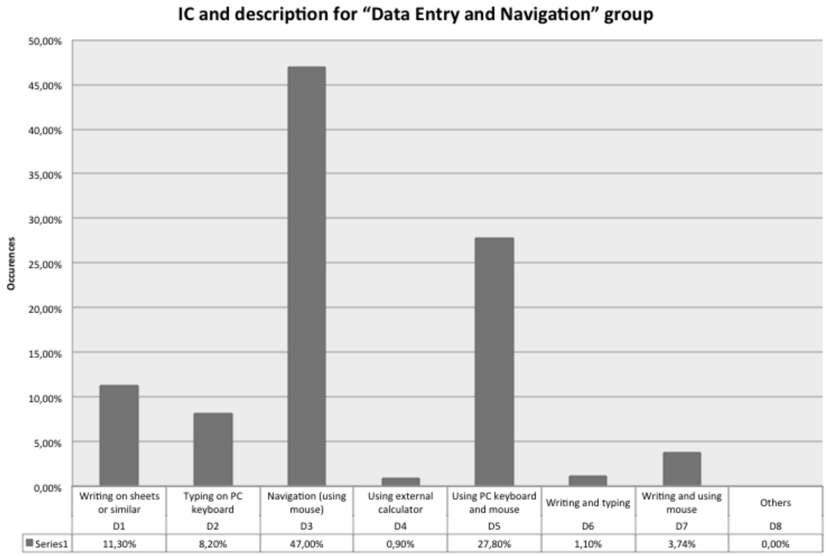

Fig. 4. Results for IC "Data Entry and Navigation" group

The Reading and/or Data Entry and Navigation are in 70.4% of all classifications. In the ICs of Reading codes, R2 occurs 39.4%, R5 corresponds to 32.3%, R1 occurs 14.7%, R6 occurs 7.50%, R3 5.8%, R7 occurs 0.3% and only 0.01% of all activities of reading at the workplace do not involve one of these categories (R8). For Data Entry and Navigation codes, D3 corresponds to 47.0%, D1 represents 11.3%, D2 with 8.2% and D4 corresponds to 0.8% of the registers. The simultaneous use of the keyboard and the mouse (D5) corresponds to 27.8% of the register, followed by mousse and writing (D7) with 3.7% and keyboard and writing (D6) with 1.1% of the registers for the occurrence of combined ICs for the Data Entry and Navigation.

4 Conclusions

The ICs of Reading and Data Input are in the most tasks of the office work. We verified a high percentage of reading from the monitor (R2 + R5 + R6 = 85.5%) in comparison with the Reading from paper (R1 + R3 + R5 + R6 = 59%), it might mean the decreasing of the use of paper as information support at modern offices. The large use of the mouse (D3) was noticed in the most of the ICs (D3 + D5 + D7 = 78.9%) and all ICs with keyboard corresponds to the half of the interaction with the mouse (D2 + D5 + D6 = 37.1%). The writing represents only 16.4% of the registered interactions (D1 + D6 + D7 = 16.4%). The influence of the mouse on the physiological damage in office workers with activities of computer assisted drawing - CAD is already known [19,20,21]. These studies also reveal the high use of this peripheral in the actual text editors and spread sheets software used at offices. These data can be related with the increase of the muscle-skeletal problems, which can be found among workers of traditional offices as found in Ijmker et al. [14].

Although we did not register the specific use of each software while users' interaction with the mouse and keyboard or only one of them, this study suggests that the graphical interface design must seek for new strategies and solutions to reduce the mouse's need using another peripheral as the keyboard or voice recognition devices; or, at least, to diminish the amplitude of movement with the mouse during the interaction with office software.

Finally, this methodology was considered efficient for the proposed objectives and the findings suggest new challenges for future research. For example, this methodology can be used to compare if different types of interaction for the same software can influence the interaction patterns. Usually these data are evaluated through the observation of the activation of keys, clicks and movements, independently of the activity and other interactions.

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References

1. Anshel, J.R.: Visual ergonomics in the workplace. AAOHN 55(10), 414–420 (2007)
2. Andries, F., Smulders, P.G.W., Dhondt, S.: The use of computers among the workers in the European Union and its impact on the quality of work. Behav. Inf. Technol. 21, 441–447 (2002)
3. Hagberg, M., Vilhemsson, R., Wigaeus Tornqvist, E., Toomingas, A.: Incidence of selfreported reduced productivity owing to musculoskeletal symptoms: association with workplace and individual factors among computer users. Ergonomics 50(11), 1820–1834 (2007)
4. Eltayeb, S., Staal, J.B., Kennes, J., Lamberts, De Brie, R.A.: Prevalence of complaints of arm, neck and shoulder among computer office workers and psychometric evaluation of a riskfactor questionnaire. BMC Musculoskeletal Disorders 8(68), 111 (2007)
5. Uchino, M., Schaumberg, D.A., Dogru, M., Uchino, Y., Fukagawa, K., Shimmura, S., Satoh, T., Takebayashi, T., Tsubota, K.: Prevalence of Dry Eye Disease among Japanese Visual Display Terminal Users. Op. hth almology 115(11), 1982–1988 (2008)
6. Karwowski, W.: International encyclopedia of ergonomics and human factors. CRC Press, Taylor & Francis (2006)
7. De Bruijn, I., Engels, J.A., van der Gulden, J.W.J.: A simple method to evaluate the reliability of OWAS observations. Applied Ergonomics (1998)
8. Engström, T., Medbo, P.: Data collection and analysis of manual work using video recording and personal computer techniques. International Journal of Industrial Ergonomics 19(4), 291–298 (1997)
9. Forsman, M., Hansson, G., Medbo, L., Asterland, P., Engström, T.: A method for evaluation of manual work using synchronised video recordings and physiological measurements. Applied Ergonomics 33(6), 533–540 (2002)
10. Hendrick, H.W., Kleiner, B.M.: Macroergonomics: An Introduction to Work System Design. Human Factors & Ergonomics Society, Santa Monica (2001)
11. Bergqvist, U.: Visual display terminal work-a perspective on long-term changes and discomforts. International Journal of Industrial Ergonomics 16(3), 201–209 (1995)

12. Fenety, A., Walker, J.M.: Short-Term Effects of Workstation Exercises on Musculoskeletal Discomfort and Postural Changes in Seated Video Display Unit Workers. Physical Therapy (2002)
13. Straker, L., Pollock, C., Mangharam, J.: The effect of shoulder posture on performance, discomfort and muscle fatigue whilst working on a visual display unit. International Journal of Industrial Ergonomics 20(1), 1–10 (1997)
14. IJmker, S., Huysmans, M., Blatter, B., van der Beek, A., van Mechelen, W., Bongers, P.: Should office workers spend fewer hours at their computer? A systematic review of the literature. British Medical Journal (2006)
15. Kroemer, K.H.E., Kroemer, A.D.: Office ergonomics. Taylor and Francis, New York (2001)
16. Rebelo, F., Filgueiras, E., Soares, M.: Behavior Video: A Methodology and Tool to Measure Human Behavior; Examples in Product Evaluation. In: Karwowski, W., Soares, M.M., Stanton, N.A. (eds.) Human Factors and Ergonomics in Consumer Product Design: Methods and Techniques, p. 320. CRC Press - Taylor & Francis (2011)
17. Burandt, U., Grandjean, É.: Sitting habits of office employees. Ergonomics 6(2), 217–228 (1963); Khalid, H.: Modelling and analysis of CAD expert behaviour in using manual input devices. International Journal of Industrial Ergonomics (2001); Lee, D. L., McLoone, H., Dennerlein, J. T.: Observed finger behaviour during computer mouse use. Applied Ergonomics 39(1), 107–113 (2008)
18. Grandjean, E., Hünting, W.: Ergonomics of posture: Review of various problems of standing and sitting posture. Applied Ergonomics 8(3), 135–140 (1977)
19. Lee, Y., Su, M.: Design and validation of a desk-free and posture-independent input device. Applied Ergonomics 39, 399–406 (2007)
20. Lee, D.L., McLoone, H., Dennerlein, J.T.: Observed finger behaviour during computer mouse use. Applied Ergonomics 39(1) (2008)
21. Khalid, H.: Modelling and analysis of CAD expert behaviour in using manual input devices. International Journal of Industrial Ergonomics (2001)

Preventive and Pro-active Ergonomics Influence on Maintenance Excellence Level

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Abstract. The equipment maintenance is an indispensable function in a manufacturing enterprise [1]. The role of maintenance is to reduce business risks in a cost effective manner. Thus achieving excellence in maintenance issues has to be treated as a strategic issue for manufacturing organizations to create world-class-manufacturers (WCM) [2]. In the following papers, the examples of activities realized to achieve excellence in maintenance area in two large companies working in food industry, especially in terms of their ergonomics, safety and employees' health.

Keywords: maintenance excellence, ergonomics, safety, health of employees.

1 Introduction

Maintenance, similarly to other areas of a company, is under continuous pressure of decreasing costs, proving achievements and supporting organization's mission. From a company's points of view, these expectations are logical, as a supportive process, maintenance plays an important role in its functioning and in the same time supports implementation of such concepts like lean manufacturing, just-in-time, total quality control and six-sigma program. That is why, from several years companies take more and more interest in implementation of the Japanese improvement approach called Total Productive Maintenance and defined by Seiichi Nakajima in the seventies of the twentieth century. TPM is an approach to management which involves all the employees in providing continuous production by team work in eliminating losses by focusing on customers' requirements and making profits. In TPM, operators perform basic equipment repairs and team of maintenance staff re-design and reconfigure equipment to make it more reliable and easier to maintain. Ensuring equipment reliability, preventing human terror, and eliminating accidents are the basic tenets of TPM [6]. TPM is not a universal tool, suitable for each company. A company has to develop its own plan, which includes requirements and problems characteristics for

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their processes, branch, production methods and type and condition of resources [5]. This is why in business practices both, classic approach to TPM, promoted by Japanese Institute of Plant Maintenance, and models realized according to World Class Manufacturing strategy are used. Disregarding the model organization has decided to choose, the common feature of initiatives taken by a company to achieve maintenance excellence is managers involvement, team work, hazards prevention, work methods improvement, work environment improvement and trainings and workshops for technical staff, to increase their competences (knowledge and skills) in techniques, safety, health and ergonomics.

2 Examples of Activities Taken by the Companies Analyzed

2.1 A Case Study – Poznan Brewery

Poznan Brewery with Tychy Brewery and Bialystok Brewery together create Kompania Piwowarska S.A. (Brewery Campaign) – a company which is the leader in polish brewery market and a part of the SABMiller group, the second beer producer in the world. The brands produced by the Kampania Piwowarska include: TYSKIE (Polish most favourite beer), ŻUBR (the second best sold brand in Poland), LECH, Dębowe Mocne, Pilsner Urquell, Redd's, Grolsch, Miller Genuine Draft and Peroni Nastro Azzurro. It is the largest producer of beer in Poland and its modern technology and strict principles of performing manufacturing processes (World Class Manufacturing) guarantee the highest quality of its products. World Class Manufacturing idea was launched in 2000 after decision concerning TPM implementation was made. Continuation and consequence of these decisions is an innovative WCM program started in 2007 and called in SABMiller "Manufacturing Way" (fig.1).

All the elements of the model are connected and related creating a system guaranteeing continuous and repeatable realization of the best practices and continuous improvement. General characteristics of the "5S & ergonomics" pillars are presented in the table 1.

Table 1. Characteristics of the "5S & ergonomics" pillar

Pillar	Description
5S & ergonomics	**General:** the pillar is to change the way of thinking about the work performance. It encourages people to feel personally responsible for safety and provides them with tools enabling realization of such approach. To make their actions fully efficient, employees should be encouraged to use the methods and techniques, they have to believe they can use them and prove the tools are efficient. **Relation with maintenance processes:** integration of technical capabilities of the maintenance department and interpersonal capabilities and Basic knowledge on ergonomics resulting in improved efficiency of Communications and safety of service processes

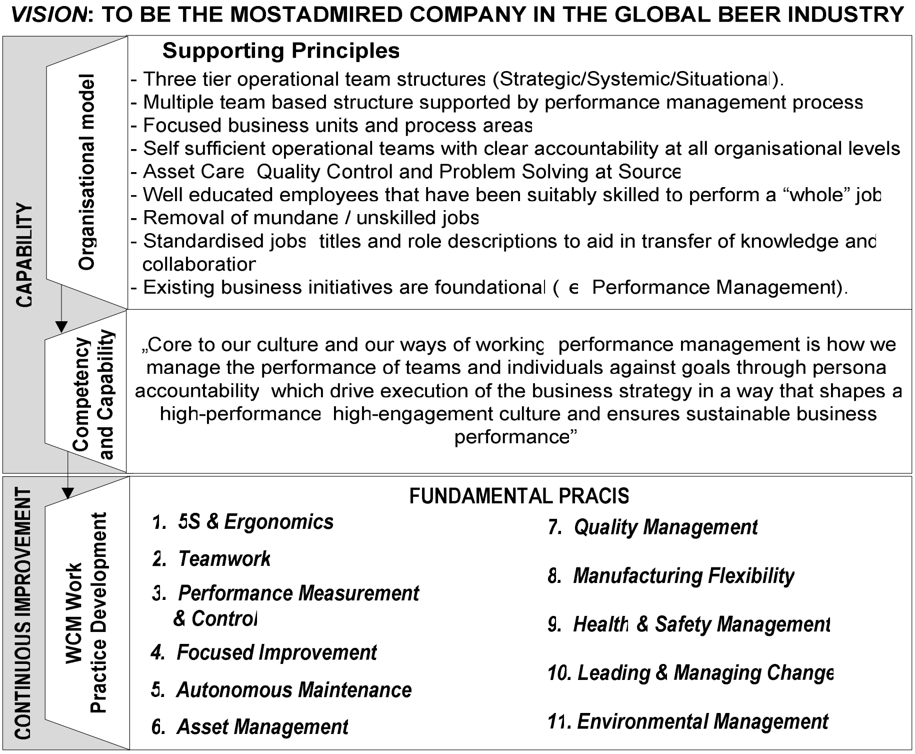


Fig. 1. "Manufacturing Way" – Model WCM SUBMiller

The tool enabling assessment of advance and improvement is „Self-Assessment Checklist", in which for every pillar (from the 1^{st} to the 11^{th}) the themes of assessment have been defined. Each of the themes is analyzed with respect to the level of fulfilling the predefined criteria and the level of excellence of practices realized is assessed. In the organization five levels of excellence have been defined with the lowest: basic – 1 to the highest: innovation – 5. Requirements are assessed in a very simple way: Yes / No (as presented in the table 2).

The final assessment of each mode is a sum of results obtained in each of the eleven pillars. "Manufacturing Way" project is supported with numerous trainings, and their efficiency is assessed with, among others, number of improvements suggested by employees and implemented. The examples of initiatives developed by operators and employees of maintenance department and realized in the company are presented in the figure below. "Ideas Campaign" on the other is a project developed in Poznan Brewery and striving for higher motivation of employees by promoting operational excellence, exceptional involvement and achievements. The program is organized by the Production Development Department. Each employee can present an idea individually or with a team. Criteria taken into consideration when giving rewards are the following: costs decreasing, efficiency improvement (of processes, time or work organization), ability to use and implement solutions suggested in other locations of Brewery, products and services

Table 2. Example of assessment schemes: Theme „Strategy"

	Theme	Stage		Example of characteristics to be assessed
5S & Ergonomics	Strategy	2	Awareness	All team members have undergone practical 5S training, emphasizing 'making work easier' through basic ergonomics such as MODAPTS (Modular Arrangement of Predetermined Time Standards). Relevant links, interfaces and */or* integration with other work practices are clearly articulated & understood (e.g. Autonomous Maintenance. Safety-Health-Environment (SHE)
		3	Foundation	The 5S master plan has been reviewed and refined to focus more extensively on equipment cleaning and equipment condition. e. g. integration with Autonomous Maintenance. There is evidence that basic ergonomic concepts (e. g. MODAPTS) have been applied to 5S improvement projects.
		4	Development	The 5S master plan has been reviewed and refined to **focus** on causes of dirt; causes of wasteful motion or ergonomics; causes of difficult cleaning conditions; causes of cleaning requirements Defined methods and procedures exist to identify ways to ensure equipment. files and supplies are up to date and **ready for use**.
		5	Innovation	The 5S master plan has been reviewed and refined to **eliminate** causes of dirt; causes of wasteful motion or ergonomics; causes of difficult cleaning conditions; causes of cleaning requirements There is evidence of an ongoing review of safety, health and environmental date for identification of potential ergonomic projects

quality improvement, safety and hygiene of work level improvement, environmental issues improvement, operational excellence and/or exceptional involvement and/or extraordinary achievements and other, bringing benefits to the company.

Employees of Techniques Department and Maintenance Department actively take part in the program presenting their own ideas and realizing ideas of employees of other departments (fig. 2).

a)

Fig. 2. Improvements in bottling line: a), washing and disinfection liquids preparation (before and after changes implementation), b) set-up, c) tools availability (a key regulating height)

b) c)

Fig. 2. (*Continued*)

2.2 A Case Study – Unilever Polska S.A

Unilever products are chosen every day by 2 billion consumer. Unilever Polska Sp.z.o.o. is a leader of the Polish market of cooking products, including soups, fixes, instant dishes etc, as well as margarines, teas, ice-creams, cleaning products and hair-care products. To meet requirements of Polish consumers, four facilities strive for reaching planned capacity and production level (Banino – producing ice-cream, Bydgoszcz – chemical products, Poznan and Katowice – foods and teas) with over 3000 people employed. .

Improvement strategy TPM, which has been realized in the company (the organization was awarded with the Award of Excellence by JIPM), is based team work and 5S practices. They are the base for nine pillars including: Autonomous maintenance (AM); Focused Improvement (FI); Planned Maintenance (PM); Quality Maintenance (QM); Safety, health and environmental (SHE); Training & education (T&E); TPM in support departments (TPM in SD); Early equipment management (EEM); Customers service (CS).

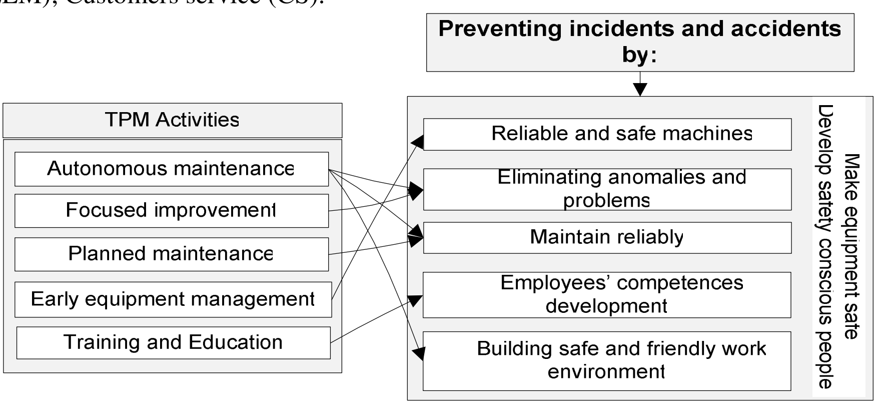


Fig. 3. TPM Activities and safety. Adapted from [6].

The main goal is achieving “zero” culture, which is in this case “zero failures”, “zero complaints”, “zero accidents”, “zero losses” and “zero problems with quality”. Each of the pillars listed above contribute to achieving the „zero” goal, f.ex. through application of 5S principles eliminates leaks and spills and makes workplaces clean, tidy, and well-organized, autonomous maintenance and focused improvements eliminate unsafe areas (fig. 3).

“Autonomous maintenance” pillar includes the following issues: team work (operator, mechanic and electrician together take care for machines and other devices to produce high quality products at reasonable costs), bringing optimal work conditions back (installations without defects, easily conservable, clean, operating according to technological and quality specifications), maintain optimal work conditions (systematic inspections, cleaning, planned lubrications). As a result of involving employees in improvement action, a system of initiatives development “Kaizen” has been developed. Participation of employees in work environment

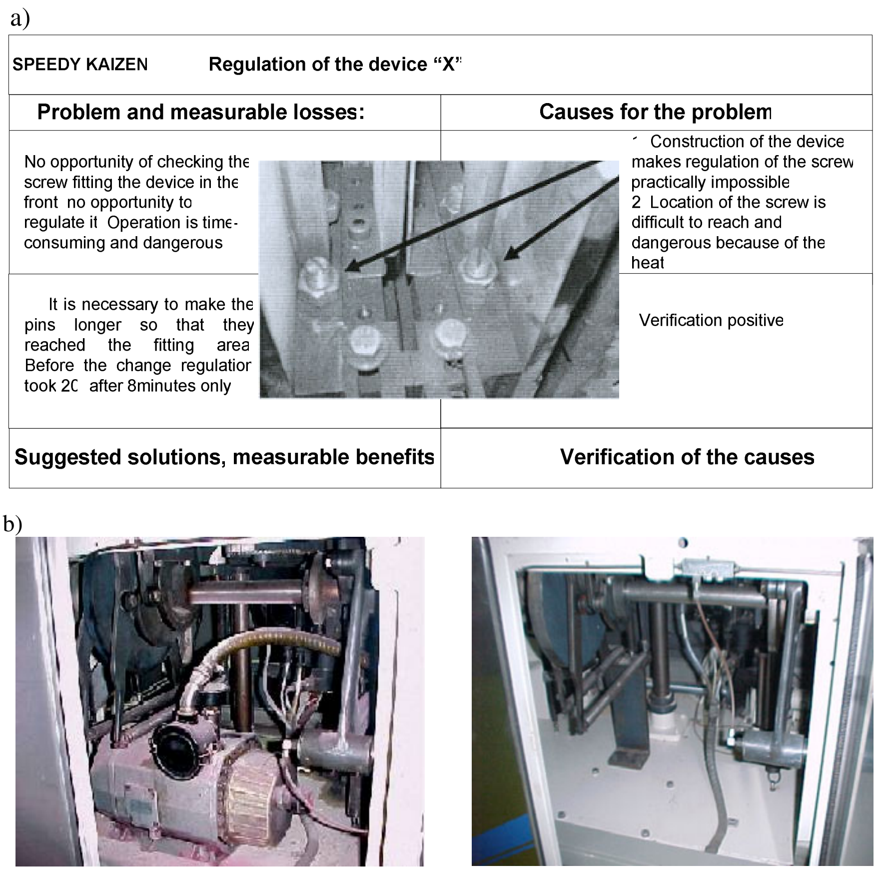
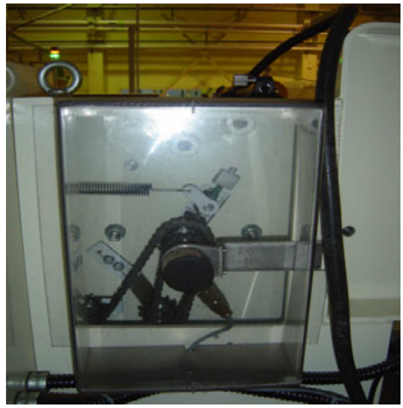


Fig.4. Examples of improvements through “Autonomous maintenance”: a) “Speedy Kaizen”, b) Improvement of Hard-to-access areas**.** Packing machine – Horizontal deployment, c) Transparent covers

Fig.4. *(Continued)*



improvement is especially valuable as employees know the problems connected with their work best, and being well prepared (thanks to trainings realized as a part of the Training & Education pillar) they can, and want deal with them. The solutions and improvements suggested by employees are realized, depending on their range, realization time and investments required, with such tools as so called "Sheet success", "Speedy kaizen" or "Big kaizen". Examples of "Kaizen" activities are presented in the figure below (fig.4).

In TPM, **SHE pillar** is the most important one. In this area focus is on to create a safe workplace and a surrounding area that is not damaged by their process or procedures. This pillar will play an active role in each of the other pillars on a regular basis. The aim is to achieve zero accidents. Two factors help people acquire a zero accident – daily practice as part of workplace and strong, visible companywide support.

The idea of SHE pillar developed in the organization is based on the assumption of parallel improvement of two areas (as presented in the figure below): operators' and technical staff's technical culture (referred to as a safe work environment –"7 steps" program) and safety culture (referred to as shaping quality through trainings, observation and workstations monitoring – currently realized with "SHE Champions program"(fig. 5)

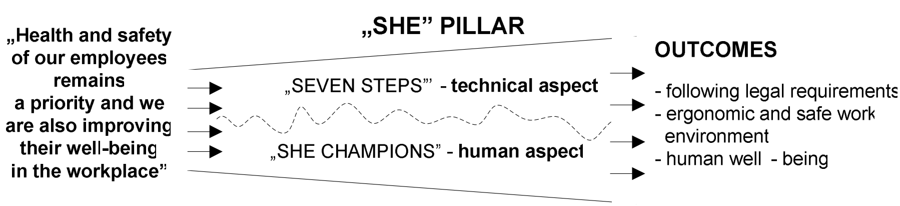


Fig.5. Model of the "SHE" pillar

She Champions program is a continuation of the two programs, realized from 2000 till 2009: “Safety month” and “I am your Archangel”, which were striving towards building knowledge and awareness among employees, shaping proper and correct behavior and elimination of dangerous activities by using so called “library model” (as presented in the fig. 6)

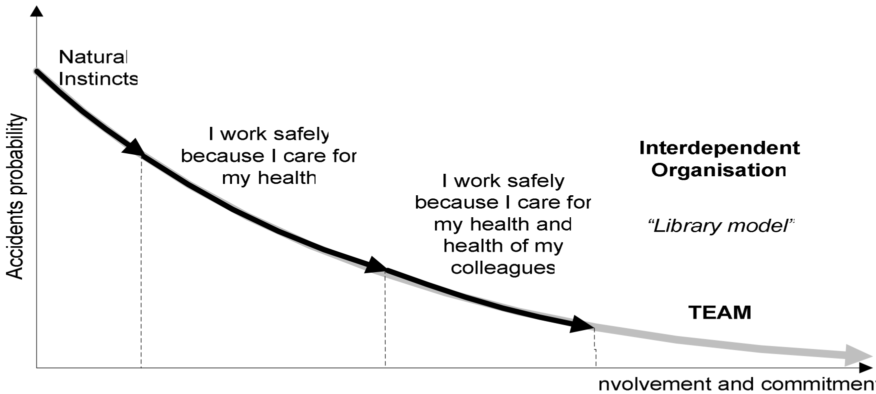


Fig. 6. Safety culture development model. Source: [4]

The goals of the launched in 2010 “SHE Champions” program are the following:

- Identification of safe and risky behavior at workplaces;
- Reaction to improper/ risky behavior (information concerning proper and improper behavior is each time given to the employee operating the workstation analyzed),
- Elimination of risky behavior.

Planning, realization and assessment of activities included in the „SHE Champions” program follows the scheme presented in the figure 7 below.

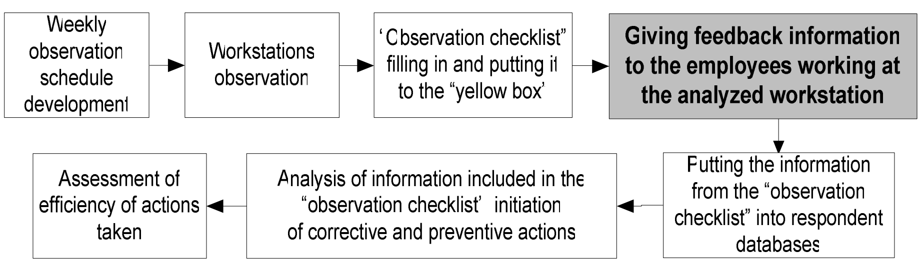


Fig. 7. Planning, realization and assessment of behavior at workplaces

The program is realized for All the Workstation of the organization and the assessment is performed by trained observers. Each of the observers has been trained behavioral observation by internal safety and hygiene of work staff supported by external experts, based on Du Pont system. The training included theoretical issues and practical skills training performer at workstations. The observers are operators as well as top managers (f.ex. CEO is the observer and is obliged to make one observation a week). Top managers commitment, both in trainings and observations, proves their positive attitude and stresses the importance of project proving priority of safety issues in corporate strategy.

Workstations observations take generally 15 to 30 minutes, depending on SHE Champion's experience. Workstations observations take generally 15 to 30 minutes, depending on SHE Champion's experience. The tools used during observation include checklists developed by internal safety and hygiene of work staff. After observation is finished, there are meetings organized to analyze observation cards and opportunities of changes implementation. Many employees are interested in participation in the program and taking the role of the SHE Champion and increased number of Kaizen initiatives is observed and implemented.

Authors notes

"DuPont System" is a program of courses and interactive training Safety Training Observation Program (STOP^{TM}), which strive for "zero injuries" and „zero incidents"[6]. It is top-down and job-focused interactive approach that helps employees to think about safety, allowing it to become fully integrated into what they do every day. The goal is to develop a culture of anticipation by focusing on behavior.

The program of courses and training includes, among others, the following modes:

– STOP™ For Supervision focuses on: regular spontaneous safety observations and frequent scheduled safety observations; everyday safety as well as observing; Conditions as well as actions of people, safe and unsafe; communication about safety every day, not just while observing, an educational approach

– STOP™ For Each Other focuses on: everyday safety – not just auditing, safety of co-workers, conditions as well as actions, peer-to-peer communication, an educational approach,

– STOP™ For Ergonomics focuses on: hazard awareness; risk identification (observing for ergonomic risk factors: static posture, awkward posture; forceful exertions; repetitive motion; contact stress; and vibration; injury prevention (preventing injuries related to musculoskeletal disorders (MSDs) and the suffering they cause; an educational approach.

The tool suggested to be used when making observation is Safety Observation Card, on which observers put their remarks and conclusions referring, among others, to: reaction of people (adjusting personal protective equipment, changing position, rearranging job, stopping job, attaching grounds, performing lock), personal protective equipment (head, eyes and face, ears, arms and hands, legs and feet, trunk, respiratory system), positions of people, tools and equipment

3 Summary

Human mistakes emerging from lack of knowledge, improper work conditions and improper tools use, during service operations (set-ups, conservation, repairs etc) and during its work, can cause threats for both operators and other employees who stay in its neighborhood. Thus, it is necessary to build employees' awareness and promote good practices in the area of safety culture. Implementation of safety procedures and safe work systems should be supported with activities striving towards safe behavior shaping, trainings and spreading useful information. System approach to safety issues with special reference to employees' and managers' participation is one of the well known ways for safety culture creating and including ergonomics in everyday activities. These elements are part of practices used in both facilities.

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References

1. Ahmed, S., Hassan, M.H., Taha, Z.: TPM can go beyond maintenance: excerpt from a case implementation. J. of Quality in Maintenance Engineering 11(1), 19–42 (2005)
2. Brah, S.A., Chong, W.K.: Relationship between total productive maintenance and performance. International Journal of Production Research 42(12), 2383–2401 (2004)
3. DuPont Sustainable Solution, http://www.coastal.com/dupont-stop/dupont-stop
4. Nakajima, S.: Introduction to TPM. Productivity Press, Portland (1984)
5. Poster "I am your Archangel". Unilever Polska S.A. Foods Division Factory in Poznan (2008)
6. Suzuki, T.: TPM in Process Industries. Productivity Press, Portland (1994)

Effects of Meeting Room Interior Design on Team Performance in a Creativity Task

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Abstract. This study examines the effects of spatial characteristics of meeting rooms on the divergent phase in the creativity process of a group and on the mood states arousal and psychological safety. Thirty participants (12 male and 18 female) were randomly allocated to 10 mixed-gender three-person groups. They performed two creativity tasks in three different rooms: neutral, with high arousal and with high psychological safety. Overall impression of the meeting room interiors, psychological safety, arousal and creative performance were measured with questionnaires. HRV was used as physiological measure. Results showed that physical space affected arousal and the impression of the meeting rooms. HRV appeared to be a good predictor for arousal. A relation was found between HRV and idea originality. An interaction effect between meeting room interior and task was found. It may be concluded that the meeting room interior has to be adapted to the type of creativity task to gain optimal results.

Keywords: New ways of working, meeting room, innovation spaces, team performance, creativity, mood, arousal, psychological safety, heart rate variability.

1 Introduction

As a part of the transition to new ways of working (NWW) organizations increasingly support innovation and creativity. Organizations need to create and commercialize new ideas and they need to spread and use innovations in order to remain competitive. For this purpose, creative teams and employees are needed who meet daily challenges related to the organization's products and services or related to the processes, procedures and work methods [1], [2].

A growing interest in innovation spaces (also known as innovation laboratories, future centers, etc.) has emerged recently. These environments reflect the organizations' strategic intentions towards innovation and provide a physical embodiment of their desired modes of working. The common goal of these spaces is to provide flexible and innovative environments, in which new business strategies

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could be developed in a fun, dynamic, rapid and novel way, and independent from the normal working environment. The physical design of these spaces is central to its functionality, emphasizing dislocation form day-to-day activity, eliminating hierarchy and encouraging participation. The physical settings are dedicated to support creativity and innovation. The spaces are often equipped with multimedia and ICT tools for group working. The flexibility of the environment is very important and it is assumed that e.g. architecture, lay-out, colors and lighting have a crucial influence on the participants' behavior. Facilitators use the physical features of these spaces to influence the creative processes [2], [3].

The present study is a first step in developing a meeting support system which assesses the creative group process and provides facilitators and practitioners with feedback on how to use and manipulate the physical features of the space in order to enhance creative processes and support innovation. Before such a system can be developed, there is a need for greater clarity on the characteristics of such spaces and how they actually support creativity or innovation. It appears that these innovation spaces are created based on instincts, visions and beliefs rather than on firm evidence. Only recently some studies have surfaced that specifically address the influence of the physical workspace on creativity, e.g. [2], [3], [4], [5]. There is still little empirical evidence of their benefits or of the wider implications of the design of the workspace on innovation.

Although little research addresses the relationship of physical space and creative achievement directly, clear linkages can be made from diverse disciplines. Much research addresses the context of creativity and the psychological and social environment [5]. For example, research shows relationships between mood or team cohesion and creativity as well as relationships between interior spaces and mood or team cohesion, [6]. Similarly, many studies show that the physical components of an office influence team performance and environmental satisfaction [5], for instance, the effect of colors, furniture arrangement and office lighting on performance and psychological mood of individuals [6] [7], [8]. Therefore, it is hypothesized that spatial effects work out through mediating factors such as team cohesion or mood state.

The goal of this study is to further examine the effects of spatial characteristics on creativity and innovation, by way of the mediating factor mood state. More specifically, we will focus on the divergent phase in the creativity process of a group as the first step of innovation and on the mood states arousal and psychological safety.

The research question of this paper is
What are the effects of a neutral, psychologically safe and high arousal level room on creativity in the divergent phase?

We propose that the effects of physical space on creativity are mediated by worker's mood state. More specifically, we are interested to see whether it is possible to induce two distinct mood states: arousal (or excited state) and safety (or relaxed state). Both mood states can be described as positive moods, although arousal can be seen as an activating whereas safety can be seen as a deactivating mood state. Furthermore, we are interested in the effects on the creativity of groups. We expect that arousal will be related to greater creativity than safety. To identify possible measurement systems that may predict outcomes of the creative process during the creative process we will use Hart Rate Variability (HRV).

2 Methods

2.1 Participants and Design

Thirty participants (12 male and 18 female) were randomly allocated to 10 mixed-gender three-person groups. Each participant signed for informed consent. Their age ranged from 19 to 62 years (M = 28.2, SD = 11.1). Participants were paid €45 for their contribution in the experiment. Furthermore, the best performing group was held out the prospect of an extra bonus of € 90,- to enhance motivation, create goal interdependency, and stimulate groups to perform at their best. None of the group members knew each other prior to the experiment.

The design was a 3 x 2 factorial, with psychological moods (neutral, excited/aroused, at ease/safe) and task type (simple, complex) as within-groups factors. The sequence of the levels was counterbalanced for all teams, but since order had no effects whatsoever it is not discussed further.

2.2 Independent Variables

Psychological moods were induced through three different physical meeting spaces. The design of these spaces was based on a pilot study with 60 participants, which was set up to identify spatial characteristics resulting in high psychological safety and high arousal [9]. The participants had to rate to which degree various physical dimensions contributed to their moods: feel at ease or activated, cf. [10]. These dimensions were: color (e.g., blue, red), lighting (e.g., soft, warm), materials used (e.g., wood, steel), sitting arrangement (e.g., round table, no table in the middle), furniture (e.g., sofa's, chairs). Also interior elements for a neutral meeting space (as control) were indicated.

Figure 1 shows the 'Green Room', designed to make people at ease. Characteristics of this room were: green colors, armchairs placed in a circle with a low round table, wooden materials, a poster showing a natural environment, curtains, table lamps and candles to create a domestic atmosphere and dimmed lighting. Figure 2 shows the 'Red Room', designed to activate people. Characteristics of this room were: warm, red colors, stand stool elements placed in a circle, a poster with an illustration of complex figures (fractals) and bright lighting. Figure 3 shows the 'Blue Room', designed to serve as control. This room has a lot of elements that resemble a traditional meeting room, such as office chairs in a U-shape with a square table in the middle, blue, grey and white as dominant colors, plastic materials and the illumination level of this room was between bright and dim.

To be able to study the effects of meeting space induced psychological moods on creativity, two tasks (association and problem solving) and three topics (soccer, politics and traffic-jams) were presented. The order in which topics were presented to participants was counterbalanced across experimental mood conditions. The two tasks for each topic were presented in the same order. Participants were given a short break after the second task and then were led to the following room.

For all of the tasks, participants had to, as a group, find creative solutions to a framed problem. Groups had 10 minutes for the simple association tasks and 15 minutes for the more complex problem solving tasks to reach consensus on solutions proposed by members and to come up with as many creative solutions as possible. An experimenter was present in the room to write down the solutions on a flip-over but did not actively participate in the session.

Fig. 1. ‘Green room’, feel at ease/ high psychological safety

Fig. 2. ‘Red room’, activating/ high arousal

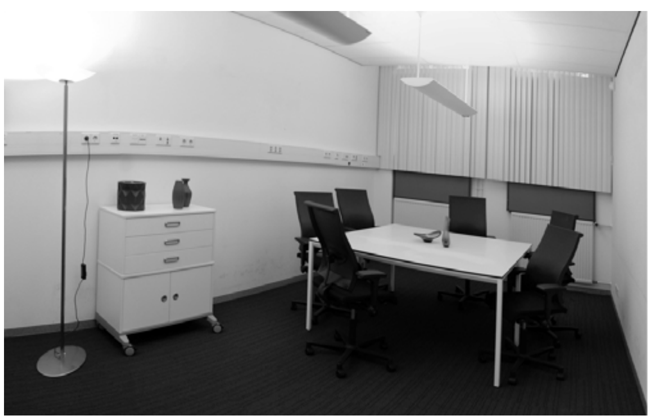

Fig. 3. ‘Blue room’, neutral

2.3 Dependent Variables

The overall impression of the meeting room interiors was measured with an adapted version of the Semantic Environment Description Method (SEDM; [11]). In our study, we reduced the questionnaire to four of the eight qualities, i.e.: Pleasantness, Originality, Social status and Complexity. The 20 adjectives that belong to these qualities were rated on a 7-point scale (ranging from 1 slightly suitable to interior, to 7 very suitable for the interior).

A psychological safety questionnaire was used, based on a questionnaire originally developed by Edmondson (1999) [12]. The questionnaire contained items concerning the perception of influence each team members has on the team and whether the team climate was open for suggestion from each individual team member. All items were measured on seven-point Likert scales. An example question is 'No one in this team would deliberately act in a way that undermines my efforts' (5 items, Cronbach's α = .61).

Arousal was measured with the Self-Assessment Manikin (SAM) [13]. The SAM is a visual method to measure the degree to which a stimulus provokes pleasure, arousal, and dominance in the participant. Reactions were recorded on a five-point scale only for arousal.

Creative performance was indicated by Fluency (the number of ideas) (cf. [14]), Originality and Quality of the solutions [15]. The Originality and Quality of the solutions to the problems were rated by a trained rater on a seven-point Likert-type scale. Originality was defined as novelty of the solution (unique approach to the problem), level of imagination (imaginative or humorous approach to the problem), and structure (whether the solution is limited by the structure of the problem or reflects thinking outside the box). Quality was defined as completeness of the solution (is the solution complete and does the solution address multiple issues raised by the problem) and effectiveness (is the solution viable, feasible, practical, appropriate, or legal/ethical).

By measuring physiological parameters we try to find a measurement system which is able to predict creativity during a brainstorm session. For this purpose we used Heart Rate Variability (HRV), because it has shown to be responsive to changes in psychological state, like mental load and emotional stress [16]. The Equivital (Hidalgo limited, model EQ-01-021) was used to measure the ECG during the experiment continuously. The Root-Mean-Square of Successive inter beat interval Differences (RMSSD) were calculated using Matlab algorithms (Mathworks. Inc. V 2006b).

3 Results

3.1 Manipulation Check

Figure 4 shows the results for the SEDM questionnaire. ANOVA repeated measures indicated significant differences between the interiors for all investigated factors: pleasantness (F 4.522, p=.016), complexity (F=53.055, p=.000), social state (F=4.813, p=.012), and originality (F=40.253, p=.000). Bonferroni post-hoc test showed that the 'Green Room' was rated higher on pleasantness than the 'Blue Room' (p<.01). On

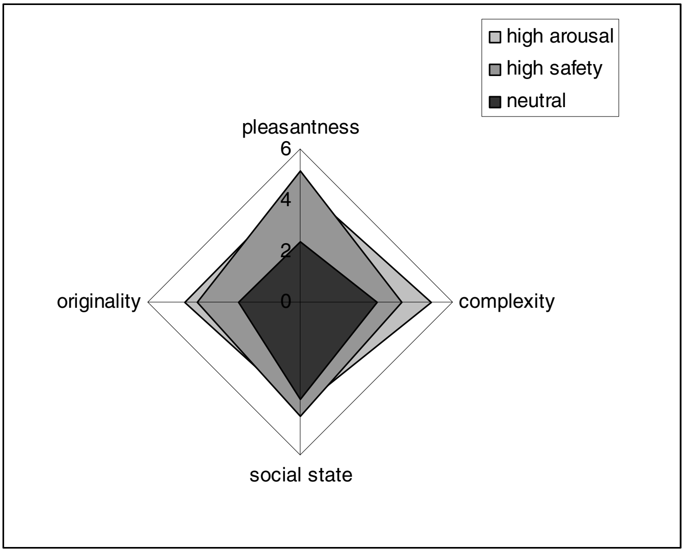

Fig. 4. SEDM factor scores on four factors

complexity, the ‘Red Room’ scored higher than the ‘Green Room’ (p<.01) and the ‘Green Room’ scored higher than the ‘Blue Room’ (p<.01). The ‘Green Room’ was rated significantly higher on social state than the ‘Blue Room’ (p<.01). For originality, both the 'Red Room’ and ‘Green Room’ were judged higher than the standard interior (p<.01).

A Friedman rank order test was performed to see whether differences exist between the rooms for arousal (SAM) and psychological safety. The ‘Red Room’ showed a significant higher rating on SAM than the other rooms (Chi square 7.29, p=.026). No significant differences were found between the rooms for psychological safety measured by the psychological safety questionnaire.

3.2 Creativity

Creativity was analyzed using ANOVA repeated measures. The fluency did not differ between the three interiors. Furthermore, no differences were found between the tasks. However, a significant interaction effect of interiors * types of tasks exist for fluency (p=.05) (Figure 5).

No differences were found between the interiors or tasks for originality and quality of the ideas. In addition, no interaction effects were found.

The average HRV was calculated for each team, during each task for each interior. A significant difference was found between the three interiors for HRV. Bonferonni post-hoc test revealed that the HRV was significantly lower in the red “high arousal” interior compared to the blue standard interior (Figure 6). No differences were found between tasks. There was no interaction effect of interiors * tasks for HRV.

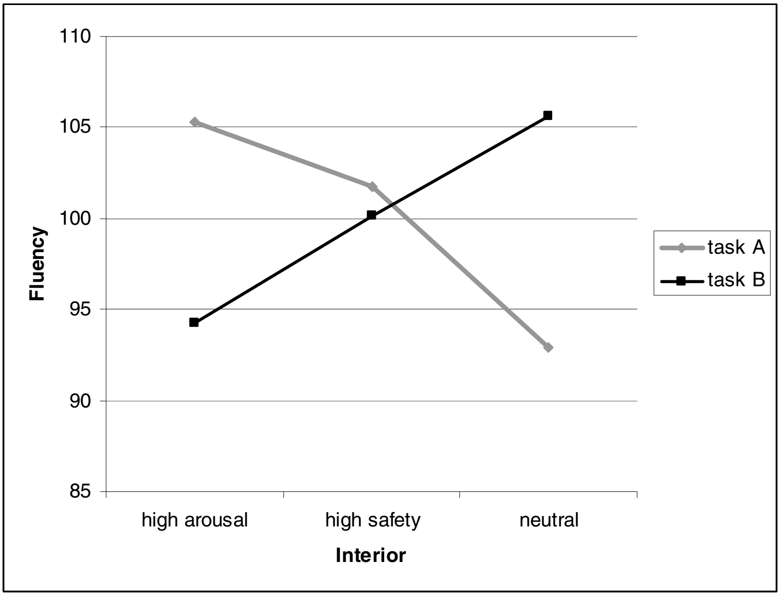

Fig. 5. Interaction effect of interior*task for fluency

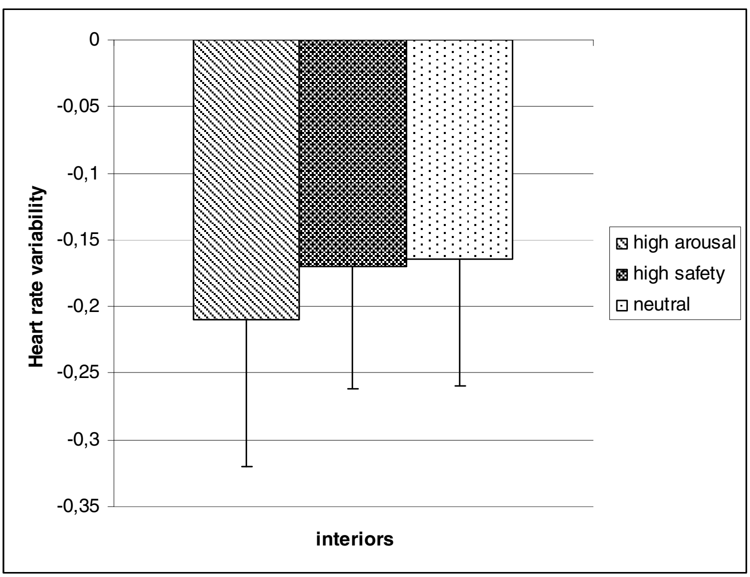

Fig. 6. HRV is significantly lower in the "high arousal" interior than in the neutral interior

HRV showed to have a negative relationship with arousal (beta -0.59), no relationship with psychological safety was found. Furthermore, for creativity, a decrease in HRV is associated with an increase in idea originality (beta -0.48), while no relationships were found for fluency and quality of ideas.

4 Discussion and Conclusion

We proposed that the effects of physical space on creativity are mediated by worker's mood state. It may be concluded that we succeeded in our attempt to induce mood states by meeting room interior design. The experiment showed that the physical space affected the participant's *impression* of the meeting room interiors. For *mood states,* participants were aroused more in the red "high arousal" interior. No differences were found for psychological safety.

The arousal effect was found in the questionnaire as well as in the HRV measurements. HRV appeared to be a good predictor for arousal, which is consistent with other studies [16]. In addition, a relation was found between HRV and idea originality. It may be concluded that, if you look for original ideas in a session, it is a good sign when the HRV is low, which is a sign for high arousal.

No direct effects were found between the meeting room interiors on *creativity*. This could have been caused by the design of the neutral interior (blue room), which contained a lot of blue (chairs, floor). According to the study of Ceylan et al. (2008) [10] who found that interiors with cool colors offer more creativity potential, this interior may have been not so neutral after all. However, an interaction effect between meeting room interior and task was found. It may be concluded that the meeting room interior has to be adapted to the type of creativity task to gain optimal results, which say much for a flexible interior.

The experiment indicates that meeting room interiors differ in terms of creativity potential. Furthermore, the results seem to support the idea that effects of spatial characteristics on creativity and innovation work through mediating factors like mood state. However, before we are able to define design principles for meeting room interiors to foster creativity, more research is needed. Future research may focus on the relationship between the specific physical characteristics and creativity. Also individual characteristics such as personality traits may be included.

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References

1. Dul, J., Ceylan, C., Hendriks, H.: A practical instrument to measure the creativity potential of the work environment. In: Proceedings of the 10th European Conference on Creativity and Innovation, Copenhagen, Denmark, October 14-17 (2007)
2. Moultrie, J., Nilsson, M., Dissel, M., Haner, U., Janssen, S., van der Lugt, R.: Innovation spaces: towards a framework for understanding the role of the physical environment in innovation. Creativity and Innovation Management 16(1), 53–65 (2007)

3. Lewis, M., Moultrie, J.: The organizational innovation laboratory. Creativity and innovation management 14(1), 73–83 (2005)
4. Haner, U.: Spaces for creativity and innovation in two established organizations. Creativity and innovation management 14(3), 288–298 (2005)
5. McCoy, J.M.: Linking the physical work environment to creative context. Journal of Creative Behavior 39, 169–190 (2005)
6. Küller, R., Mikellides, B., Janssens, J.: Color, arousal, and performance - a comparison of three experiments. Color Research & Application 34(2), 141–152 (2009)
7. Klitzman, S., Stellman, J.M.: The impact of the physical environment on the psychological well-being of office workers. Social Science and Medicine 29, 733–742 (1989)
8. Knez, I., Enmarker, I.: Effects of office lighting on mood and cognitive performance and a gender effect in work-related judgment. Environment and Behavior 30, 553–567 (1998)
9. Kuijt-Evers, L.F.M., Van der Kleij, R., De Korte, E.M.: Spatial characteristics of interior spaces characterized by high psychological safety or high arousal level (unpublished data)
10. Ceylan, C., Dul, J., Aytac, S.: Can the office environment stimulate a manager's creativity? Human Factors and Ergonomics in Manufacturing 18(11), 1–14 (2008)
11. Bodil, S.A., Karlsson, N.A., Svensson, K.A.: Using semantic environment description as a tool to evaluate car interiors. Ergonomics 46, 1408–1422 (2003)
12. Edmondson, A.: Psychological safety and learning behavior in work teams. Administrative Science Quarterly 44, 350–383 (1999)
13. Lang, P.J.: Behavioral treatment and bio-behavioral assessment: computer applications. In: Sidowski, J.B., Johnson, J.H., Williams, T.A. (eds.) Technology in Mental Health Care Delivery Systems, pp. 119–137. Ablex, Norwood (1980); Mehrabian, A., Russell, J.A.: An approach to environmental psychology. The MIT Press, Boston (1974)
14. De Dreu, C.K.W., Baas, M., Nijstad, B.A.: Hedonic tone and activation in the mood – creativity link: Towards a Dual Pathway to Creativity model. Journal of Personality and Social Psychology 94, 739–756 (2008)
15. Runco, M., Illies, J.J., Reiter-Ralmon: Explicit instructions to be creative and original – a comparison of strategies and criteria as targets with three types of divergent thinking tests. The Korean Journal of Thinking and Problem Solving 15(1), 5–15 (2005)
16. Goedhart, A.D., Van der Sluis, S., Houtveen, J.V., Willemsen, G., De Geus, E.J.C.: Comparison of time and frequency domain measures of RSA in ambulatory recordings. Psychophysiology 44, 203–215 (2007)

LED Office Lighting to Promote Performance and Well-Being

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Abstract. This paper aims to introduce a research project to investigate and compare the effect of dynamic lighting on people for different light sources in an office setting. Basic differences of short term effects on human between static and dynamic lighting as well as light-emitting diodes (LED) and fluorescent lamps will be investigated in a laboratory study. Two identical rooms will be set up, with the light source LED and fluorescent lamp being the only difference. Four different dynamic sequences will be compared for each light source. Therefore eight lighting situations will be investigated. Long-term effects will be investigated within a field study of one year. To study the impact of dynamic lighting on performance and well-being different methods will be used as questionnaires, tests and the collection of physical data, especially heart rate variability.

Keywords: lighting, office, dynamic, LED, heart rate variability, well-being.

1 Introduction

Within the last years the lighting community saw two major changes. A new light source, the LED, appeared on the scene. And a till then unknown third photoreceptor, the intrinsically photoreceptive ganglion cell (ipRGC) has been found. The ipRGC has been identified as the link between lighting and many biological functions, especially endocrine and circadian rhythms [1-3].

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Since then numerous studies have been undertaken to investigate the link between lighting and its impact on human health and well-being. Brainard et al. [4, 5] and Thapan et al. [6] studied the action spectrum of the melatonin suppression at night and could find a maximum at 460nm. Ten years later we know that blue-enriched light as well as high levels of illumination and dynamic lighting enhance alertness and vigilance [7-12]. The activating effects of high color temperature lighting can be improved by planar light sources or indirect lighting using the ceiling or walls [13]. But we also know that one should not increase vigilance and alertness of people ignoring the time of day and the natural rhythm, since this could create several disorders [14-17].

With dynamic lighting during the day it should be possible to enhance well-being. Increased illuminance levels and high color temperature in the early afternoon together with a relaxing atmosphere generated through warm white light and low illuminance levels in the evening will help to stabilize circadian rhythms [18, 19]. This does not only lead to an increased performance during the day but also to an improved sleep quality at night [20].

Besides the paradigmatic change in indoor lighting due to increased knowledge about the biological effects the difference of the spectral light distribution of LED compared to conventional lamps has to be taken into account. The new light source is now not only used in event lighting and media applications anymore. It starts to capture the market of indoor lighting and will soon be used in various applications, e.g. offices, schools and nursing homes.

The above mentioned studies were performed using conventional light sources, such as fluorescent lamps. Due to the different spectral distribution of LED compared to fluorescent lamps (Fig.1) it has to be questioned whether the results of former studies on the impact of light on humans can be replicated using LED lighting.

2 Basic Knowledge

For billions of years, humans have been exposed to light of specific spectral compositions. In particular humans are exposed to sun light, which changes its colour (and temperature) within the day [21]. Sun light supports the production of serotonin and vitamin D which can improve health and subjective well-being [22-25]. Vitamin D is pivotal for the calcium metabolism, for the built-up of bone matter [26]. Serotonin (5-HT) is a carrier substance in the brain at which dearth depressions can occur [27]. 5-HT is necessary for the production of melatonin, which is built in the pineal gland and has a connection to light as well as to the circadian rhythm [28]. Light represses the production of melatonin especially the blue and green fractions (465nm), the short-wave part of the visible spectrum [2, 4, 5, 29-31].

In fact, short-wavelength monochromatic light has a higher impact than light of longer wavelengths on circadian phase-shift, melatonin-suppression, the increase of subjective and objective alertness as well as the change of the body temperature [5]. Numerous studies concerning the color temperature of light have shown that fluorescent lamps with a high color temperature have a bigger impact on the stated effects than fluorescent lamps with lower color temperature [8-11].

Since electric lighting has been introduced people spend more and more time inside while lacking sufficient amounts of daylight. Until a few years ago interior lighting design was restrained only to the visual needs of humans. But we now know that the existing artificial lighting systems cannot be a satisfying replacement for natural daylight. In fact, many people suffer from issues due to light deficiency, such as lack of concentration and motivation, fatigue or even sleeping disorders and depression [32].

By implementing well-designed lighting systems, the interior lighting can help to increase concentration and motivation as well as improve subjective and objective well-being. Circadian rhythms can be stabilised leading to a better sleeping quality. We have to take into account that light at the wrong time could have opposite effects and might therefore cause health problems.

Former Studies. Within the last years numerous studies have been undertaken to investigate the link between the lighting systems and their impact on health and well-being. Most of these studies on the effect of dynamic lighting on performance and well-being have been run using conventional light sources, such as fluorescent lamps. The different effects of varied illumination levels and color temperatures on the well-being, the acceptability of the lighting system and the performance of the subjects have been analyzed in diverse applications (e.g. schools, offices, nursing homes).

High illumination levels as well as high color temperatures increase subject's alertness and activity. Also higher concentration and motivation levels could be found when lighting with high illumination levels and high color temperatures were applied [8, 13, 18]. To add to this effect planar light sources or indirect lighting using the walls and the ceiling will be useful. In contrast low illumination levels and color temperature create a relaxing atmosphere [13].

In office lighting mixed systems are preferred compared to direct or indirect lighting only. Furthermore, a lighting system should not be designed focused on an increase of the worker's performance only. If the circadian rhythm is disturbed by a purely activating lighting scenario, this could lead to several disorders, as studies on shift workers have shown [14].

Current knowledge about the biological effects of indoor lighting is largely based on results from laboratory or short term studies. We do not know much about the impact of light in real life situations. There are a few field studies as well, those looking into the effects of light sequences in the course of several weeks or months while rating well-being and health only at the beginning and the end of the intervention time. We do not have sufficient data on the progression of health related parameters, well-being, sleeping quality and performance over the course of at least one year.

3 Objects of Study

So far, studies on the effects of light on human, especially in office environments, have mainly employed conventional light sources like fluorescent lamps. However, currently there is an increasing demand on office lighting systems with LED, whose characteristics vary significantly from those of fluorescent lamps. The most obvious difference between the two light sources is their shape, the LED being a point light source compared to the linear shape of a fluorescent lamp. But also less obvious differences may result in different effects on well-being, perception and performance of people. Compared to the fluorescent lamp the LED has a continuous spectrum. This affects not only the visual perception, but might also result in different biologic effects of the lighting system.

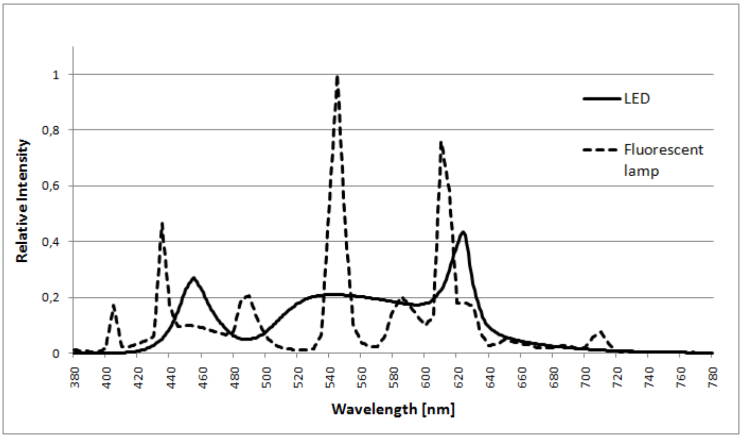

Fig. 1. Spectral distribution of an LED and a fluorescent lamp at 4000K

We will investigate the long-term effects of dynamic office lighting on humans, compared for the light sources LED and fluorescent lamp due to their varying spectra. The dynamic office lighting used in this study will be designed considering the knowledge from chronobiological research and investigations within the community of lighting technology. Fig. 2 shows the dynamic change of color temperatures, illumination levels and the shares of indirect lighting. The office day starts with lower lighting levels, high direct lighting and a low color temperature of 3000K in the morning. Until noon all parameters increase to their maximum of about 1000 to 1500lx and 6500K at 1pm. During the afternoon color temperature, illumination level and share of indirect lighting decrease to reach their starting point by the end of the working day. The dynamic sequence is designed to promote the circadian rhythm, increase sleeping quality and therefore improve well-being and performance of office workers.

4 Methods

The short term effects of dynamic office lighting will be investigated in a laboratory setting. Two identical rooms will be set up, with the light source LED and fluorescent lamp being the only difference. Four different sequences will be compared for each light source: one static lighting situation and one dynamic sequence with three maximum levels of illumination (800lx, 1200lx, 1500lx). Combined with the two light sources eight lighting situations will be investigated.

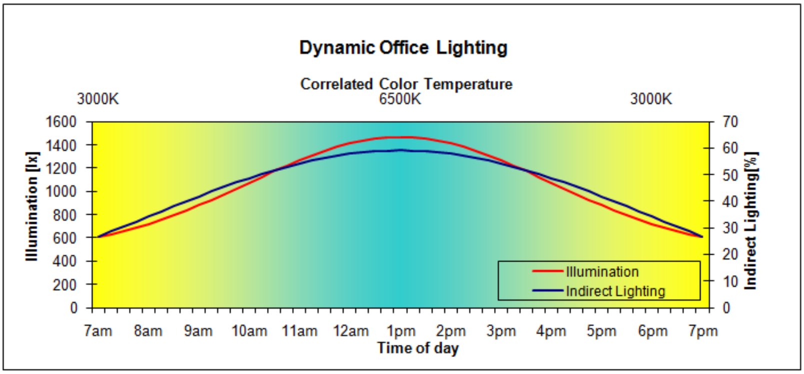

Fig. 2. Dynamic change of color temperature, illuminance and indirect lighting

Forty subjects in the age of 20 to 55, male and female, will be measured in their subjective well-being, concentration and visual performance at several times a day. Additionally physiological data will be collected measuring heart rate variability (HRV) to study activation cycles and recovery periods as well as sleep quality of the subjects. The independent variables are the light source (LED and fluorescent lamp) and the lighting sequence, as described above. Dependent variables are subjective well-being, concentration, sleep quality, visual perception and HRV.

The subjects will spend an entire workday in the laboratory for each sequence, eight workdays altogether. To avoid biased results due to different weekdays, they will be in the laboratory at the same weekday in a time span of eight weeks.

The day starts with an evaluation of the subjective sleeping quality (HRI-Sleep [33]), the general quality of life (QLI [34]), health (SF-12 [35]; MKSL [36]) and stress and recovery behavior (EBF [37]). During the day we will test concentration (KLT-R [38]), sleepiness (Karolinska Sleepiness Scale [39]) and visual perception of colors and contrast, two times in the morning and two times in the afternoon. At each measuring point the subjects will rate their subjective well-being (BSKE [40]). In the evening they will answer the MKSL-questionnaire on physical complaints once again and rate their subjective well-being during the day in general. Each day the subject spends in the laboratory, HRV will be collected continuously over 24 hours for objective cardiac-autonomic data on stress and recovery.

To investigate the long term effects over the course of one year a field study will take place in a company in Austria. Two open plan offices will be equipped with the new lighting system, allowing dynamic office lighting. One office will be provided with LED luminaires, the other office will be lighted by fluorescent lamps. In a third office we will keep the already existing lighting system in order to install a control group. In the course of one year the subjects will rate their well-being, concentration and subjective health every week. During the days of measurement 24h-HRV will be collected as indicator for sleep quality, objective well-being and stress-recreation-patterns [16].

5 HRV – Heart Rate and Heart Rate Variability as Indicators of Human Health

As mentioned, we will use HRV as an indicator for physiological health related effects. Heart rate is one of the main operating parameters of a complex network in which the heart, circulation, respiration, temperature, and metabolism respond to physical and psycho-mental influences. On top of intrinsic chronobiological rhythms, the heart rate gets its typical temporal structure that can be measured as variability [16, 41]. The modulations of instantaneous heart rate are analysed to describe the tone (activity) of both branches of the autonomous nervous system. Rapid changes are assigned to the vagus (primary nerve of the parasympathetic part of the autonomous nervous system). The vagus is active at rest and in states of recreation. The sympathetic nervous system acts more slowly and becomes active when the organism is strongly stimulated.

During the last three decades an increasing interest evolved in the identification of heart rate variability (HRV) and its value as a health indicator [42]. It is based on the assumption that an organisms flexibility and ability to respond to external stimuli is reflected appropriately in the activity of the autonomic nervous system and thus in the heart rate fluctuations. The clinical relevance of HRV was first highlighted by Hon and Lee (1965, quoted by [42]). Basically, HRV decreases when stress occurs as a result of the activity of the sympathetic nervous system [43]. Psychological stressors increase the cardiac activation of the sympathetic nervous system which can be noticed by an increased concentration of plasmacatecholamin and altered autonomic parameters of HRV [44, 45]. The Framingham study [46, 47] found a connection between a decreased HRV and increased mortality.

Lately, HRV was established not only in occupational medicine [48], sports [49, 50] and in sleep medicine [51-56] but also in wide areas of health care and disease prevention. Especially in the case of heart-related pathologies, such as myocardial infarction [57, 58], heart transplants and other cardiovascular diseases [59, 60], the measurement of HRV is recognized as an additional diagnosis and process support [61, 62]. But also in other diseases, such as diabetes [60, 63] or indexed psychiatric problems, such as depression [64], anxiety disorders [41, 65], in sleep research and cancer [17], new approaches of treatments are arising from practical application of HRV analysis.

Basically, any condition modulating autonomic nervous system activity is a candidate for HRV assessment. This very general approach puts HRV in the position of providing a parameter bundle of low specificity but high sensitivity for overall assessment of an organism's status and reactions to environmental changes. Due to high interindividual variances alongside good reproducibility, repeated measurement designs are the method of choice. Thereby, the age-related differences in heart rate variability between men and women have to be taken into account [66].

Stress and Recreation. Madden and Savard [67] found significant links between HRV and mental stress. Moriguchi et al. [68] documented an increase in the sympathetic nervous activity performing mental tasks depending on the degree of stress. Hjortskov et al. [69] described the HRV as a more sensitive and specific indicator for stress experienced at computer work compared with simultaneously performed blood pressure measurements. The neurobiological bases of the link between psychological stress and HRV are depicted e.g. by Critchley et al. [70].

The literature and research results up to now, clearly illustrate that not enough attention is currently paid to the possible health related effects of lighting situations at the workplace. With our study design and the applied methods we should be able to measure psychophysiological activation and recovery processes over a working day to demonstrate the importance of office-lighting for people's well-being and performance. The multidimensional approach, combining the use of questionnaires, performance tests and circadian heart rate variability measurements, should be able to give reliable and valid conclusions for future configurations of specific lighting situations at the workplace.

6 Outlook

At the time of the presentation at the HCII2011 in Orlando, it is in its second phase. We hope to be able to give an overview on the first results.

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References

1. Lok, C.: Vision science: Seeing without seeing. Nature 469(7330), 284–285 (2011)
2. Berson, D.M., Dunn, F.A., Takao, M.: Phototransduction by retinal ganglion cells that set the circadian clock. Science 295(5557), 1070–1073 (2002)
3. Lockley, S.W.: Circadian Rhythms and other brain functions. In: 2nd CIE Expert Symposium on Lighting and Health, p. 22–26 (2006)
4. Brainard, G.C., et al.: Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. J. Neurosci. 21(16), 6405–6412 (2001)
5. Brainard, G.C., Provencio, I.: Photoreception for the neurobehavioral effects of light in humans. In: 2nd CIE Expert Symposium on Lighting and Health, pp. 6–21 (2006)
6. Thapan, K., Arendt, J., Skene, D.J.: An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. J. Physiol. 535(Pt 1), 261–267 (2001)
7. Lockley, S.W., et al.: Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans. Sleep 29(2), 161–168 (2006)
8. Geerdinck, L.M., Schlangen, L.J.: Well-Being Effects of high color temperature lighting in office and industry. In: 2nd CIE Expert Symposium on Lighting and Health, pp. 126–130 (2006)
9. Knoop, M., Tenner, A., Schriek, M.: Energieeffizienz und erhöhte Akzeptanz von Lichtlösungen mit nichtvisueller Wirkung. In: Licht 2008, pp. 512–518 (2008)
10. Rea, M.S., et al.: Implications for white light sources of different colour temperatures. In: 2nd CIE Expert Symposium on Lighting and Health (2006)
11. Rea, M.S., Figueiro, M.G., Bullough, J.D.: Circadian photobiology: an emerging framework for lighting practice and research. Lighting Research Technology 34, 177–190 (2002)
12. Fostervold, K.I., Nersveen, J.: Proportions of direct and indirect indoor lighting - The effect on health, well-being and cognitive performance of office workers. Lighting Research Technology 40, 175–200 (2008)

13. Lang, D., Fassian, M.: Planungsempfehlungen für biologisch effiziente Beleuchtung. Licht und Lebensqualität (2007)
14. Boyce, P.: Education: the key to the future of lighting practice. Lighting Research Technology 38(4), 283–294 (2006)
15. Hildebrandt, G., Moser, M., Lehofer, M.: Chronobiologie und Chronomedizin. Stuttgart, Hippokrates (1998)
16. Moser, M., Frühwirth, M., Kenner, T.: The Symphony of Life - Importance, Interaction and Visualization of Biological Rhythms. IEEE Eng. Med. Biol. Mag. 27, 29–37 (2008)
17. Moser, M., et al.: Cancer and rhythm. Cancer Causes Control 17(4), 483–487 (2006)
18. van Bommel, W.: Dynamic Lighting at work - Both in level and colour. In: 2nd CIE Expert Symposium on Lighting and Health (2006)
19. Veitch, J., et al.: Lighting appraisal, wellbeing and performance in open-plan offices: A linked mechanism approach. Lighting Research Technology 40, 133–151 (2008)
20. Rea, M.S.: Light - Much more than vision. In: Light and Human Health: EPRI/LRO 5th International Lighting Research Symposium, pp. 1–15. The Lighting Research Office of the Electric Power Research Institute, Palo Alto (2002)
21. Rea, M.S., et al.: Circadian light. Journal of Circadian Rhythms 8(2) (2010)
22. Glerup, H., et al.: Commonly recommended daily intake of vitamin D is not sufficient if sunlight exposure is limited. J. Intern. Med. 247(2), 260–268 (2000)
23. Lambert, G.W., et al.: Effect of sunlight and season on serotonin turnover in the brain. Lancet 360(9348), 1840–1842 (2002)
24. Reichel, H., Koeffler, H.P., Norman, A.W.: The role of the vitamin D endocrine system in health and disease. N. Engl. J. Med. 320(15), 980–991 (1989)
25. Young, S.N., Leyton, M.: The role of serotonin in human mood and social interaction. Insight from altered tryptophan levels. Pharmacol. Biochem. Behav. 71(4), 857–865 (2002)
26. Poduje, S., Sjerobabski-Masnec, I., Ozanic-Bulic, S.: Vitamin D–the true and the false about vitamin D. Coll. Antropol. 32(2), 159–162 (2008)
27. Owens, M.J., Nemeroff, C.B.: Role of serotonin in the pathophysiology of depression: focus on the serotonin transporter. Clin. Chem. 40(2), 288–295 (1994)
28. Mirick, D.K., Davis, S.: Melatonin as a biomarker of circadian dysregulation. Cancer Epidemiol. Biomarkers Prev. 17(12), 3306–3313 (2008)
29. Jasser, S.A., Blask, D.E., Brainard, G.C.: Light during darkness and cancer: relationships in circadian photoreception and tumor biology. Cancer Causes Control 17(4), 515–523 (2006)
30. Vandewalle, G., Maquet, P., Dijk, D.J.: Light as a modulator of cognitive brain function. Trends Cogn. Sci. 13(10), 429–438 (2009)
31. Hattar, S., et al.: Melanopsin-containing retinal ganglion cells: architecture, projections, and intrinsic photosensitivity. Science 295(5557), 1065–1070 (2002)
32. Fisch, J.: Licht und Gesundheit. Das Leben mit optischer Strahlung, TU Ilmenau (2000)
33. Grote, V.: Schlaferholung und Herzratenvariabilität als Indikatoren für Wohlbefinden und Gesundheit. In: Naturwissenschaftliche Fakultät, p. 211. Karl-Franzens-Universität, Graz (2009)
34. Mezzich, J.E., et al.: The Multicultural Quality of Life Index: presentation and validation. J. Eval. Clin. Pract. (2011)
35. Mc Horney, C.A., Ware, J.E., Racek, A.E.: The MOS 36-item short-form health status survey (SF-36): II. Psychometric and Clinical Tests of Validity in Measuring Physical and Mental Health Constructs. Medical Care 31, 247–263 (1993)
36. Erdmann, G., Janke, W.: Mehrdimensionale körperliche Symptomliste aktuell (MKSL-ak). Psychologisches Institut, Berlin-Würzburg (1994)
37. Kallus, K.W.: Erholungs-Belastungs-Fragebogen (EBF) (Recovery Stress Questionnaire). Swets Test Services, Frankfurt (1995)

38. Düker, H., et al.: Konzentrations-Leistungs-Test (KLT-R) (Concentration achievement test – Revised version). Hogrefe, Göttingen (2001)
39. Akerstedt, T., Gillberg, M.: Subjective and objective sleepiness in the active individual. Int. J. Neurosci. 52(1-2), 29–37 (1990)
40. Janke, W., Hüppe, M.: Befindlichkeitsskalierungen durch Kategorien und Eigenschaftswörter: Die BSKE (EWL), Lehrstuhl für Biologische und Klinische Psychologie (1994)
41. Bernston, G.G., Cacioppo, J.T.: Heart Rate Variability: Stress and Psychiatric Conditions. In: Malik, M., Camm, A.J. (eds.) Dynamic Electrocardiography, pp. 57–64. Blackwell/Futura, New York (2004)
42. Task Force of the ESC and NASPE, Heart Rate Variability. Standards of Measurement, Physiological Interpretation and Clinical Use (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology). Circulation 93, 1043–1065 (1996)
43. Kang, M.G., et al.: Association between job stress on heart rate variability and metabolic syndrome in shipyard male workers. Yonsei Med. J. 45(5), 838–846 (2004)
44. Cacioppo, J.T., et al.: Autonomic and neuroendocrine responses to mild psychological stressors: effects of chronic stress on older women. Ann. Behav. Med. 22(2), 140–148 (2000)
45. Chida, Y., Hamer, M.: Chronic psychosocial factors and acute physiological responses to laboratory-induced stress in healthy populations: a quantitative review of 30 years of investigations. Psychol. Bull. 134(6), 829–885 (2008)
46. Tsuji, H., et al.: Impact of reduced heart rate variability on risk for cardiac events. The Framingham Heart Study. Circulation 94(11), 2850–2855 (1996)
47. Tsuji, H., et al.: Determinants of heart rate variability. J. Am. Coll. Cardiol. 28(6), 1539–1546 (1996)
48. Pfister, E.A.: Herzrhythmusanalyse in der Arbeitsmedizin. Arbeitsmed Sozialmed Umweltmed 42(6), 348–353 (2007)
49. Hottenrott, K.: Herzfrequenzvariabilität im Sport. Prävention, Rehabilitation und Training. Schriften der Deutschen Vereinigung für Sportwissenschaft. CzwalinaVerlag (2002)
50. Hynynen, E., et al.: Heart rate variability during night sleep and after awakening in overtrained athletes. Med. Sci. Sports Exerc. 38(2), 313–317 (2006)
51. Patzak, A., et al.: Empfehlungen für die Bestimmung der Herzfrequenzvariabilität im pädiatrischen Schlaflabor. Somnologie 6(1), 39–50 (2002)
52. Toskani, L., et al.: Human heart rate variability and sleep stages. Ital. J. Neurol. Sci. 17, 437–439 (1996)
53. Trinder, J., et al.: Autonomic activity during human sleep as a function of time and sleep stage. J. Sleep Res. 10(4), 253–264 (2001)
54. Brandenberger, G., et al.: Age-related changes in cardiac autonomic control during sleep. J. Sleep Res. 12(3), 173–180 (2003)
55. Busek, P., et al.: Spectral analysis of the heart rate variability in sleep. Physiol. Res. 54(4), 369–376 (2005)
56. Vandewalle, G., et al.: Robust circadian rhythm in heart rate and its variability: influence of exogenous melatonin and photoperiod. J. Sleep Res. 16(2), 148–155 (2007)
57. Pagani, M., et al.: Sympathovagal interaction during mental stress. A study using spectral analysis of heart rate variability in healthy control subjects and patients with a prior myocardial infarction. Circulation 83(4 suppl), II43–II51 (1991)
58. Sleight, P.: The importance of the autonomic nervous system in health and disease. Aust. N Z J. Med. 27(4), 467–473 (1997)
59. Sgoifo, A., et al.: Cardiac autonomic reactivity and salivary cortisol in men and women exposed to social stressors: relationship with individual ethological profile. Neuroscience and Biobehavioral Reviews 27, 179–188 (2003)
60. Eller, N.H.: Total power and high frequency components of heart rate variability and risk factors for atherosclerosis. Auton. Neurosci. 131(1-2), 123–130 (2007)

61. Malik, M., Camm, A.J.: Heart Rate Variability. Futura Publishing Company, Armonk (1995)
62. Moser, M., et al.: Heart rate variability as a prognostic tool in cardiology. A contribution to the problem from a theoretical point of view. Circulation 90(2), 1078–1082 (1994)
63. Pagani, M., et al.: Spectral analysis of heart rate variability in the assessment of autonomic diabetic neuropathy. J. Auton. Nerv. Syst. 23(2), 143–153 (1988)
64. Moser, M., et al.: Increased heart rate in depressed subjects in spite of unchanged autonomic balance? Journal of Affective Disorders 48, 115–124 (1998)
65. Carney, R.M., Freedland, K.E., Stein, P.K.: Anxiety, depression and heart rate variability. Psychosom. Med. 62(1), 84–87 (2000)
66. Bonnemeier, H., et al.: Circadian Profile of Cardiac Autonomic Nervous Modulation in Healthy Subjects: Differing Effects of Aging and Gender on Heart Rate Variability. Journal of Cardiovascular Electrophysiology 14(8), 791–799 (2003)
67. Madden, K., Savard, G.K.: Effects of mental state on heart rate and blood pressure variability in men and women. Clin. Physiol. 15(6), 557–569 (1995)
68. Moriguchi, A., et al.: Spectral change in heart rate variability in response to mental arithmetic before and after the beta-adrenoceptor blocker, carteolol. Clin. Auton. Res. 2, 267–270 (1992)
69. Hjortskov, N., et al.: The effect of mental stress on heart rate variability and blood pressure during computer work. Eur. J. Appl. Physiol. 92(1-2), 84–89 (2004)
70. Critchley, H.D., et al.: Human cingulate cortex and autonomic control: converging neuroimaging and clinical evidence. Brain 126(Pt 10), 2139–2152 (2003)

Is the Presence of a Companion Animal Dog Beneficial for Computer Operators?

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Abstract. This research was conducted to assess whether workers' social facilitation-inhibition could be evoked by introducing a companion animal dog into the workplace or not. The experiments were carried out with three kinds of work conditions: working alone, presence of a person, and presence of a dog. There were two different discrimination tasks using PC. During each task performance, participants' response times and the number of errors were measured to investigate their performance. Also, workers' Heart Rates and Oxidation-Reduction Potentials of Saliva were measured to monitor their physiological changes. Before/after each performance, their emotional states, as defined by the Profile of Mood States questionnaire, were measured. The results suggest that for complex tasks, a companion animal can produce inhibition effects. However, the results also suggest that for more complex and difficult tasks, the presence of a familiar companion animal dog might produce facilitation effects.

Keywords: companion animal dog, social facilitation and inhibition, task performance, physiological changes.

1 Introduction

Companion animals have recently been introduced into hospitals and nursing home facilities for therapeutic and recreational purposes; i.e., rehabilitation and mental support. They have become increasingly popular in Japan. Those activities may be beneficial in terms of health and performance for company employees who are engaged in word processing using PC in the workplace. In fact, a few companies allow employees to bring their companion animals into the workplace in Japan.

In the literature of social psychology, one classical test shows how the presence of others affects task performance. It is called the social facilitation-inhibition effect. It refers to performance enhancement of a simple or well learned task and performance impairment of a complex or novel task when completed in the presence of others. Zajonc (1965) suggests that this phenomenon is due to the facilitation of dominant responses that occur under increased physiological arousal. If the presence of a companion animal increases workers' physiological arousal, it can be said that social facilitation-inhibition may occur with a companion animal.

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Therefore, the present study was undertaken to assess performances on the simple task and the complex task with three kinds of work conditions: working alone, presence of a person, and presence of a dog and to examine if this theory from social psychology carries over to interacting with companion animal dogs in the context of social facilitation-inhibition. Also, to investigate participants' physiological and emotional changes before/during/after each performance, their Heart Rates, Oxidation- Reduction Potentials of Saliva, and emotional states, as defined by the Profile of Mood States questionnaire, were measured.

2 Method

The experiments were carried out in a shield room (W3.5m x D2.6m x H2.4m). The experimental setup used in this study and the description of performance tasks including participants and experimental procedure are described below.

2.1 Experimental Setup

A Pentium 4 Dell Dimension Desktop PC with a 20.1-inch monitor, 3.20GHz (CPU), and Windows XP (OS) were used to run the performance tasks and store the response times.

Companion Animal Dog. A medium size mixed male dog participated in the experiments as the companion animal dog. The dog was well-trained and in good health.

Heart Rates (HR). A heart rate monitor (Polar RS800CX) was used to measure the heart rates (HR: the number of heart beats per minute) and beat-to-beat (R-R) intervals. HR reflects parasympathetic and sympathetic activity (Randall, 1984). Based on the data collected, each participant's coefficient of variation of R-R interval ($CV_{R\text{-}R}$) was calculated to find out the level of physiological arousal during each task. It is said that if $CV_{R\text{-}R}$ decreases, the sympathetic nervous system holds a dominant position (Wheeler & Watkins, 1973; Pfeifer et al., 1982; Ogawa & Sakamoto, 2003); in other words, the level of physiological arousal can be said to have increased.

The Polar Pro trainer 5^{TM} program was used to calculate low-frequency (LF) power (reflecting a mixture of parasympathetic and sympathetic activity) and high-frequency (HF) power (reflecting parasympathetic activity) by integrating the spectra from 0.04 to 0.15 Hz and from 0.15 to 0.4 Hz, respectively. The ratio of the power at low- and high-frequencies (LF/HF) has been suggested to be an indicator of sympathetic nervous system activity (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996).

Oxidation-Reduction Potential of Saliva (ORPS). An oxidation and reduction potential monitor (ARAGENKI LL-001, Live & Love, Japan) was used to measure the oxidation-reduction potentials of saliva (ORPS) to monitor oxidative stress levels (Okazawa, 2009).

Profile of Mood States (POMS) Questionnaire. The emotional state of each participant was evaluated by the Japanese version of the short form of Profile of Mood States (POMS) (McNair et al., 1992). This instrument consists of six factors: "tension-anxiety," "depression," "anger-hostility," "vigor," "fatigue," and "confusion." POMS score for each factor was calculated based on the results of the questionnaire. Ogawa (2006) suggested that the emotional states of "tension-anxiety" and "vigor" were better after the break period with the companion animal dog for the data input task and the addition task, respectively.

2.2 Performance Tasks

There were two different discrimination tasks using a personal computer: a simple and a complex task. For each task, a target symbol and some sample symbols were displayed on the computer screen as shown in Figure 1.

Simple Task. For the simple task, each participant was required to choose and input the corresponding number to one of the two symbols which was matched to the target symbols and appeared on the computer screen.

Complex Task. For the complex task, each participant was required to choose and input the corresponding number to one of the eight symbols which was matched to the target symbols and rotated by 180 degrees on the screen.

Participants were asked to respond as quickly as possible with the minimum number of errors for each task. Both tasks consisted of 10 test sessions of 8 trials following 2 learning sessions of 8 trials; test sessions lasted from 2 to 8 minutes.

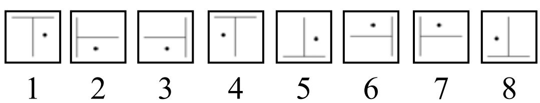

Fig. 1. Symbols used in the performance tasks

2.3 Participants

Fourteen university students (five male and nine female), between 19 and 23 years of age, participated in the experiments. Seven of them were familiar with the dog (dog-familiar) and the others were not (dog-unfamiliar). All participants had normal visual acuity and none of them disliked companion animals. Each participant provided written informed consent prior to participation.

2.4 Experimental Procedure

A 2 x 2 x 3 mixed experimental design was applied with two levels of dog-familiar factor (dog-familiar and dog-unfamiliar), two levels of task complexity (simple and complex), and three levels of work conditions (working alone, presence of a person, and presence of a dog). All participants experienced both tasks with three kinds of work conditions. The person and dog were positioned 130cm to 190cm from the participant and no physical contact could be made. The order of the work condition and the task was randomly assigned to each participant.

The experimental procedure for each condition is shown in Figure 2. On the day of each condition, an orientation of the experiment was given. The two performance tasks were carried out on the same day, and a break period of 10 minutes was given between them. During each task performance, their response times and the number of errors were measured to investigate their performance. Also, their HR and ORPS were measured to monitor their physiological changes. Before/after each performance, their emotional states, as defined by the POMS questionnaire, were measured.

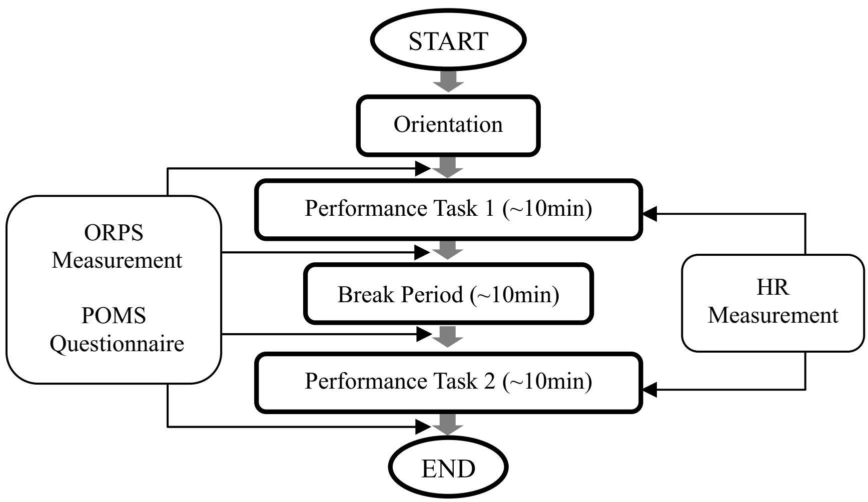

Fig. 2. Experimental procedure for each condition

3 Results

The task performance and the physiological data were treated with a repeated measure ANOVA to test for the between subject effect of dog-familiar factor, and the within subject effect of task complexity and work conditions.

3.1 Task Performance

Response times and the number of incorrect responses were automatically recorded for each participant on every trial. Response times were measured from the presentation of the symbols until the completion of the participant's response. Responses that were more than two standard deviations from the mean were not included in the analysis. Mean response times were calculated for the remaining correct responses. The number of errors was computed by summing the number of incorrect responses across the 80 trials in each condition.

Figure 3 shows the mean response times in milliseconds for each task by three work conditions and dog-familiar factor. There was a significant main effect for task complexity, F (1, 12) =327.11, $p<0.01$. Participants responded significantly faster on the simple task (mean=1040ms) than on the complex task (mean =3070ms). There was no main effect of dog-familiar factor and the work condition. However, for the simple task, 7 participants responded faster and only 2 participants responded slower when working alone. Also, for the complex task, 7 participants responded faster and only 3 participants responded slower when working alone.

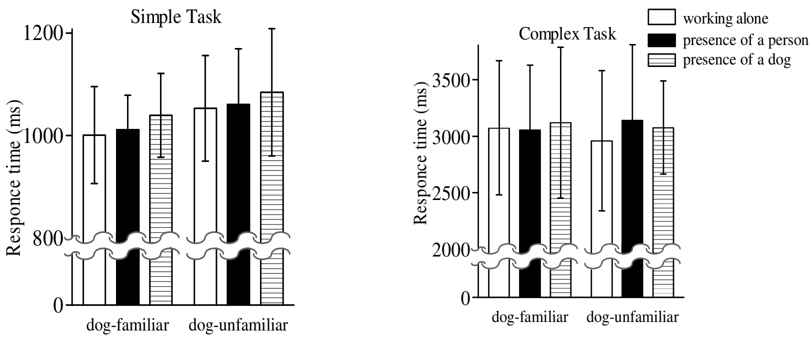

Fig. 3. Mean response time for each condition for the different tasks

Figure 4 shows the number of errors for each task by three work conditions and dog-familiar factor. There was a significant main effect for task complexity, F (1, 12) =4.77, $p<0.05$. Participants responded significantly better on the simple task (mean =1.41) than on the complex task (mean =3.98). There was no main effect of dog-familiar factor and the work condition. However, for the simple task, most dog-familiar participants (6 of 7 participants) responded with fewer errors when working alone, and with many errors when working in the presence of a dog. For the complex task, all dog-familiar participants responded with fewer errors when working in the presence of a dog.

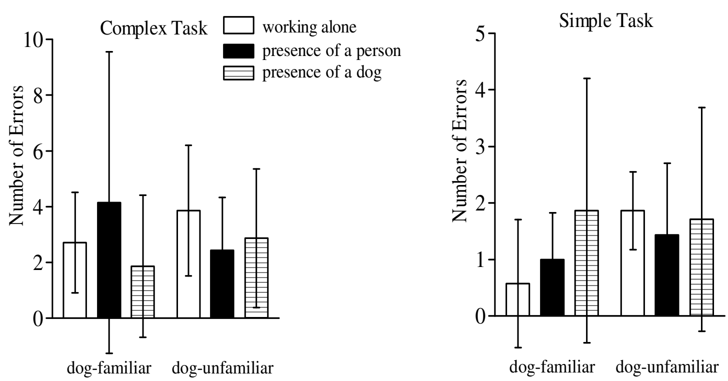

Fig. 4. Mean number of errors for each condition for the different tasks

3.2 Physiological and Emotional Changes

Figure 5 shows the mean HR for each condition for the different tasks. There was a significant interaction effect of work condition by dog-familiar factor, $F(1, 12) = 11.01$, $p<0.01$. For dog-familiar participants, HR was the highest when working in the presence of a dog. On the other hand, for dog-unfamiliar participants, HR was the lowest when working in the presence of a dog. Table 1 shows the power spectrum analysis of heart rate variability for each condition. As a result of ANOVA, there was no main effect of dog-familiar factor and the work condition. Also, Pearson correlation coefficients between the task performance data and the physiological measurements for each condition are shown in Table 2.

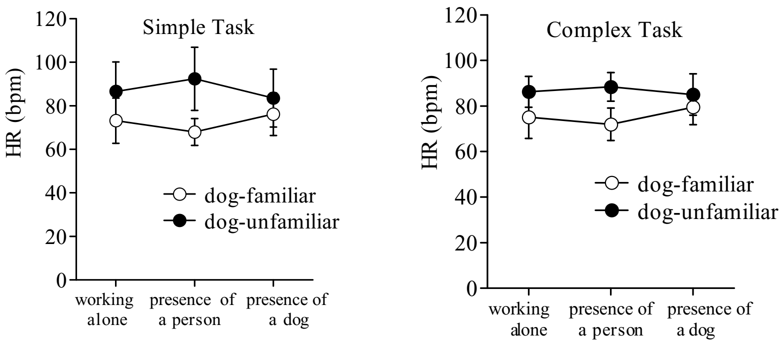

Fig. 5. Mean HR for each condition for the different tasks

Table 1. Power spectrum analysis of heart rate variability for each condition

	Simple Task					
	dog-familiar (n=7)			dog-unfamiliar (n=7)		
Condition	**working alone**	**presence of a person**	**presence of a dog**	**working alone**	**presence of a person**	**presence of a dog**
HF (ms^2)	657±587	846±503	563±400	460±447	236±214	400±308
LF/HF	118±52	126±74	191±192	210±148	294±213	182±68
CV_{R-R} (%)	5.2±1.5	5.6±2.3	4.9±1.1	5.2±1.4	4.5±1.1	5.6±1.2
	Complex Task					
	dog-familiar (n=7)			**dog-unfamiliar (n=7)**		
Condition	**working alone**	**presence of a person**	**presence of a dog**	**working alone**	**presence of a person**	**presence of a dog**
HF (ms^2)	625±484	626±373	410±351	360±314	247±202	345±170
LF/HF	117±83	132±112	199±119	197±156	293±311	150±86
CV_{R-R} (%)	5.4±1.1	5.7±2.2	4.9±0.8	4.7±1.0	5.0±1.6	5.8±1.6

For the simple task, there was a correlation between response times and HR ($p<0.05$), HF ($p<0.05$) and LF/HF ($p<0.05$), when working alone. For the complex task, there was a positive correlation between response times and LF/HF ($p<0.05$), and there was also a correlation between the number of errors and HR ($p<0.01$), HF ($p<0.05$) and CV_{RR} ($p<0.01$), when working alone. However, for both tasks, there was no correlation between response times and any physiological measurements when working in the presence of a familiar dog. For the complex task, there was also no correlation between the number of errors and any physiological measurements when working in the presence of a dog.

Table 2. Correlation Coefficients between the task performance data and the physiological measurements

		Simple Task				
Condition		**HR**	**HF**	**LF/HF**	**CV_{RR}**	**ORPS**
working alone	**response time**	0.631*	-0.577*	0.629*	-0.378	-0.233
	errors	0.255	-0.214	0.156	-0.032	-0.063
presence of a person	**response time**	0.249	-0.381	0.326	-0.077	0.650*
	errors	0.429	-0.052	-0.048	-0.101	-0.096
presence of familiar dog	**response time**	0.185	-0.298	-0.487	0.296	0.531
	errors	0.639	-0.624	0.925**	-0.676	-0.485
presence of unfamiliar dog	**response time**	0.839*	-0.254	-0.131	0.147	0.683
	errors	0.058	-0.229	0.279	0.139	0.362
		Complex Task				
Condition		**HR**	**HF**	**LF/HF**	**CV_{RR}**	**ORPS**
working alone	**response time**	0.094	-0.193	0.539*	-0.041	0.253
	errors	0.765**	-0.653*	0.468	-0.787**	-0.076
presence of a person	**response time**	-0.123	-0.080	0.291	0.234	0.327
	errors	0.074	-0.121	-0.136	-0.230	0.687**
presence of a familiar dog	**response time**	0.149	-0.009	-0.279	0.280	0.422
	errors	-0.219	-0.015	-0.637	-0.526	0.136
presence of an unfamiliar dog	**response time**	-0.023	-0.327	-0.100	-0.796*	-0.438
	errors	0.261	0.254	-0.051	0.215	-0.378

** $p < .01$ (two-tailed test). * $p < .05$ (two-tailed test).

Table 3 shows Pearson correlation coefficients between task performance data and emotional changes defined by the POMS scores, with the work conditions and dog-familiar factor. For simple task, there was a positive correlation between response times and tension-anxiety factor when working alone. However, for that task, there was no correlation between response times and tension-anxiety factor when working in the presence of a person or a dog. There was a negative correlation between response times and vigor when working in the presence of a person or an unfamiliar-dog and between response times and fatigue, and response times and confusion when working with a familiar-dog. For complex task, there was no correlation between response times and any POMS score.

Table 3. Correlation Coefficients between the task performance data and the POMS scores

Condition		Simple Task					
		tension-anxiety	depres-sion	anger-hostility	vigor	fatigue	confu-sion
working alone	response time	0.617*	0.327	-0.433	-0.529	-0.195	0.472
	Errors	0.143	-0.055	-0.207	-0.066	0.089	0.054
presence of a person	response time	0.098	-0.098	0.121	-0.566*	-0.228	-0.146
	Errors	-0.273	0.089	-0.113	0.248	-0.334	0.306
presence of familiar dog	response time	-0.661	-0.174	0.474	0.035	-0.788*	-0.861*
	Errors	0.410	0.250	0.162	-0.766*	0.764*	0.419
presence of unfamiliar dog	response time	-0.165	0.125	NA	-0.759*	0.199	-0.069
	Errors	0.213	0.076	NA	0.008	0.719	0.159
Condition		**Complex Task**					
		tension-anxiety	**depres-sion**	**anger-hostility**	**vigor**	**fatigue**	**confu-sion**
working alone	response time	-0.290	0.097	-0.405	-0.161	0.293	-0.053
	Errors	0.029	0.474	-0.236	-0.183	0.364	0.293
presence of a person	response time	0.214	-0.464	0.197	-0.343	-0.189	-0.058
	errors	-0.039	-0.326	-0.246	0.109	-0.554*	0.456
presence of familiar dog	response time	-0.141	0.549	NA	-0.506	-0.539	-0.494
	errors	0.298	-0.401	NA	-0.609	0.135	0.683
presence of unfamiliar dog	response time	-0.378	0.608	-0.399	0.467	-0.467	-0.336
	errors	-0.196	-0.211	0.737	0.657	0.292	0.347

**$p < .01$ (two-tailed test). *$p < .05$ (two-tailed test). NA = not applicable.

4 Discussion

The following discussion can be made within the limitation of the experiments.

4.1 Task Performance

Social facilitation effect did not occur with a companion animal dog or a person in this study. Generally speaking, for both tasks, the presence of a dog or a person did not improve the participants' performances. This may be due to the fact that both tasks in this study might have been too complex and challenging for the participants. In other words, the results suggest that for complex tasks, a companion animal can produce social inhibition effects just as in the presence of a person. However, for the complex task in this study, all dog-familiar participants responded with fewer errors when working in the presence of a dog. For the more complex and difficult task, the presence of a familiar companion animal dog might produce facilitation effects different from a person.

4.2 Physiological and Emotional Changes

HR showed a different tendency in the dog-familiar factor. The presence of a familiar-dog may raise heart rate. In other words, the presence of a dog may increase the dog-familiar participants' physiological arousal. However, there was little correlation between task performance and the physiological measurements when working in the presence of a dog, while there was a correlation when working alone. These results cannot be explained by social facilitation-inhibition. For the simple task in this study, there was a negative correlation between the response time and the POMS score of fatigue and confusion when working with a familiar-dog. The results suggest the presence of a familiar-dog may be effective in relieving fatigue and confusion when the performance was slower.

5 General Discussion

Whether the presence of a dog increases workers' physiological arousal and facilitates task performance or not may depend on the task complexity and the workers' dog-familiar factor. In other words, the presence of a dog may change the atmosphere even in the workplace. This is one of the reasons why activities with companion animal dogs have become popular in hospitals and nursing home facilities. However, further study is needed to verify the findings obtained from this study not only for more complex and difficult tasks but also for many workers in the workplace. It is our hope that the findings here will increase awareness of the benefits of introducing companion animal dogs into the workplace.

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References

1. McNair, D.M., Lorr, M., Dropplemann, L.F.: Manual for the Profile of Mood States (POMS). Educational and Industrial Testing Service, EdITS, San Diego, CA (1992)
2. Ogawa, I.: The effect of companion animal dogs on office workers to relieve job stress – an experimental study using the Profile of Mood States (POMS) -. Health Sciences 22(2), 227–239 (2006)
3. Ogawa, I., Sakamoto, T.: What is the most beneficial type of recreation for computer operators? In: Proceedings of Human-Computer Interaction International 2003, vol. 3, pp. 118–122 (2003)
4. Okazawa, M.: Limitation of salivary ORP value and the confirmation of the physical condition. Journal of Medical Technology 53(7), 767–777 (2009) (in Japanese)
5. Pfeifer, M.A., Cook, D., Brodsky, J., Tice, D., Reenan, A., Swedine, S., Halter, J.B., Porte, D.: Quantitative evaluation of cardiac parasympathetic activity in normal and diabetic man. Diabetes 31, 339–345 (1982)
6. Randall, W.C. (ed.): Selective Autonomic Innervation of the Heart: Nervous Control of Cardiovascular Function, pp. 46–67. Oxford University Press, New York (1984)

7. Task Force of the European Society of Cardiology and The North American Society of Pacing and Electrophysiology: Heart rate variability – Standards of measurement, physiological interpretation, and clinical use. European Heart Journal 17, 354–381 (1996)
8. Wheeler, T., Watkins, P.J.: Cardiac denervation in diabetes. Br. Med. J. 4, 584–586 (1973)
9. Zajonc, R.B.: Social Facilitation – A solution is suggested for an old unresolved social psychological problem. Science 149, 269–274 (1965)

Analysis on Flight Fatigue Risk and the Systematic Solution

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Abstract. The aim of this study was trying to analyze flight fatigue risks and find out a systematic solution for risk controlling. Firstly the model of Human Information Processing was introduced to analyze fatigue manifestations and risks in flight operation. Secondly causes leading to flight fatigue were specified from the 4 aspects of personal, organizational and social factors. Thirdly a framework of controlling flight fatigue risk was put forward in the systematic perspective. The framework contains three levels which are Fatigue Contributing Factor Level, Fatigue Measurement Level and Fatigue Prevention Countermeasure Level. Then a Fatigue Measurement and Warning System was worked out as a case study. Finally it concluded that flight fatigue is an important and long-term issue in aviation transportation industry, the systematic solution proposed in this paper is effective but there is a long way to go for implementing it.

Keywords: flight fatigue, risk, fatigue measurement.

1 Introduction

Fatigue refers to a degradation of mental and physical abilities and a demotion of emotional status due to the isolated or combined effects of insufficient sleep, working/resting against the body's natural circadian rhythms, and certain aspects of the work demands and workload such as time on task, ergonomic considerations and so on[1] [2].

Fatigue is a threat to aviation safety because of the impairments in alertness and performance it creates. Fatigue risk exists widely among flight and cabin crews, air traffic controllers, technicians, mechanics, dispatchers and ramp workers. Especially for pilots who should suffer the tire brought by sleep loss, night and shift work, and long duty cycles, and also the pressure of remaining alert by their actions, observations and communications. For example, fatigue played an important role in the crash of Comair Flight 5191, according to the report of US National Transportation Safety Board (NTSB) report where pointed out that lack of sleep hindered the performance of three important players in the crash – the captain, the co-pilot and the air traffic controller [3].

The Federal Aviation Administration (FAA) has now recognized that "incorporating fatigue risk management systems into everyday operations is the ultimate goal, but

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doing so will take innovation in addressing a myriad of regulatory issues" [4]. Not only in US, but also in other countries or organizations the fatigue issue attracted more and more attentions in recent years. European Aviation Safety Agency (EASA) also implemented new regulation on Flight Time Limitations (FTL) for controlling flight fatigue in 2010, International Air Transport Association (IATA) established its own FTL Task Force under its Operations Committee and International Civil Aviation Organization (ICAO) proposed to mandate pilot fatigue risk management and addressed crew member fatigue in regulation [5] [6] [7].

Fatigue risk management system (FRMS) currently is seen as a popular tool and has been applied in aviation industry of many countries. But mostly this kind of system was developed by just consideration of one or two fatigue contributing factors such as flight and duty time limitations. Generally to say, fatigue risks exist in aviation industry universally and chronically. Especially in the countries or regions where there is large air traffic volume or air transport volume is increasing rapidly, the fatigue problem is becoming more visible and serious. So it needs to explore a more systematic and effective solution to solve it.

2 Fatigue Manifestations and Risks

The definition has indicated that fatigue is one kind of human mental or physical state, so individuals play a critical role when they face fatigue. Some research has pointed out that fatigue can manifest itself both physically and psychologically. Physical manifestations were demonstrated as general feeling of tiredness, nodding off / inadvertent napping, slowed reaction time, growing and irresistible need to sleep and so on. Mental manifestations were demonstrated as difficulties in memorizing information, lack of concentration, slow understanding, and poor decisions and so on.

After analyzing on lots of flight incidents related to fatigue, we found that most of crew personal errors always happened in every link of human information processing. Therefore we tried to use a Model of Human Information Processing to illustrate fatigue influences on operator [8] [9]. The model is as following and the fatigue influences in every stage were listed.

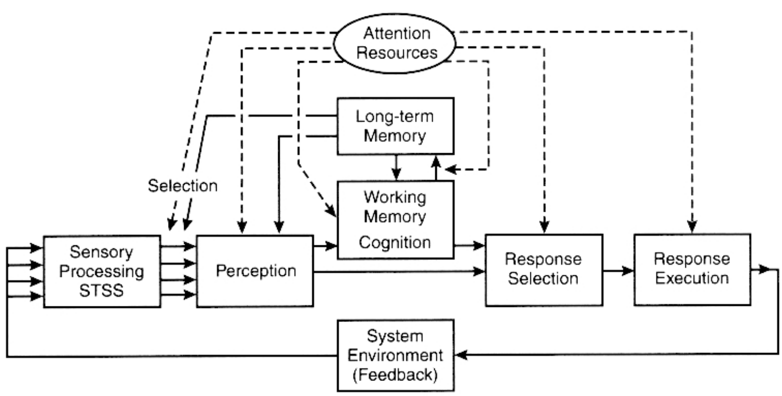

Fig. 1. Human Information Processing Model

Table 1. Fatigue Manifestations in Information Processing

Stage of Information Processing	Fatigue Manifestations
Perception	• Diminished vision • Lack of awareness • Slow understanding
Attention	• Channeled concentration • Easily distracted by unimportant matters • Impossible to be distracted • Reduction in vigilance
Memory	• Short-term memory problems • Difficulties in memorizing information • Diminished standards
Response selection	• Poor judgment • Poor decision-making • Slowed reaction time
Response execution	• Diminished motor skills • Slow reactions

As seen from above analysis, the main harmful result of fatigue is its impairment on information processing ability and performance, and then further leading to occurrence of human errors. Meanwhile it should be noted that these manifestations are just the external features of fatigue. In fact, the risk arising from fatigue is the outcome of a chain of preconditions and contributing factors. Fatigue risks exist in personal level, organization level and even beyond where there are contributing factors. For example, Holmes and Stewart (2008) indicated that "fatigue risk" is not a simple reflection of how fatigued an operator (pilot, AME) or a team of operators is; rather, it depends on how fatigue interacts with operational processes and in turn threatens the integrity of the operation as a whole[10]. Obviously fatigue problem is complicated that we should find a systematic solution to control the risks it arouses. We will analyze the contributing factor in detail in next section.

3 Statistics and Contributing factors of Fatigue

3.1 Statistics

Although estimates vary, official statistics indicate that fatigue is involved in at least 4-8% of aviation mishaps. Lyman and Orlady (1980) showed that fatigue was specifically implicated in 77 (3.8 %) of 2,006 incidents reported by pilots to NASA's Aviation Safety Reporting System (ASRS) [11]. When the ASRS analysis was expanded to include all factors that could be directly or indirectly linked to fatigue, incidents potentially related to fatigue increased to 426 (21.2 %). Since NASA added a fatigue category in June 2009 there have been more than 200 reports from flight crew members concerned about fatigue affecting work performance and safety.

A study in Victoria found that approximately 70 deaths and 500 serious injuries occur each year in road accidents as a result of fatigue [12].

The incidents regarding with crew factors which happened in Chinese civil aviation from 2006 to 2010 were analyzed and the statistic result shows that there were 3 incidents (3.9%) caused by pilot fatigue directly. There is also a typical case of flight accident happened in July of 1992 in Nanjing airport, the fatigued crew members did not execute checklist carefully and have not found the stabilizer was set in a wrong position when they took off. It leads to aircraft crash and 106 passengers were killed. Except for this case, there are several cases that fatigue made an indirect influence such as the Captain left cockpit for sleep. Seen from reports of Sino Confidential Aviation Safety reporting System (SCASS), the reports related to flight duty time hold a great proportion (around 25%) among total pilot reports.

Major problems with statistics relating fatigue to accidents and incidents include the lack of a coherent definition of fatigue itself and the absence of a reliable and valid assessment tool to measure it retrospectively. Fatigue is generally difficult to investigate on a systematic basis and to code in databases. Therefore, any statistics related to fatigue and incidents/accidents are likely to be an underestimate and should be interpreted as such.

3.2 Contributing Factors

The contributing factors of fatigue are various in the commercial aviation environment and there have been many research outcomes which mostly were focusing on analysis of sleep loss, circadian disturbances and so on. In this research we tried to find out the deep reasons leading to fatigue in an integrated perspective and analyze these contributing factors from the 3 levels which are social level, organizational level and personal level.

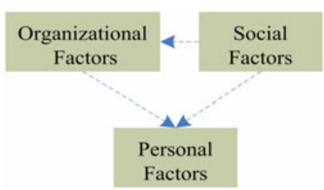

Fig. 2. Three Levels of Fatigue Contributing Factors

As showing in Fig.2, individual is the last level facing fatigue and also the most important defense line to fatigue meanwhile. Combining with previous research and incident analysis results, we listed all contributing factors as following table.

Table 2. Fatigue Contributing Factors

Level	Fatigue Contributing Factors
Social factors	• Recognition degree of administration • Regulations and policies • Social competition pressure • Interpersonal relationship • Social activity
Organizational factors	• Fatigue management measures • Flight shift arrangement • Working area and environment (flight deck) • Human resources (pilot numbers and quality) • Fatigue reporting mechanism • Safety culture (positive reporting culture) • Fatigue education and training
Personal factors	• Sleep loss • Circadian Disturbances • Medical factors • Physical factors (Health state) • Psychological factors (ability of information processing) • Emotional factors • Age and gender • Diet factors • Team factors (ability of cooperation)

4 Integrated Framework of Managing Flight Fatigue

The analysis results show that the flight fatigue was caused by multi-level factors and the controlling flight fatigue risk is a systematic engineering. So finally this paper puts forward a framework of preventing flight fatigue incidents in the systematic perspective.

The framework model contains three levels which are Fatigue Contributing Factor Level, Fatigue Measurement Level and Fatigue Prevention Countermeasure Level. The function of Contributing Factor Level is to reveal the total personal and environmental factors causing flight fatigue, the Fatigue Measurement Level aims to develop and find new method or technique to monitor flight fatigue in real time and in a period. The Prevention Countermeasure Level is the last and critical level founded on the former two levels.

The contributing factors of fatigue were classified into social factors, organizational factors and personal factors which were discussed carefully in last section. Here what needs to be reinforced is the relationship existing among the 3 factors. Social factors and organizational factors may lead to fatigue by influencing personal physical and mental state. For example, bad shift arrangement and unexpected social activity both will cause sleep loss in some extent. The psychological pressure from social competition or family life also will affect personal fatigue accumulation.

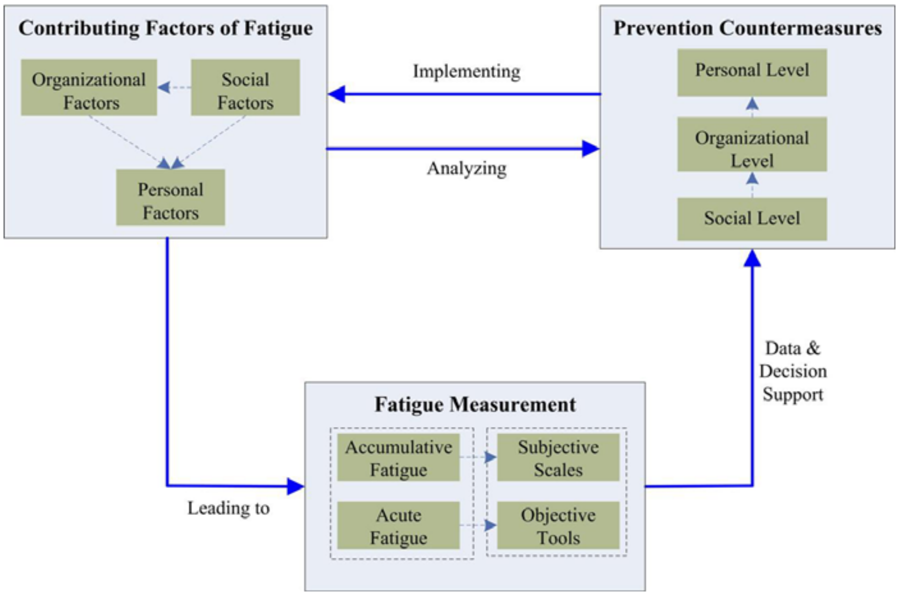

Fig. 3. Integrated Framework of Managing Flight Fatigue

Table 3. Fatigue Countermeasures in Systematic Perspective

Level	Countermeasures
Social Level	• Regulations and requirements from administration • Actions of controlling fatigue risk (assessment, audit, investigation and so on) from administration • Develop voluntary reporting system of fatigue incident • Social concern and understanding on pilot
Organizational Level	• Develop and implement Fatigue Risk Management System • Make rational shift plan for pilot • Create comfortable flight deck environment (temperature, no smoking, space for rest or nap and so on) • Nourish positive safety culture • Ensure enough human resources and training
Personal Level	• Keep effective sleep (duration and quality) • Maintain regular circadian rhythm • Obtain adequate rest and recovery (proper nap) • Report errors and incidents caused by fatigue • Keep healthy and steady psychological state • Be cautious to use of medicine and alcohol drinks • Keep a healthy dietetic habit (avoid high fat and high carbohydrate foods)

In the Fatigue Measurement Level, two ways of fatigue measurement were proposed to be applied into practice together. One of them is subjective scales to measure accumulative fatigue and the other one is objective tools to measure acute or real time fatigue. The results of the two measuring ways should be analyzed in an integrated perspective and then expected to provide data and decision-making support for fatigue prevention.

In Prevention Countermeasure Level, we put forward that fatigue prevention countermeasures should be found from the three levels corresponding to fatigue contributing factors. Here we list these countermeasures generally.

5 Case Study-Fatigue Measurement and Warning System

Fatigue measurement is a key link in the fatigue management framework because it can provide objective data for decision-making of fatigue prevention. Here a prototype of Fatigue Measurement and Warning System which we designed and developed was introduced as a case.

Combining with face recognition and eye tracking technique, a framework of real time Fatigue Measurement and Warning System (FMWS) was proposed out as follow figure.

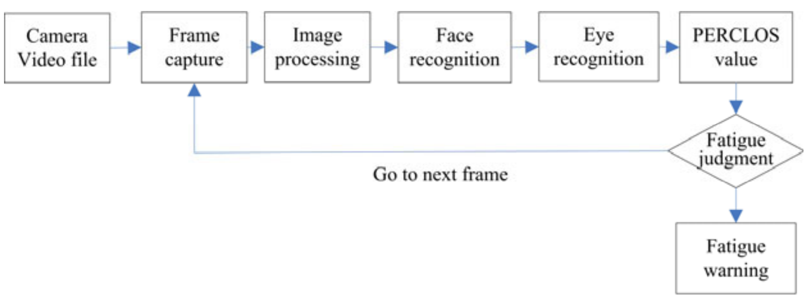

Fig. 4. Framework of Fatigue Measurement and Warning System

The system consists of four components: face detection, eye detection, eye tracking, and fatigue detection. Firstly a frame of image will be captured from an ordinary camera or video files. The first frame will be processed by using image process methods and then used for initial face detection and eye location. If any one of these detection procedures fails, then go to the next frame and restart the above detection processes. Otherwise, the current eye images are used as the dynamic templates for eye tracking on subsequent frames, and then the fatigue detection process is performed. If eye tracking fails, the face detection and eye location restart on the current frame. These procedures continue until there are no more frames. When all frames in a time limit were detected over and a statistic regarded with eye-closed frames will be made later. The statistic value is called PERCLOS which is an accredited threshold of judging fatigue.

Based on above framework, we used Visual C++ and Open CV as tool and finished the developing of prototype system. The main interface of the FMWS is as the following figure. It was tested in laboratory environment and proved to be effective and extensible for applying into practice.

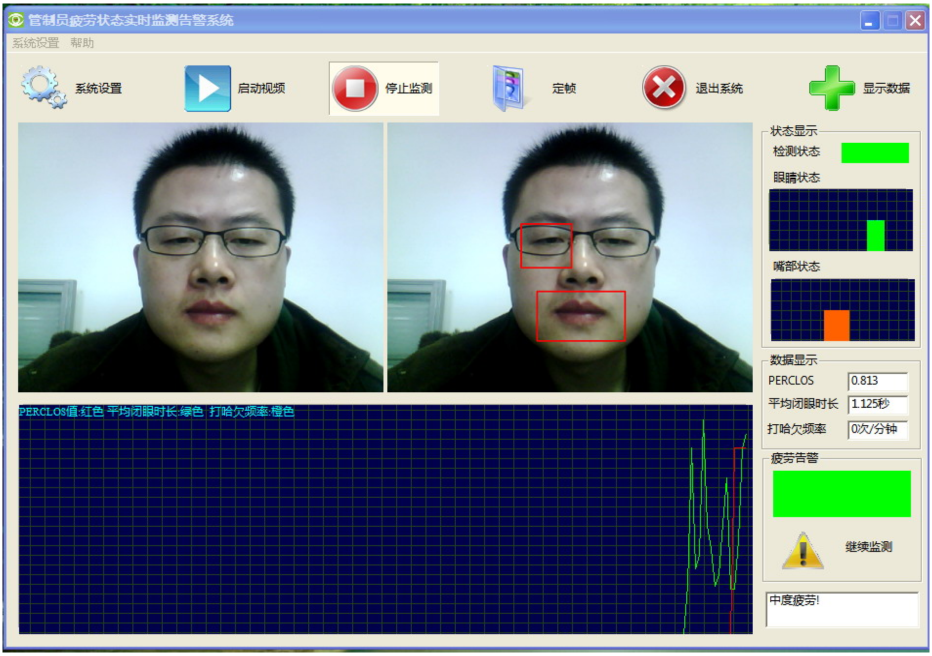

Fig. 5. Interface of Fatigue Measurement and Warning System

6 Conclusions

Flight fatigue is a stubborn but very significant issue in aviation transportation industry. The main viewpoint of this paper is to illuminate that it requires a systematic solution for controlling of flight fatigue risk. Based on this idea, we started this research and the main works are concluded as following.

1) Fatigue manifestations and risks were listed out basing on flight incident analysis and a model of Human Information Processing was introduced to illustrate fatigue influences on operators. Fatigue always makes negative affecting on information processing of human.
2) The statistic on incidents showed that fatigue is a universal and realistic problem existing in many countries and areas. But the problem probably is more serious than what we expected because of the statistic limitations.
3) The contributing factors of fatigue were analyzed from three aspects. Then a framework of preventing flight fatigue was put forward in the systematic perspective. The framework model contains three levels which are Fatigue Contributing Factor Level, Fatigue Measurement Level and Fatigue Prevention Countermeasure Level.
4) A prototype system (FMWS) was designed and worked out. This system is a key component of flight fatigue management and expected to be perfected and applied into use.

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References

1. Gander, P.H., Rosekind, M.R., Gregory, K.B.: Flight crew fatigue VI: an integrated overview. Aviation, Space, and Environmental Medicine 69, B49–B60 (1998)
2. Dawson, D., McCullough, K.: Managing Fatigue as an Integral part of a Fatigue Risk Management System. In: ISASI, Australia (2004)
3. NTSB Accident Report. Attempted Takeoff From Wrong Runway Comair Flight 5191 (2007), http://www.ntsb.gov/publictn/2007/AAR0705.pdf
4. FAA Press Release. FAA Statement on the Aviation Fatigue Management Symposium (2008), http://www.faa.gov/news/press_releases/news_story.cfm?newsId=10246
5. Cabon, P., Mollard, R., Debouck, F., Chaudron, L., Grau, J.Y., Deharvengt, S.: Toward a fatigue Risk Management System: application for the regional French airlines. In: Proceedings of the 79th Aerospace Medical Association Annual Scientific Meeting, Boston, MA (2008)
6. Bennett, S.A.: Flight Crew Stress and Fatigue in Low-Cost Commercial Air Operations – An Appraisal. International Journal of Risk Assessment and Management 4, 207–231 (2003)
7. Signal, T.L., Ratieta, D., Gander, P.H.: Flight crew fatigue management in a more flexible regulatory environment: an overview of the New Zealand aviation industry. Chronobiology International 25(2-3), 373–388 (2008)
8. Wickens, C.D., Hollands, J.G.: Engineering Psychology and Human Performance, 3rd edn (1999)
9. Zhu, Z.: Engineering Psychology Tutorial. People's Education Press (2003)
10. Holmes, Stewart: The easyJet Fatigue Risk Management System (FRMS). In: FAA Fatigue Management Symposium: Partnerships for Solutions, Vienna, VA (2008)
11. The NTSB and FAA Address Fatigue in Aviation Operations, http://www.faa.gov/news/press_releases/news_story.cfm?newsId=10246
12. Bennett, S.A.: Pilot Stress and Fatigue in Low-Cost Operations. Journal of the Institute of Civil Defense and Disaster Studies (2004)

Healthcare and Security: Understanding and Evaluating the Risks

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Abstract. Part of the job of healthcare providers is to manage client information. Most is routine, but some is sensitive. For these reasons physicians' offices provide a rich environment for understanding complex, sensitive information management issues as they pertain to privacy and security. In this paper we present findings from interviews and observations of 19 physician's offices in rural-serving southwest Virginia. Our work presents examples of what might be labeled as security violations. In particular, we found that the tensions between work practice and security, and between electronic and paper records, resulted in issues that need broader discussion in relation to the role of the social in the management of patient information.

Keywords: Healthcare, security, usable security, privacy, work practice.

1 Introduction

Traditionally, electronic and physical security have been concerned with creating rules, locks, and passwords. However, security systems that neglect people as a significant part of the equation "are seldom secure in practice" [3]. Practice is what happens in the moment; it is the activity; it is what is actually done. It is often in the human-centered moment, and not in the computer-centered planning stages, when security policies or mechanisms break down and the safety of sensitive information is compromised. In 2011 millions of patient records will become readily available in digital format which experts in privacy, trends, technology, regulatory, data breach, and governance say "will lead to potential unauthorized access, violation of new data breach laws and exposure to the threat of medical and financial identity theft" [9]. For these reasons we propose that there exists a need to study socio-technical systems to understand and evaluate what role both humans and technology play in creating usable and secure health systems [1].

Specifically, we propose focusing on physician's offices, where there is a plethora of sensitive patient information that exists in various stages and forms of documentation. Physicians' offices are valuable locations of study given the collaborative nature of the work and the increasing adoption of electronic medical records [7]. However, it is expected that patients will gain a heightened awareness and concern for the security of their medical records as patient agency increases [9]. There

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has been an “endemic failure” to adapt to advancing best practices and technology that has created “antiquated data security, governance, policy plaguing in the healthcare industry” - as argued by healthcare security experts [9]. Digital security in the healthcare industry has not adapted to meet current challenges; however, despite the obvious need for increased information security in physicians’ offices, little work is being done in the area.

To further discuss these issues we present data from interviews and observations of 19 physicians’ offices in Southwest rural-serving Virginia to continue the discussion of usable security within a *particular location* and with a focus on social and technical *practice*. By focusing on practice within physicians’ offices our work represents an important contribution of where security in action is and is not located within healthcare systems.

2 Related Work

The work of usable security in healthcare is an amalgamation of prior work on healthcare, security, and HCI [1, 6]. Patients serve as users, owners of sensitive information, and as part of the healthcare system. In regards to security, prior work has demonstrated balance is essential between policies and software solutions that are constructed accounting for: social and organizational context, temporal factors from actions in that context, possible threats from information usage, and trade-offs made by the user [1]. Some considerations would be the location of electronic and paper records within the physician’s office and healthcare being inconvenienced by extra steps, such as using a password every time they return to a computer. Bardram states that the current electronic medical record systems do not incorporate any “usage context” [14]. The entire situation is essential to the process of information usage in physician’s offices because it is “seamlessly interwoven with other working activities” [16]. These factors demonstrated that all solutions are not technical: the social context must be accounted for in order to fully represent the needs of the users – as argued more generally in the work of Paylen & Dourish [4]. Despite the need for such context, there has been little work done in real social practices in regards to privacy and security, and specifically within healthcare. Thus, our work is a valuable contribution to the growing need of observations in social environments.

When looking at the context of a medical information system, research suggests that “context is more than location.” Context can include the location of physical artifacts that are being used with a given task, the room the tasks are carried out in, where patients are, their treatment, schedules for nurses, and many more factors. Furthermore, the “digital context” is also important to consider. Other computer systems that a medical staff is using are relevant. A study found that in general hospital work there is often a “simple connection between a clinician accessing some physical things and the activity s/he is engaged in” [14]. For these reasons it is essential that we examine the context of the physician’s offices in order to fully comprehend the socio-technical system.

Other research has found that, in order for a security fix to be successful, it must be both correct and dependable. Dependability comes as a result of the system working as the user desires. Correctness of a security fix means that the countermeasures will block threats to the system [15]. In reference to secure technological systems, they are effective only if the "countermeasures will neutralise the threat" and the "countermeasures are working as intended" [15]. But socio-technical systems are also comprised of people, as described by Flechais et al [15]. Socio-technical systems use a combination of countermeasures for prevention, detection, reaction, and deterrence that are different than purely technical ones .

In prior work within the medical context, Adams & Blanford [1] discussed with members of two hospitals the use of passwords to protect access to sensitive data when computers were unattended. They found that many users were simply ignoring the password protection system -- so many that it became difficult to enforce the security mechanisms in place. Similarly, Adams & Sasse discussed that system security often lacks "user-centered design and user training" [2]; however, users are a critical component in a successful secure system. These systems are not psychologically acceptable, that is to say the user's perceived cost of using the systems is out weighted by their perceived benefits [15]. However, considering security beyond password use has received little attention. For this reason we present findings below that include an analysis of security mechanisms that extend beyond password usage (or the lack there of).

Within prior work there have been few examples of qualitative analysis in regards to security and privacy in healthcare (with valuable exceptions [1]). Qualitative methods, such as interviews and observations, allowed researchers to gain a "deeper understanding of lived experiences by exposing taken-for-granted assumptions" by witnessing how "participants live in their environment" [5]. In particular, what work that is being done has focused on technologically adept locations, with little research regarding those who opt not to use technology [8]. For these reasons we present qualitative data from rural-serving physicians' offices in regards to their security practices.

3 Methods

3.1 Participants

Fourteen interviews were conducted with directors of physicians' offices; and, 61.25 hours of observation were carried out at 5 locations. The participants had, on average, 20.16 years of experience as a director. The average staff size was 10 people with approximately 128 patients seen weekly. All offices provided non-life-critical care. Given the dearth of diversity of physician's offices in this location, more identifying information cannot be provided as to the type of centers that were observed due to participant anonymity. All participants were unpaid.

3.2 Interview and Observation Process

The interview protocol was developed and vetted by two external researchers to the project. Participants were asked demographic questions, questions in regards to their daily information management practices, and questions in regards to their electronic systems. Pictures and forms were collected from offices during interviews.

Prior to starting each of the observations each observer re-read all prior interviews and final reports. The observers were centrally located in the physician's office and able to watch over the shoulder of the healthcare staff. Observations were spanned to watch during all times of the day and across days of the week where patient load and temporal work rhythms can vary.

3.3 Data Analysis and Phenomenology

We used a phenomenological approach to data analysis to derive the essence of security and privacy within collaborative management of patient information. Phenomenology is a qualitative method used frequently in healthcare research, but has also been used within human-computer interaction research to understand the experience of interacting with technology – with the Heidegger's canonical 'ready-at-hand' example serving as a popular instance [10]. The power of phenomenology is the concentration on the essence of a phenomenon [12]. It is applied by focusing on a particular object and rendering the experience of interacting with that object to make explicit inferences and derived themes [11].

For our study we do not engage in the continual (and valuable) discourse on aspects of phenomenology, but instead affirm the value of studying subjectivity. Understanding the subjective nature of security and privacy as lived experiences affords a deep understanding of loci of these phenomena refocusing on the social along with the technical, thus facilitating user-centric design. To do this, phenomenology avoids categorization and organization, but instead the action of the method is focused on the description. A powerful tool for phenomenology is therefore the presentation of the phenomenon with narrative descriptions, as we have done in our results section below [13]. To derive these narratives three researchers engaged to thematically organize similar experiences, establishing agreement between the researchers, and then examining the resulting body of data related to the essence of security and privacy in physicians' offices as presented in our discussion section.

4 Results

We present these results not to point at any one place where security and privacy were not accounted for. Instead, we present these results to provide interlaced examples to construct a broader understanding of security and privacy in the collaborative management of patient information.

4.1 Password Sharing

There were two instances where a participant with special access would log into a computer or medical system in order for another office member with a lower level of access or no access at all to utilize the system. In one case, an employee that worked primarily with Medicare needed to log into the hospital's electronic database to collect information on a newborn infant. However, she had not attended the required course which would have granted her access to the system. To obtain the information she was seeking, she asked one office staff member who did have this access to log her in. This scenario demonstrated that, when users share login information, the ability to audit who has accessed and modified patient information is lost.

The second example comes from an interview where the director explained how the staff would log into their computers and use that login all day long. Office staff will use another's machine but everyone in the office "has the same access" and "there is no really privacy act between employees," as one participant explained. Because all users of the system have the same level of permissions, there is not a need to have an explicit rule specifying that they can or cannot use each other's computers.

4.2 General Lack of Passwords

Even more prevalent than sharing passwords was the general lack of password use. There was only one observed use of passwords to enter an individual center's electronic system. An observer wrote "...<PR2> is still typing and clicking in MediaDent. She quickly checks her hotmail and re-launches MediaDent and logs into it with her user ID and password." During interviews researchers additionally learned that of the physician's offices that did have electronic systems only 6 used passwords. For instance, the observer writes while watching the director, "<the director> brings a paper over and punches it on the counter next to me. She leaves her office with it, leaving her computer unlocked." This example is canonical of how office staff would (a) leave their computers open when they would leave their workstation, and (b) the general lack of concern about leaving a computer insecure. There were three additional instances describing a similar lack of password use.

4.3 Difficulty Locating Patient Files

There were fourteen occurrences of medical staff having difficulty locating client files. These problems resulted in additional patient files being created, files not being in the correct location, and lost client information. Furthermore, the office workflow was often not conducive to locating paper files. For example, one physician's office had a separate location for when a patient's file needed a transcription, if the patient was going to be seen that day, if the patient's file had been audited by the doctor, if the patient had a particular medical device, and different locations for how long it had been since the patient had last been seen (within the last year, within seven years, or more than seven years). Due to the different users carrying out different activities on the file, the file would be placed in different locations dependent upon a particular user's activities and not the next activity that the file may be needed for. This workflow system resulted in conflicts when there was not a shared understanding of where a patient's file should be located.

4.4 Electronic Record Systems Crashing and Loosing Client Information

Out of the nineteen physicians' offices that we visited, eighteen of them had some form of electronic records used to manage their patients' care. There were five instances where the offices' electronic system crashed and lost pertinent information. One director explained how her office had been making automated electronic back-ups when they experienced a fatal crash. This crash led to the discovery that the back-up system had not been properly working for three weeks. As a result the director "worked a lot of weekends" in order to re-enter all of the lost information from their paper records, which they had still been maintaining. Similarly the director of another physician's office explained that a virus destroyed their patient's medical and account information in their system. This practice now does additional electronic back-ups of their system. All offices still maintained their paper-based files "just in case."

Fig. 1. One participant's patient's files demonstrating open access for anyone in the office

4.5 Patient Information Left in the Open

Given the diverse array of uses for client information, sensitive information is dispersed and left in the open environment. This includes sensitive information being left on countertops, patient names being shouted across rooms, and sensitive files being taken outside of the office where they are not secure. Information in these spaces and places do not necessarily indicate a breach in safety, but reflects the uses of sensitive information that are not accounted for with the current technology systems.

There were two incidents where private patient information was mistakenly left out of a patient's file which resulted in the information being exposed. During an observation there was a client X-ray that was left on the counter detached from the file. During the observation not only did a nurse with no cause view the file, but also due to the lack of identifying information the X-ray ostensibly remained file-less. All offices had patient records freely available to anyone to access as shown in Figure 1. These files hold highly sensitive information, and the fact that they are freely available for anyone to be able to access illustrates that they appear to be not very secure. No filing cabinets were observed to be locked at night or during the day.

4.6 Lost Paper Patient File and Information

During one interview, a director discussed that, when files go missing, he "will then recreate the file." He does not notify the patient that the file is missing, or report the missing information to any other relevant individual. There additionally was documentation missing from a patient's file four times. Such documentation was observed to come from a variety of sources - nurses entering information during a patient visit, annotations being made by a doctor, transcriptions, etc. In an example, a nurse discovered missing information about a patient's medicine dosage in the patient's file while calling the patient. With chagrin, the nurse apologized and made an update in the patient's file while reflecting upon how dangerous an incorrect dosage would be to the patient.

4.7 Missing Electronic File

There were four instances where participants were not able to locate an electronic file. In the three out of four incidents in this category, the problem occurred because the patient record had not yet been created when someone in the office attempted to access it. In the first instance, a patient came to the office over the weekend for treatment. However, despite someone being available to treat the patient, no one created the electronic record. The second example involved a healthcare worker entering information about a visit prior to the record being made about the client. The third incident involved a patient calling the practice for medical advice prior to the first visit, and the electronic file had not yet been created. In the fourth incident a nurse was not able to look up a patient in the EMR system based on their name.

4.8 Files Being Kept Outside of Office

Due to the extended duration that physicians' offices keep their patient records, many records past a certain span of years are moved to a secondary location. There simply is not enough space at the physician's office to store all patient records. At some locations even currently active patient files are temporarily removed from the office. For example, a doctor had a "homework pile" that he would bring take every night for calling the patients to make sure they were recovering well. When files are stored offsite, they are kept in locations such as basements ("he keeps them in his basement"), central storage facilities ("we have a central storage room"), and "storage." All solutions prescribe a new set of stakeholders who have access to the patients' files that were previously unaccounted for.

5 Discussion

It has been one of the central tenants of the research on computer supported collaborative work that people do not act as individuals. Instead, people interact, react, and are mediated through the actions that they have with one another. The interaction with computing systems is no different. Computers are used as tools to interact, react, and mediate actions with one another. However, when it comes to the design of secure systems, many have been designed for the individual rather than as an actor within a community of people bound together in joint activity. For example, one person is given one password to work at their one computer; or, one file is associated with one client which has one unique ID for locating it which is to be associated with one person's ID.

Yet, as was demonstrated in the previous sections, this is not how the people of these centers account for their work. The use of passwords, or the lack there of, and the open access to client information at physicians' offices is perhaps the strongest example of the problem of assumed individuality in these centers. Staff shared passwords, shouted passwords, and many centers did not use them at all. When questioned why, one director explained it is because "<people in the office> can access anything. That's their job." It is the job of the people there to do the work, not for them to follow them to individually account for their work. With this point in mind, we propose two discussion points.

5.1 Systematic Flaws

Electronic record systems crashing, data backups failing, difficulty of locating paper patient files, and leaving files in the open can all be attributed to flaws within the socio-technical system. The work of the electronic system is invisible (to individuals and to the group) which results in the inability to determine if they are still working correctly. Furthermore, the users have little knowledge of when a crash has occurred and, subsequently, their information lost. The perceived and real unreliability of electronic systems require practices to maintain their paper files as a reliable backup source, resulting in twice the amount of files to maintain and twice the amount of data to secure. Leaving information out of files or files off the shelf, even temporarily in between uses, is in direct conflict with keeping the information secure in the sense that it is not locked away and protected from prying eyes. Redundant information represents a system flaw in regards to security, but was created to support the social system. Designers should consider the affordances of paper files that are difficult for electronic systems such as having a physical location, recognizable handwriting, and spotting inconsistencies in the system (e.g., missing information within a file).

The open access of patient information has many valuable functions within physicians' offices. The files are easier to access when the office becomes busy. It keeps what work needs to be done more visible by showing places where files are missing. It also signals to new clients that they already have repeated successful business. However, it can also mean that the information is more susceptible to theft.

5.2 Is Patient Privacy a Fallacy?

Further improvements can be made to enhance the reliability and security of electronic systems. Updates can be tracked and system backups can alert the system administrators when they fail to run successfully. Additionally, machine learning algorithms can process individual user access to patient files in order to identify unusual behavior. However, solutions like these can be accused of throwing more technology at the problem without accounting for the work that people do. A tenant of usable security literature states that people will find a way to circumvent a security measure when it comes in conflict with another task. We therefore have presented the previous security issues that demonstrate security flaws in the everyday work of a physician's office staff. These are not flaws of malice, but flaws of negligence where the work of making client information secure and private is not clearly embodied in the collaborative practice of managing patient information.

6 Conclusion

Patient files were lost, privacy was breached, and the patient files were relatively insecure. Taken together these provide an alarming picture. However, no patient died, and in general the records were not stolen. The question has to become why do these problems exist and what can be done about it. Therefore, in this paper we have presented the critical and timely need for a deeper understanding of the context of security and privacy practices in physicians' offices. Additionally, we provided data to demonstrate the kinds of security and privacy issues present in physicians' offices to start this discussion within the HCI community.

One of the issues that is embedded with this work is the distinction between 'is' and 'ought.' People ought to use passwords, and they ought to not leave patient information unaccounted for. People ought to lock their filing cabinets, and not shout patient information. There are many things that people *ought* not to do. However, that is not the goal of human-computer interaction. Instead, as human-centered designers, it is our responsibility to represent the 'is' in the socio-technical system. We propose to do this through enabling communities of security to manage patient records. This means sharing passwords, detecting and supporting shouting patient information, and knowing the location of decontextualized information. Future work will build on this idea to demonstrate new methods of supporting healthcare workers. Additional work should be done to identify the costs and benefits of open access systems, especially in life-critical situations.

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References

1. Adams, Blandford: Bridging the gap between organizational and user perspectives of security in the clinical domain. IJHCS 63(1-2) (2005)
2. Adams, Sasse: Users are not the enemy. Communications of the ACM (1999)
3. Bellotti, Sellen: Design for Privacy in Ubiquitous Computing Environments. In: Conference on CSCW. Kluwer Academic Publishers, Dordrecht (1993)
4. Palen, Dourish: Unpacking "privacy" for a networked world. In: Conference on Human Factors in Comp. Sys. ACM, Florida (2003)
5. Starks, Trinidad: Choose your method: A comparison of phenomenology, discourse analysis, and grounded theory. Qual. Health Res. 17(10) (2007)
6. Carayon: Human factors of complex socio-technical systems. Applied Ergonomics 37(4) (2006)
7. Berner, Detmer, Simborg: Will the Wave Finally Break? A Brief View of the Adoption of Electronic Medical Records in the United States. JAMIA 12(1) (2005)
8. Satchell, Dourish: Beyond the user: Use and non-use in HCI. In: OZCHI. ACM, Melbourne (2009)
9. Merrill: Experts name top 7 trends in health information privacy for 2011. Healthcare IT News (2011), http://bit.ly/faClsS (accessed January 10, 2011)
10. Heidegger, M.: Being and Time, Harper Perennial Modern Classics (2008)
11. Toombs: The Meaning of Illness: A Phenomenological Approach to the Patient-Physician Relationship. J. of Medicine and Philosophy 12(3), 219–240 (1987)
12. van Manen: Researching lived experience: Human science for action sensitive pedagogy. State University of New York Press, New York (1990)

13. Friesen, Feenberg, Smith: Phenomenology and Surveillance Studies: Returning to the Things Themselves. Information Society 25(2), 84–90 (2009)
14. Bardram: Applications of Context-Aware Computing in Hospital Work - Examples and Design Principles. In: ACM Symposium on Applied Computing, pp. 1574–1579 (2004)
15. Flechais, Riegelsberger, Sasse: Divide and Conquer: The Role of Trust and Assurance in the Design of Secure Socio-Technical Systems. AMC, Lake Arrowhead (2006)
16. Reddy, Dourish: A Finger on the Pulse: Temporal Rhythms and Information Seeking in Medical Work. ACM, New Orleans (2002)

The Disability-Simulator: Simulating the Influences of Disabilities on the Usability of Graphical User Interfaces

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Abstract. Today's software systems and especially graphical user interfaces are mostly designed to fit to the needs of an ideal target audience – most often purely focusing on young, physically and mentally healthy persons. Not even the development of tailored (e.g. to elderly people) user interfaces but also the testing is a challenging task, because a large set of test persons suffering from specific impairments needs to be recruited which in practice often is unfeasible and the reason for statistically insignificant results. But software systems and their graphical user interfaces have to be designed to cope with the special needs of also handicapped persons. In this paper we introduce a method to support the target oriented design process and evaluation of such graphical user interfaces by simulating specific disabilities and typical impairments. Therefore we emulate the influences of such impairments on the performance while using any graphical user interfaces by applying specific filter algorithms on the target interface. This enables evaluations of the GUI under realistic conditions without being forced to actually involve real impaired participants.

Keywords: Disability Simulator, Impairment Simulator, Usability Test Tool.

1 Introduction

A graphical user interface of a railway controlling system is informing the user about critical system states via red text messages and indicating normal behavior by using green messages. Unfortunately, about 7% of the overall male population is not able to distinguish between red and green and therefore are unable to use such user interfaces 0. Another example is a GUI of a building automation system for elderly persons having very small buttons and labels, but due to physical restrictions for elderly it not only is hard to make use of such systems, also their capabilities may get worse over time. There are many more examples of graphical user interfaces being almost unusable by persons with special handicaps or disabilities such as Parkinson's disease or Alzheimer's disease – the persons who are the intended users of the system. Even with the knowledge about these potential problems it is still a challenging and costly

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task for software engineers to plan and realize adequate software and graphic user interfaces that can cope with these problems. This is partly due to the problem that every disability is different with unique influences on the user's ability to perform certain tasks or the way she perceives specific signals. A specific element of a graphical user interface may be properly perceivable by persons with red-green colorblindness while it is not suited at all for totally colorblind users.

To design these interfaces properly many things like severity and specific characteristics of potential handicaps have to be considered and adequate countermeasures and respective modifications developed. But even if this is done there is no real evidence that these modifications and countermeasures are really helpful and enable the users in question to properly use the software. If the respective developer is not exactly familiar with these handicaps, its severity, and characteristics, which is almost never the case, she can design and modify the user interface only based on very vague assumptions. Quality and usefulness of the resulting modifications will remain unpredictable and cannot be validated without the help of test with persons actually having these specific handicaps.

Recruiting a statistically significant sample of test persons covering various impairments is not only a very challenging task but also extremely expensive because of the combinatorial explosion.

2 Related Work

Dealing with disability induced issues regarding the use of graphical user interfaces is not a completely new topic of research in the domain of human computer interaction. Especially due to the worldwide ongoing demographic change that results in an increasing percentage of elderly in society, often suffering of typical age-related handicaps like agitated paralysis, far-sightedness or colorblindness, questions about the usability of modern information systems came up [1]. Due to the designers of these systems seldom having expert knowledge about handicaps and disabilities themselves, methods to simulate these disabilities are inevitable to be able to reproduce the respective way of perception. This led to a variety of different simulation approaches, differing in their scope, the variety of covered disabilities and the used technical realization techniques. Approaches of the first category of simulation are purely physical like the *Agnes Age Suit* project from MIT Age Lab [3]. These suits and devices primary aim at simulating age-related disabilities by artificially immobilizing parts of the human body, modifying the perception by the use of ear plugs and specially designed glasses as well as damping movement and agility by using inflexible suit materials. While this approach is well suited to get familiar with age-related issues and challenges, enabling a better understanding of typical problems when dealing with hardware devices, it is barely usable to test software based systems due to its inflexibility, the limited scope of simulated disabilities and the comparably high effort and costs.

To test the usability of software based systems and websites along with their graphical user interfaces, it is more reasonable to use software simulation approaches. Software based approaches like *aDesigner* from IBM Research [6] or the *Visual Impairment Simulator for Java Swing Applications* [7] allow to check websites or Java swing applications for accessibility and usability by visually impaired persons. To do so they manipulate the website or Java swing form in a way that makes them look like the respective person would perceive it. However, these approaches only focus on simulating a limited set of specific disabilities by manipulating static (preprocessed) images, websites or software components and are not able to deal with dynamic contents like videos or to integrate directly into the window management system for direct interaction.

To fill this gap simulation systems like the *Digital Lens* system from Microsoft Research Innovation Labs [4], the Visual Impairment Simulator from the University of Illinois [5] or Fujitsu's *Color Doctor* [8] achieve a simulation of a selection of visual disabilities by a real-time manipulation of the display content. While all these approaches offer a dynamic real-time adaptation of the content to be displayed, they lack a possibility to simulate complete *disability profiles*, combining several disabilities and disability types to simulate a person with multiple handicaps. Also they are not capable of simulating non-visual impairments like e.g. agitated paralysis. Therefore they are often not completely suited to simulate the perception of a handicapped person entirely, because this person is often influenced by more than just one type of impairment.

In contrast to the above mentioned approaches we propose in the following a new method to support the developer in this issue, capable of simulating complete *disability profiles* that combine several visual and movement related handicaps, rather than just simulate one particular disability.

3 Concept and Design Goals

Main idea of our Disability-Simulator came from searching for a good solution to test our own applications in the application domain of Ambient Assisted Living for potential usability problems resulting from disabilities, while especially focusing on elderly people, without actually having to involve real disabled persons in the tests [1][2]. In contrast to already available simulation approaches described above, we wanted to come up with a dynamic solution.

3.1 Disability Profiles

The Disability-Simulator allows the simulation of several disabilities simultaneously by defining explicit *disability profiles*, which in our opinion is the more realistic approach due to the fact that a person often is affected by several disabilities in combination. These disability profiles contain a list of disabilities that should be simulated along with their respective level of severity target values. An exemplary disability profile, with typical age-related disability settings like Parkinson's disease, Glaucoma and Hyperopia, is depicted in Figure 1. In addition, all comparable simulation approaches we found so far are very limited in simulating a certain disability while also at the same time allowing interactions with the underlying user interface. The Disability-Simulator allows an interaction with the graphical user interface under observation while performing a real time manipulation of the graphical representation. This means that it is able to do for example a real time blurring of the graphical output of an application to simulate a certain type of hyperopia while also giving the user a possibility to interact with the blurred graphical user interface. This approach enables a more realistic testing environment, because problems concerning usability may only be found during the interaction with the particular application.

```
# DisabilitySimulator disability profile
glaucoma = true
glaucoma_degree = 2
hyperopia = true
hyperopia_degree = 5
parkinson = true
parkinson_degree = 20
```

Fig. 1. Disability profile (simulation of an elderly user)

3.2 Simulation Approach

Our main goal, simulating the impact of disabilities on the performance and user experience in graphical user interfaces for testing purposes, required us to come up with a solution that allows distinguishing influences coming from the simulated disabilities from possible side effects due to bad user interface design. Therefore, the Disability-Simulator leverages a two (cloned) screen approach to display both, the original interface and the interface manipulated with respect to the configured disabilities. The first monitor always displays the original interface without any modifications, the second one the modified version of the interface with simulated disabilities.

Figure 2 shows an example where the original image on the first monitor (left hand side) is transformed into a modified image on the second monitor (right hand side), to simulate hyperopic vision. Thus, this solution usability test focusing on disability based problems can be easily conducted by test persons without any disabilities. Only the specification of a suitable disability profile is required. So a test person has to fulfill a defined list of tasks on the user interface which is displayed on the second monitor, while the observer can witness the actions on the first monitor showing the interface without any modification and determine the source of a possible usage error.

To document the performance of the test person and to allow further analyses of the results, the Disability-Simulator additionally includes logging capabilities. Mouse movement and clicking activities are continuously logged in combination with the according timestamps to allow tracking of user actions on a time line and computing the time consumed in order to accomplish a specific task. By analyzing this data,

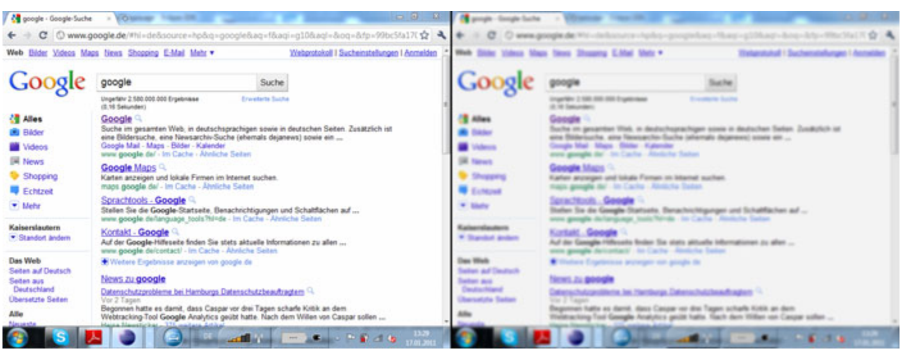

Fig. 2. Original and transformed screen output

comparison with captured data and calculating the respective task-completion times and failure rates from tests with the unmodified user interface disability, related usability problems can be derived to develop adequate countermeasures.

4 Structure and Technical Realization

In the following we discuss the basic design concepts and implementation of the Disability-Simulator prototype focusing on the concept of using special filters to both simulate visual impairment as result of disabilities like hyperopia or glaucoma and movement disorders like agitated paralyses.

4.1 Structure

The prototype of the Disability-Simulator consists of three different components which manage different disability profiles and control their respective filters, are responsible for modifying the graphical output and adjusting mouse movement activities according to the disability that shall be simulated. The main component of the Disability-Simulator offers a possibility to load different previously defined disability profiles. These profiles contain information about the disabilities with their level of severity which should be simulated if the profile is loaded and are stored as plain Java property files. Figure 3 shows an abstract view on the structure of the Disability-Simulator framework.

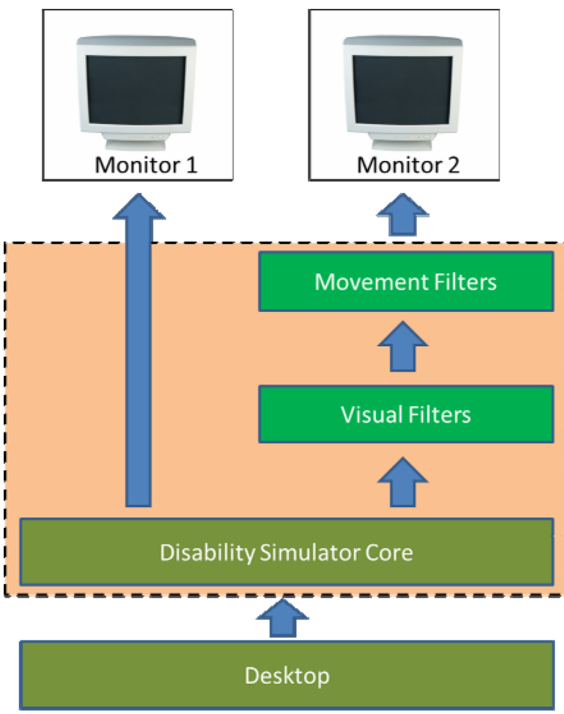

Fig. 3. Abstract structure

After loading the selected profile the main component selects and instantiates the components containing the needed visual filters and movement filters needed to simulate the disabilities specified in the loaded disability profile.

In order to achieve appropriate visual modifications of the displayed image to simulate a certain disability the visual filter components perform several image manipulation algorithms in real time. To simulate the blurring effect a hyperopic person experiences when looking at a graphical user interface without corrective lenses the Disability-Simulator for example uses a special kind of Gaussian filter. Influences of movement disorders are simulated by movement filter components adding jitter to the intended movement of the user or delaying the user input artificially.

In the following sections we introduce two different kinds of filters which can be used to simulate certain disabilities. Due to the modular design of the Disability-Simulator it is comparably easy to define additional filters or to extend the functionality of existing ones. Therefore, we only introduce a small subset of the filters we implemented so far to exemplify the general structure of typical visual or movement filters.

Fig. 4. Hyperopia and colorblindness filters applied sequentially

4.2 Visual Filters

The visual filter components aim at manipulating the display output in such a way that the user has a similar visual impression as a real handicapped user, having the handicap that should be simulated with this filter, would have it. Therefore, the visual filter component takes the content of the framebuffer of the first unmodified monitor, transforms it applying specific image manipulation algorithms on it and then returning the modified image back to the Disability-Simulator application. Each visual filter modifies the image with exactly one image manipulation operation, simulating exactly one specific disability. The only thing the user can vary when using this filter is the level of intensity of the respective visual transformation by changing the parameters appropriately. The visual filter for simulating hyperopia for example uses a Gaussian filter to blur the image like it would look like if seen by a hyperopic person. Depending on which degree of hyperopia that should be simulated, for example +3 diopters, the Gaussian filter is applied several times in sequence.

Another example would be the simulation of complete colorblindness, where the visual filter simply exchanges the colors of the pixels with a gray value with similar contrast behavior. An example for the application of two visual filters in sequence is depicted in Figure 4.

4.3 Movement Filters

While the visual filters are only able to simulate visual impairments, the ability to simulate agitation related disabilities like for example agitated paralysis, depends on the possibility to also manipulate the interaction commands coming from the user. Movement filters aim at blurring, delaying or slightly randomizing user input like mouse movement or keyboard input or decreasing precision. The agitated paralysis filter for example tries to simulate the typical tremor usually coming along with this kind of disability by decreasing the mouse movement and clicking precision. Therefore, the filter simply adds, depending on the level of severity settings specified via the parameters, random noise to the intended mouse movement and clicking positions, resulting in an unpredictable and imprecise interaction behavior. An example for this blurring approach can be seen in Figure 5.

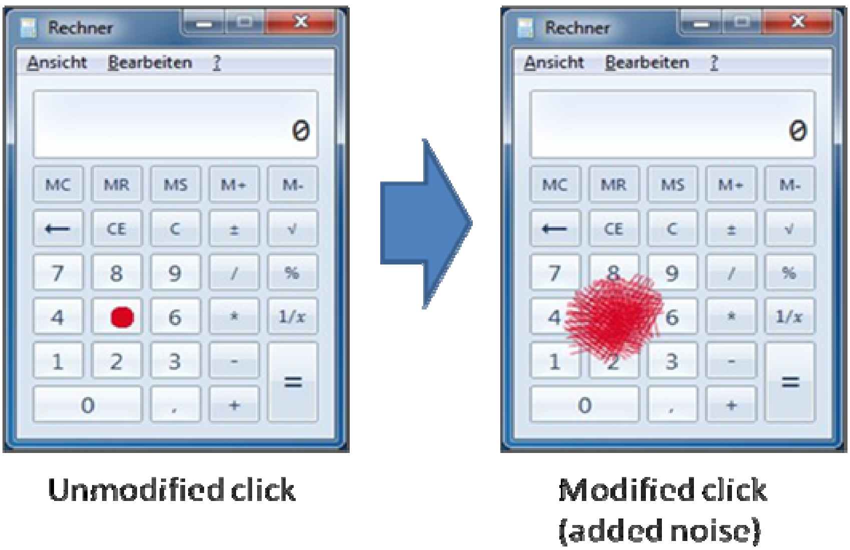

Fig. 5. Agitated paralysis filter

4.4 Technical Realization

To realize the above mentioned concepts in form of a prototype, we implemented a Java SE 6 based version of the Disability-Simulator to achieve a high level of portability, which was necessary to be able to test the approach on different devices and operating systems. The prototype consists of the main *DisabilitySimulator* component, responsible for instantiating the filters and applying them to the to-be manipulated screen, the *ProfileManager* component, which takes care of loading, saving and changing disability profiles in form of standard Java property files and the various filter components implementing at least one filter interface. The high-level prototype design can be seen in figure 6 together with some exemplary filters. The design decision to separate disability profiles and filter implementation from the actual simulation application was made to enable a high level of flexibility, which

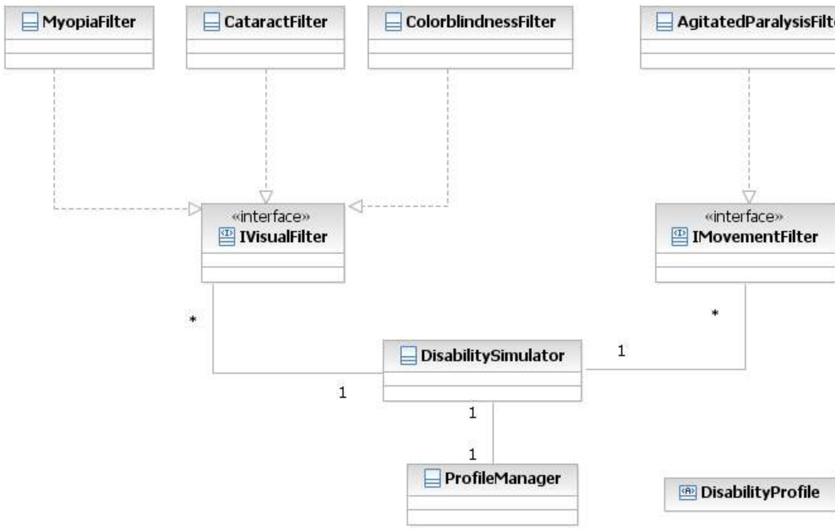

Fig. 6. High level prototype design with some exemplary filters

makes it easy to implement additional filters and assemble a variety of different disability profiles. Therefore, each filter component must implement either the *IVisualFilter* or the *IMovementFilter* interface to enable a dynamic loading of the filters at runtime through Java Reflection.

When starting the application, the *DisabilitySimulator* component instantiates the *ProfileManager* and loads all available disability profiles. After finishing the loading procedure the *DisabilitySimulator* requests the user to select the profile that should be used for simulation from the list of loaded profiles and parses the corresponding profile to determine needed filters and severity values.

Following this the *DisabilitySimulator* component loads all internally implemented filters referenced in the respective profile and – for cases in which a corresponding filter cannot be determined – tries to load the missing filters from a defined external filters-folder via Java reflection. This method makes it easier to externally implement new and adapt existing filters without the necessity to change the actual source code. When all available visual filters are loaded, they are sequentially applied to the captured screen content of the first screen and displayed on the second screen. This is done by copying the screen content repeatedly either by using a Java robots method or by using a faster JNI invocation of the Windows Media Encoder API [12], converting the captured image to a pixel array, and then manipulating them with the loaded filters. Although the first method results in considerable lags of up to 100 ms when refreshing the screen, it is the only platform independent way of capturing the screen content. Using the Windows Media Encoder API libraries limits the user to the use of Windows operating systems, but allows faster refresh rates.

In addition to the loaded visual filters the loaded movement filters result in a direct manipulation of the user input. This is done by intercepting all user input events and manipulating them in terms of precision, speed or failure rate. An agitated paralysis simulation for example is done by constantly adding random noise to the mouse movement and click events, resulting in less precise and controllable interactions with graphical user interfaces. Furthermore, the *DisabilitySimulator* component monitors every user interaction and input manipulation and writes them together with time stamps and applied filters together with their severity parameters to a log file allowing further analyses of the user behavior and simulation effects afterwards.

5 Threads to Validity

Finding appropriate settings to achieve a convincing result (close to the perception of a real disabled person) was the hardest task when designing these visual filters. Due to the fact that there is often no clear mathematically describable relationship between visual perception and the internal representation of a video output of a computer, appropriate settings often have to be elicited empirically. For some filter types we did this using evaluations and user tests based on actually impaired users.

The hyperopia filter for example was tested with hyperopic test persons, each having a distinct level of hyperopia. During this evaluation a test person first had to look on the unmodified screen without the help of corrective lenses and then had to look on the modified screen with corrective lenses on. The blur level was then continuously increased starting from a very low level, until the test persons subjectively had the impression that the perception was similar in both cases. Although we did not come up with statistically significant results so far, this approach helped us to gain a subjective correlation between different diopters and different blur levels which enable us to adjust the settings of the hyperopia filter accordingly to simulate different levels of hyperopia.

6 Conclusion and Future Work

Since traditional disability simulator approaches aim on the simulation of either one particular impairment or only work in constructed scenarios, we presented our novel idea of a Disability-Simulator able to simulate various – and extendable – impairments on any graphical user interface. Additionally, this approach addresses the problem of recruiting impairment specific test persons in order to have sample sizes producing statistically significant results. Using the presented Disability-Simulator, test persons – without these disabilities – can be used to perform standard usability tests on any graphical user interface while being affected by a previously defined impairment.

Our approach addresses impairments on both channels within human-machine interaction: perception and haptic interaction. The underlying architecture enables for providing visual effects (by a visual filter) similar to specific symptoms of impairments as well as influencing the input given by the user (by a movement filter). According to a given disability profile, the visual filter and the movement filter will apply transformation rules on the content to be displayed to the user and the input given by the user. Influenced by these manipulations operating errors will be provoked that are similar to operating errors occurring during human-machine interaction involving impaired persons. During the execution of usability tests, tester can determine the origin of the operating error (if caused by the simulation or the poor graphical user interface itself) by a not manipulated life feed on the user interaction with the graphical user interface.

Initial settings and disability profiles are based on experience and typical decease pattern that are validated in pilot studies indicating the reliability of the simulations but without a statistically significant result, yet. At the moment we are conducting controlled experiments that will provide evidence about the simulated result. This is a very time and resource consuming task, because of the diversity and characteristics of different impairments.

Despite of functional extension of the already implemented filters there are various options to extend the Disability-Simulator by hardware like eye tracker or other input/output channels e.g. involving haptic modality.

As mentioned earlier, some of the algorithms used during the simulation lack in terms of performance according to the significance of the impairment to be simulated. Thus, simulation of severe cases of certain impairments will result in a delayed refresh of the simulation.

References

1. Nehmer, J., Becker, M., Karshmer, A., Lamm, R.: Living assistance systems: an ambient intelligence approach. In: Proceedings of the 28th International Conference on Software Engineering, ICSE 2006, Shanghai, China, May 20-28, pp. 43–50. ACM, New York (2006)
2. Adam, S., Mukasa, K.S., Breiner, K., Trapp, M.: An apartment-based metaphor for intuitive interaction with ambient assisted living applications. In: Proceedings of the 22nd British HCI Group Annual Conference on HCI 2008, pp. 67–75. British Computer Society, Swinton (2008)
3. MIT Age Lab, Age Suit Agnes, http://www.agelab.mit.edu/agnes-age-gain-now-empathy-system (last accessed January 10, 2011)
4. Microsoft Innovation Labs, Digital Lens, http://www.ilabs.microsoft.com/Project/Pages/Project.aspx?ProjectId=5 (last accessed January 10, 2011)
5. University of Illinois at Urbana, Visual Impairment Simulator, http://www.vis.cita.uiuc.edu/index.php (last accessed January 10, 2011)
6. IBM Research Tokyo, aDesigner, http://www.alphaworks.ibm.com/tech/adesigner (last accessed January 10, 2011)
7. Oikonomou, T., Votis, K., Korn, P.: A Standalone Vision Impairments Simulator for Java Swing Applications. In: HCI and Usability for e-Inclusion. Springer, Berlin (2009)
8. Fujitsu: Color Doctor, http://www.fujitsu.com/global/accessibility/assistance/cd/ (last accessed January 10, 2011)
9. Langdon, P., Clarkson, J., Robinson, P.: A Case Study of Simulating HCI for Special Needs. In: Designing Inclusive Futures. Springer, London (2008)
10. Sebillo, M., Vitiello, G., Schaefer, G.: Perception Model for People with Visual Impairments. In: Sebillo, M., Vitiello, G., Schaefer, G. (eds.) VISUAL 2008. LNCS, vol. 5188, pp. 279–290. Springer, Heidelberg (2008)
11. Montgomery, G.: Breaking the Code of Color: Color Blindness: More Prevalent Among Males. A Report from the Howard Hughes Medical Institute (2011), http://www.hhmi.org/senses/b130.html (last accessed January 17, 2011)
12. Windows Media Encoder API, http://www.microsoft.com/expression/products/Encoder4_Overview.aspx (last accessed January 24, 2011)

Advancing Critical Care in the ICU: A Human-Centered Biomedical Data Visualization Systems

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Abstract. The purpose of this research is to provide medical clinicians with a new technology for interpreting large and diverse datasets to expedite critical care decision-making in the ICU. We refer to this technology as the medical information visualization assistant (MIVA). MIVA delivers multivariate biometric (bedside) data via a visualization display by transforming and organizing it into temporal resolutions that can provide contextual knowledge to clinicians. The result is a spatial organization of multiple datasets that allows rapid analysis and interpretation of trends. Findings from the usability study of the MIVA static prototype and heuristic inspection of the dynamic prototype suggest that using MIVA can yield faster and more accurate results. Furthermore, comments from the majority of the experimental group and the heuristic inspectors indicate that MIVA can facilitate clinical task flow in context-dependent health care settings.

Keywords: Biomedical data visualization, human-computer interaction, health care, health information technology, interface design.

1 Introduction

Healthcare is a risky business. Patients are at risk from disease and poor health habits, with interventions like medicine and surgery carrying the risk of adverse effects. The Institute of Medicine's report *To Err is Human: Building a Safer Health System* [1] highlighted the risk of adverse medical events in clinical settings, with patient deaths in U.S. hospitals annually exceeding 44,000, at a cost of $38 billion. In extreme instances lives have been lost due to poor software design. For example, between 1985 and 1987 the problematic design of the Therac-25 radiation system resulted in massive overdoses of radiation and at least five patient deaths [2]. An investigation into user error pointed at the interface design, which had a complex and misleading operator console. Ultimately, a lack of human-centered design and testing techniques resulted in poor design and a range of critical errors in the interaction routines.

The technologies and information systems needed by clinicians can produce adverse effects when they do not yield practical solutions during implementation. For example, systems that display large amounts of complex patient data can result in confusion when designed without knowledge of human-computer interaction (HCI) and usability principles. This body of knowledge includes human factors engineering, as well as a social science approach to human-centered design. Human-centered design employs cognitive

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psychology, anthropology, and sociology, as well as interface and interaction design, which take into consideration the specific medical device, the users, the development process, and the organization and context of use. Human-centered design in health information technology (HIT) can improve clinical care. For instance, it can address preventative medicine compliance issues in unusually complex health care environments, specifically with respect to the number of interactions between clinicians and data visualization systems [3]. Designing and implementing HIT is not about IT per se nor an isolated use of traditional usability or human factors engineering. Rather, as Zhang [4] argues, HIT design is a “human project about human-centered computing such as usability, workflow, organizational change, medical error, and process reengineering” (p. 1). In the past, too much of HCI and usability engineering has been a superficial enterprise of designing form (e.g., the graphic user interface) rather than context-centered interaction based on an in-depth analysis of cognition, task, symbol, and workflow. It is no wonder that HIT often hinders health care. Bernstam et al [3] point out that “there is evidence of significant, unintended and deleterious effects of well-meaning HIT efforts” (p. 1).

The intensive care unit (ICU) is a uniquely complex environment for which computing technology needs to be developed. The authors call for HIT based on novel design principles and practices. ICU clinical decisions are sometimes made with data from multiple sources, changing circumstances, and limited clinician knowledge. Such situations dictate quick adjustments in the planning of actions. In many cases, clinical error is the result of cognitive overload due to the inability of humans to adapt to excessive and complex physical, social, and cultural environments [5]. Horsky, Zhang, and Patel [5] note that a “lack of attention to the principles of human-computer interaction (HCI) in clinical software design is becoming a critical safety hazard” (p. 264). The authors concur that there is a need for a framework of human-centered design principles that are grounded in HCI theory specifically developed for clinical environments. Unfortunately, a health care culture still remains that accepts poorly designed systems. As Johnson, Johnson, and Zhang [6] and Horsky, Zhang, and Patel [5] all argue, clinicians should not tolerate such conditions. Rather, they should demand that health care technologies be designed to match user capabilities [6].

The ICU is a setting where there can be an enormous flow of data. Patients can have significant organ system derangement, as well as limited physiological reserve. Therefore, optimal medical care requires close and concentrated monitoring of organ function, frequent multimodal diagnostic testing, and many consultations from subspecialty physicians. In this type of intensive critical care space, physicians may find it difficult to make rapid and accurate evaluations of a patient's condition. This is because there is an overwhelming volume of data generated from multiple sources on a moment-by-moment basis. Data streaming from medical devices include continuous automatic physiological monitoring and intermittently determined data that is gathered from various diagnostic testing devices. These are combined with traditional bedside paper reports. In addition to patient-generated data, there are vast arrays of clinical data generated that document the patient’s treatments, including drug, respiratory, and physical therapy, surgical procedures, and many other clinical interventions [7].

Clinical decisions pertaining to the care of patients are best made when physicians can easily organize and understand the vast flood of data from these various sources. Unfortunately, physicians and other critical care providers have to retrieve this data from various locations and organize it into a cohesive profile of the patient’s current condition. Furthermore, the data that is retrieved from these diverse sources is usually presented in a form that does not allow trends and relationships between co-variables to be immediately recognized. As a result, the process of monitoring, evaluating and treating the critically ill is labor intensive, time-consuming, and demands that clinicians analyze data in text and numeric form. These difficulties are compounded by the highly stressful, time-restricted character of the ICU environment.

Although the monitoring devices of a modern ICU are intended to support the immediate recognition of problems, only a limited amount of historical data can be reviewed on the monitor on-the-fly. For example, although current monitoring devices maintain a reasonably comprehensive log of a patient's critical care period, its output is in conventional spreadsheet form, with, at best, a few parameters displayed as X-Y plots. Some existing systems provide some degree of relational multi-source review of data, but have interfaces that are often antiquated, resembling a graphic user interface (GUI) from an early 1990s version of Microsoft Windows. As a result, clinician's find it difficult and cumbersome to make rapid critical evaluations of a patient's condition.

What is needed is an integrated platform through which data can be organized into a uniform, multivariate data visualization as the primary means to represent and manage complex patient critical care data. This includes intuitive human-centered applications of data that allow access to various time resolutions and subsets of patient data over minutes, hours, and days. This system must allow clinicians to control and compare current and past events and trends to better explore and examine longitudinal relationships in patient data.

2 Previous Medical Information Visualization Systems

One of the earliest designers to address medical data visualization was Edward Tufte [8]. Although his work was not multivariate, his attempt at consolidating, integrating, and visualizing a broad array of data was a first step in addressing this need in the health care area. Tufte [8] effectively combined several timescales in one horizontal axis. Subsequent data visualization systems for the ICU have attempted to connect time-oriented information to a coherent interactive visualization, presenting different interactive visualization techniques and enabling the users to reveal the data at several levels of detail and abstraction [9]. The first known data visualization system for the ICU was developed by Horn, Popow, and Unterasinger [7]. Their computer-based patient data management system (PDMS) stored data that had been collected online or entered manually within a specified time frame. The purpose of this system was to quickly generate and observe graphics for detecting changing patient parameters. Horn et al [7] described PDMS as a data visualizing, time-oriented system of analysis of electronic patient records in an ICU. The focus of the product was to make it easier for clinicians to quickly assess the overall situation of a patient and to recognize essential changes over time. They described the method of the system as using graphics to sketch the most relevant parameters for characterizing an ICU patient's situation over a 24 hour time frame presented in one display.

The authors argue that such medical devices and HIT system applications must be human-centered in their initial and iterative design implementation to ensure that such systems can adequately and safely support clinical care. A medical data visualization system is proposed, with several initial pilot studies that suggest that it can support clinical work in the ICU or other data rich health care environments.

3 Proposed System

The authors recently designed and developed a medical data visualization system, referred to as the *Medical Information Visualization Assistant* (MIVA). The purpose of MIVA is to provide valuable assistance for data analysis and decision making in a real-world critical care environment. In particular, MIVA provides a means to integrate and display data from a range of bedside biometric devices and health care provider data sources in the ICU. According to Bellazzi and Zupan [10], the decision-making process should always be supported by relevant and reliable data that is presented in a "context-related" fashion. MIVA attempts to do this by contextualizing data in visualization-form to better respond to an immediate patient status. Also, data visualizations can be prioritized according to particular clinical problems, while being customizable on-the-fly.

For example, an anesthesiologist will have different data visualization priorities than a cardiologist. Similarly, a child who has undergone cardiac surgery may have different data presentation requirements than a 70-year-old man who has an acute exacerbation of chronic respiratory disease. Thus, data visualization must be tailored to the patient, the disease, the consulting specialty, and/or the acute medical problem at the moment or historically. MIVA provides a uniquely new solution for addressing contextual health care issues with a multivariate data visualization.

MIVA improves diagnosis speed and accuracy by recognizing essential changes to multiple and relational physiological data over a designated time frame. Using selection menus, physicians control the necessary data sources, time periods, and time resolutions to narrow down their diagnosis and final assessment of a patient's condition. Hence, the MIVA interface has been designed to maximize the clinician's ability to control what data is visualized during a specific context-related patient episode or general periodic diagnosis.

4 Design Process

Stage 1. Early discussions centered around possible design models for visualizing data using Tufte's [8] visualization research and publications. After several visits to existing bedside and visualization systems in the Intensive Care Unit, a clearer understanding of the complexity of data delivery to health care staff was realized. The first visualization sketches focused on five data biometrics: iNO (nitric oxide), RR (ventilator rate), PAP (pulmonary artery pressure), ABP (arterial pressure), and SvO_2 (venous oxygen saturation). See Figure 2-A. This sketch evolved into a series of visualization design iterations. See Figure 2-B through 2-D. This phase of the design process included ongoing informal focus groups with medical faculty about placement of data points, system of time display (minutes, hours, days), size of numeric information, and general location of biomedical, time, and numeric information. Most critical was the need of clinicians to see data visualized in various histories, with various levels of time and data resolution.

Stage 2. The next stage of visualization design involved HCI graduate students assisting in concept development of the interface and visualization tools. Students were instructed to use the authors' preliminary work (shown in Figure 2, A-D) as the basis for their continued design. This design phase included ethnographic studies at the ICU at Riley Hospital, including photographs of the ICU environment and of bedside devices. The concept of a "scrubber" was borrowed from audio editing software, as seen in the program ProTools. In the case of longitudinal patient data, the scrubber tool would allow the user to identify a specific point in time and instantly obtain readings for all intersecting points between the Y axis and the scrubber sitting at the X axis (or point in time). See Figure 3. This stage also yielded a published paper discussing its development [11].

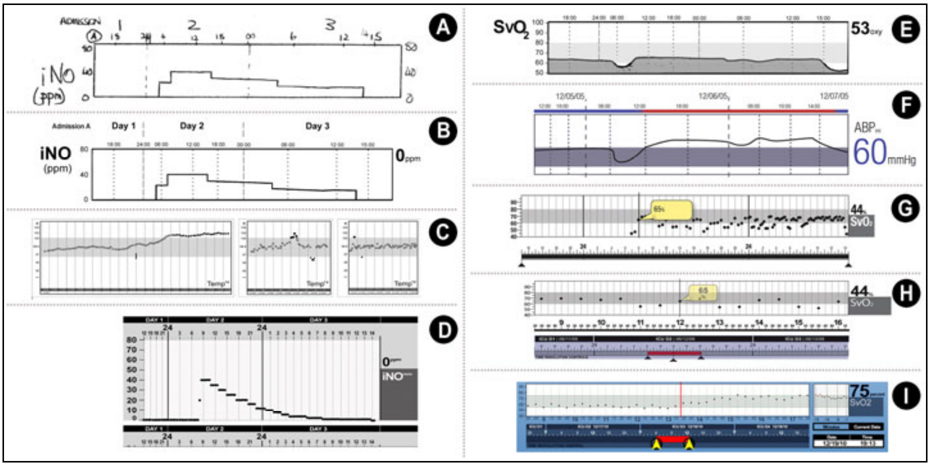

Fig. 2. A-I. Illustration of development of MIVA interface over a four year period

The outcome of our joint efforts was the creation of several static prototypes, with recommendations and solutions for technically integrating the data from multiple sources. As a result, the completed designs shown in Figure 2, E-G, suggested a further development of the MIVA interface. In this second stage of the design process, the team worked to resolve several major design issues related to clinician workflow and cognitive modeling.

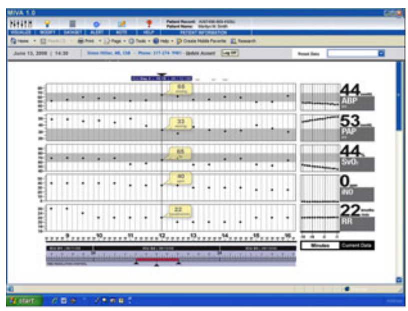

Fig. 3. One example of the static MIVA interface used in first usability study

Stage 3. The primary mission of this stage was to further enhance the existing interface and prepare detailed static prototypes for the first usability study. Figure 2, H, shows the further development of the visualization line of a single biometric parameter, as compared to the forgoing designs. Figure 3 shows the full design that was used in the first usability study, to be discussed below. Finally, Figure 2, I, shows the final and current state of the interface after the findings of the first usability study.

Stage 4. This stage included the creation of a dynamic prototype using Flash Action Script. See Figure 4 for the current state of the visualization interface. As noted above, MIVA's multivariate, relational display of information allows clinicians to observe contextual changes in patient data over selected periods of time at various time resolutions. A multivariate comparative analysis is vital if physicians want to do a relational diagnosis. `Also, the longitudinal data streams from each parameter have time-aligned clinical and intervention notes that are inserted at the appropriate point in time with icons above the parameter visualization display. See Figure 5. Figure 4 shows the Display Sets from which clinicians can choose a range of physiological parameters. The clinician must first select and drag-n-drop the needed parameter into the primary visualization display (e.g., Ca, iNO, or CO2). Figure 5 also shows the drag-n-drop model used to change physiological parameters.

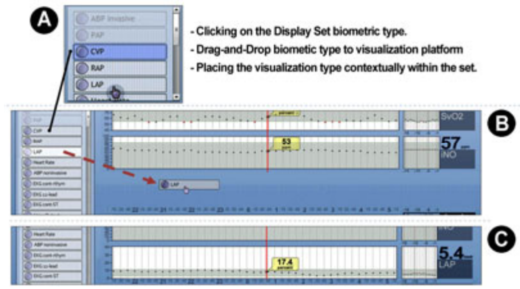

Fig. 4. A-C. Illustrates the drag-n-drop process for inputting a new parameter into the visualization display

The physiological parameter (LAP) is clicked (Figure 4, A) and dragged onto the visualization platform to the right (Figure 4, B), and the new parameter with its corresponding data is now in place on the visualization platform (Figure 4, C). The data streams from bedside monitoring devices reach the MIVA interface after being routed through the hospital's electronic medical record (EMR) system. The clinical and intervention notes entered by the health care practitioners will also be sent to the EMR, in addition to being displayed on the timeline. In this way, MIVA becomes another node integrated into the hospital's network.

5 Human-Centered Design and Testing of the MIVA Interface

5.1 MIVA Study One – Static Prototype

A usability and clinical test was performed on the MIVA Phase One prototype to add to the value of this project. The MIVA study used control and experimental groups (*n*16) from the medical resident population at Indiana University School of Medicine to compare traditional methods of gathering and assessing critical patient data using paper charts (Figure 6) versus MIVA (Figure 3).

- **Participants**: The study used participants from the medical resident population at Indiana University School of Medicine, Indianapolis, IN. The control group and the experimental group consisted of eight participants each, *n*16. The average experience level of the resident participants across the control group was 3.38 years, of which seven out of eight were male. The average experience level of the resident participants across the experimental group was 3.25 years, of which six of eight were male.
- **Methods:** The study was conducted in the Indiana University Schools of Medicine and Nursing. Participants from each group were given the same clinical scenario and eight questions to answer about the scenario. As each participant read the question, he or she sought the answer from either the traditional medical paper charts or MIVA. Participants in the control group answered the questions using traditional paper-based charts as their data source, and participants from the experimental group used screen shots of the MIVA interface to answer the same questions. The screen captured interface images were not interactive, but were prepared and displayed sequentially in

a PowerPoint presentation, shown in Figure 3. Experimental group participants were directed to walk through the slide presentation, one interface slide at a time, to ascertain the correct answer to the eight questions. Both the control and experimental group participants were provided a 3-5 minute priming session (before the test session) to understand the basic placement of data on the medical charts and MIVA interface. After completion of the eight tasks, participants from both groups answered a post-test questionnaire.

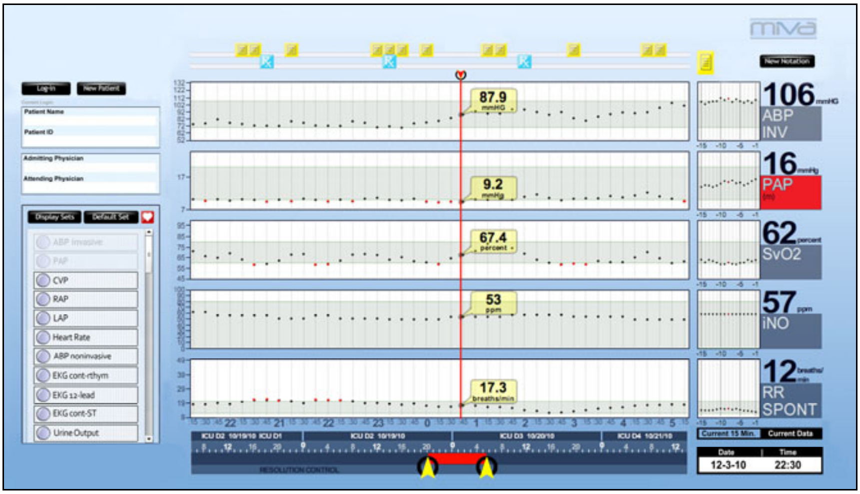

Fig. 5. Example of MIVA interface with control panel and data visualizations. Note the clinical and intervention notes entered by clinicians at top, designated with icons above the visualization display.

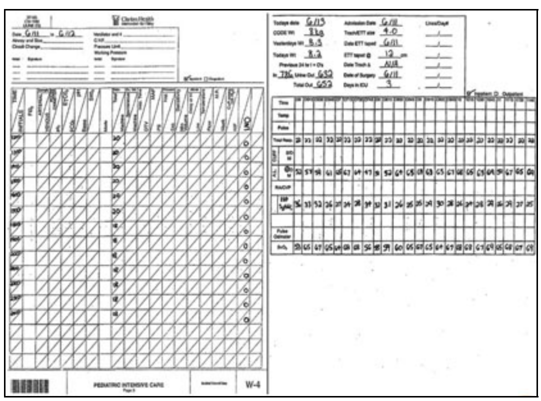

Fig. 6. Sample of traditional paper medical charts

- **Results:** Findings of the time-on-task (*answering speed*) portion of the study were first analyzed using Levene's test for equality of variances and an independent samples t-test, which showed the experimental group to be significantly faster in answering questions one and two than the control group. Because of the smaller sample size and non-normal data, we performed a nonparametric Mann-Whitney test, which also showed that tasks one and two were performed significantly faster by the experimental group than the control group. Overall, the experimental group performed six of the eight questions faster than the control group. Findings of the correct-answer data (*answering accuracy*) were analyzed using chi square analysis, which showed that participants of the experimental group performed task one correctly significantly more than participants from the control group. Because each participant from each group performed task six incorrectly, it was eliminated from the analysis. However, each task was examined on an individual basis. Therefore, the exclusion of task six did not change the results.

- **Discussion:** Overall, if we review all test data, for both speed and accuracy, the experimental group was generally faster and more accurate, while also being significantly faster in answering two questions. When responding to a 10 question post-task survey by the experimental group, an overall mean score of 3.78 (1-5) suggests a positive response. For example, participants agreed (with a score of 4.0) that MIVA had the potential to support critical decision-making.

5.2 MIVA Heuristic Inspection

As a result of these findings from the MIVA static prototype, a dynamic prototype was developed using Flash Action Script and is currently undergoing testing to ensure that it will reliably support the demanding workflow within the ICU. As part of this ongoing process, the first step has been a detailed heuristic inspection with the goal to identify and correct any common interaction and interface problems.

- **Methods:** In order to conduct a heuristic inspection on MIVA, we first developed a set of medical heuristics against which the device was assessed.[1] The medically-relevant heuristics developed for judging the MIVA interface are shown in Table 1. The MIVA prototype was examined by three IT professionals who are also HCI graduate students in the School of Informatics, IUPUI.[2]
- **Results and Discussion:** The inspection yielded considerable data, which are consolidated in Table 2. In sum, the prototype inspection suggested that there were no catastrophic errors, but rather that the interface and interaction design of MIVA were well conceived. Only one serious issue was noted concerning possible security issues or disruptions to the data flow using the HL7 protocol[3] if data were to be transmitted wirelessly. This was not considered to be an interface issue, since the method of sending data to MIVA would be determined upon implementation by the health care administrator. However, a number of lower priority improvements were recommended to improve the general usability of MIVA. Some examples of these were: (1) The Minutes/Current Data and Date/Time labels must be clarified, (2) The background window of each notation should match the color of that notation's icon, (3) The background of the current-data box should be red if any of the data are out of range, and (4) A pop-up legend should be created, explaining the types of icons. Some of these changes were made immediately, and some were put on the list of items to fix during the next development iteration.

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[1] This was accomplished by pulling together information from both software design references [12] and medical design references [13].

[2] We would like to acknowledge several HCI Ph.D. and MS students from the School of Informatics who helped in a portion of the discussion for this paper and their time in preparing the results of the heuristic inspections: Crystal Boston-Clay, Jay Wheeler, and Dennis Mann.

[3] HL7 is an international health care interoperability protocol or communication rules for the exchange, integration, sharing, and retrieval of electronic health information, while supporting clinical practice and the management, delivery, and evaluation of health services.

Table 1. Medically-Relevant Heuristics

A. Factors Affecting General Usability
1. Keeps display simple and free of clutter
2. Maintains content accuracy
3. Supports content currency
4. Provides orientation clues
5. Supports content accessibility
6. Demonstrates clarity in display of content
7. Provides information sent
8. Supports intuitiveness
9. Grouping is appropriate
B. Factors Affecting Visibility of Actions and Options
10. Supports user mental model of the system
11. Provides contextual informational "zoom"
C. Factors Affecting Monitoring of Condition
12. Design reflects clinician cognition
13. Includes appropriate graphics that support / clarify data
14. Graphically condenses data
15. Provides comparisons to references & normal limits
16. Reduces short-term and long-term memory load
D. Factors Affecting Determination of Diagnosis
17. Provides relevant task information & features to user
18. Displays the level of confidence in information
19. Provides patient data portability and security
E. Factors Affecting Initiation of a Treatment Plan
20. Eases data entry
21. Supports both overview and details on demand
22. Gives feedback on treatment / diagnosis (task) status
23. Ensures patient safety and care

Table 2. Example of Heuristic Inspection Findings

Heuristic	Rating	Description of Rating
1. Keeps display simple and free of clutter	**Medium**	A non-critical, limited problem (no data lost or system failure) that does not hinder operation and can be temporarily circumvented or avoided, but causes users moderate confusion or irritation
a. As range of elapsed time on chart grows, notations on the top of the screen become condensed and start to overlap. b. Icons at the top of the screen illustrating notes are small and cause confusion to the user. There is not a legend provided to quickly explain each icon reference without moving the mouse over it. c. Categorical controls that are permanently displayed should be minimized when not in use, to maximize real estate, especially for smaller form factors.		
2. Maintains content accuracy	**Low**	Non-critical problems, general questions about the product, minor inconsistencies, or small aesthetic issues like labels and fields that are not aligned properly.
a. List of sets appears to have random sorting (not alphabetic); perhaps most common used? b. The screen is consistent and users can clearly understand various sections because the labels are well-defined.		

6 Conclusion

Next steps for the MIVA evaluation will be a more comprehensive clinical usability study and focus group of the dynamic prototype. Methods used will replicate those used for the static prototype. In this way, comparison data will provide insights into improvements made to the interface overall. One key difference, of course, is that the data is active, rather than merely being simulated by showing multiple PowerPoint slides. This will cause dynamic and fundamental changes in the experience of the participants.

Finally, failure to follow an iterative, human-centered design methodology when creating new medical devices can impact clinical decision-making. By describing the theory behind the MIVA interface and the design and testing processed used to develop it, we hope to encourage others to use this level of care in medical product development. Both the usability study and the medically-relevant heuristic inspection can provide guidance for testing other medical and health care systems and applications.

References

1. Kohn, L.T., Corrigan, J.M., Donaldson, M.S. (eds.): To err is human: Building a safer health system. National Academies Press, Washington, DC (1999)
2. Leveson, N., Turner, C.S.: An Investigation of the Therac-25 Accidents. IEEE Computer 26(7), 18–41 (1993)
3. Bernstam, E., Hersh, W., Sim, I., Eichmann, D., Silverstein, J., Smith, J., Becich, M.: Unintended consequences of health information technology: A need for biomedical informatics. Journal of Biomedical Informatics 43(5), 828–830 (2010)
4. Zhang, J.: Human-centered computing in health information systems, Part I: Analysis and design. Journal of Biomedical Informatics 38, 1–3 (2005)
5. Horsky, J., Zhang, J., Patel, V.: To err is not entirely human: Complex technology and user cognition. Journal of Biomedical Informatics 38, 264–266 (2005)
6. Johnson, C., Johnson, T., Zhang, J.: A user-centered framework for redesigning health care interfaces. Journal of Biomedical Informatics 38, 75–87 (2005)
7. Horn, W., Popow, C., Unterasinger, L.: Support for fast comprehension of ICU data: Visualization using metaphor graphics. Methods of Information in Medicine 40, 421–424 (2001)
8. Tufte, E.R.: Visual explanations: Images and quantities, evidence and narrative. Graphic Press, Cheshire (1997)
9. Bade, R., Miksch, S., Schlechtweg, S.: Connecting time-oriented data and information to a coherent interactive visualization. In: ACM Conference on Human Factors in Computing Systems (CHI 2004), vol. 6(1), pp. 105–112 (2004)
10. Bellazzi, R., Zupan, B.: Intelligent data analysis: Special issue. Methods in Informatics Medicine 5, 362–364 (2001)
11. Faiola, A., Hillier, S.: Multivariate Relational Visualization of Complex Clinical Datasets in a Critical Care Setting: A Data Visualization Interactive Prototype. In: Proceedings of the HCI Symposium –Information Visualization Conference 2006, pp. 460–465. IEEE, London (2006)
12. Triacca, L.: MiLE+ (Milano-Lugano Evaluation method) Library of Technical Heuristics. Web Usability Enhancing Effectiveness of Methodologies and Improving their Communication Features. Ph.D. Thesis, USI COM (2005)
13. Armijo D., McDonnell C., Werner K.: Electronic Health Record Usability: Evaluation and Use Case Framework. AHRQ Publication No. 09(10)-0091-1-EF. Agency for Healthcare Research and Quality, Rockville, MD (2009)

A Comparative Study of Children's eHealth Design between East and West: A Case Study of Children's Health Websites in China, Taiwan, the UK, and the US

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Abstract. A good developing model of children's health could reduce health care costs and improve quality of life across the children life span. What are the key communication issues and technology concerns involved in the design of children's health websites? When parents evaluate a children health website, they always have some concerns: Is the health information credible? Is the interpretation clear and adequate? Is the media application suitable? Is the interface design user-friendly? With recent advances in computer technology, its impact on health communication is continually increasing. However, how to design an effective children's health website to enhance parents' cognition, to promote their active processing, and to increase their interaction frequency, is still very much a question that remains unanswered. This research was implemented in three stages. Firstly, the Chinese keywords, "兒 " and the English keywords, "children's health website" were entered into Google to search for the 20 most popular Chinese and English-speaking websites. Secondly, existing literature was reviewed to ascertain the critical category and evaluation guidelines for designing children's eHealth. Thirdly and finally, a selection of these websites from China, Taiwan, the UK, and the US were evaluated by using a content analysis methodology, applying the criteria developed from the literature review. This study finds that in terms of information design, credibility is better presented in the West than in the East, whereas users' needs are better presented in the East than in the West. In terms of multimedia design, demonstrations and humanity are better presented in the West than in the East, and the segmentation of demonstrations is valued by both the East and the West. In terms of interface design, the West presents a better appearance than the East, and methodology is valued by both the East and the West.

Keywords: eHealth Evaluation, Information Design, Multimedia Design, Interface Design.

1 Introduction

Research Background. With the rapid development of computer technology and growing demand for health information, health websites are emerging as one of the

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most effective media to meet the public's needs for health information. Fox & Jones (2009) stated that 61% of American adults go online to locate health information, and the results of online health information searches had a strong effect on how they managed their own health or the health of someone else. There has been a great proliferation of research into eHealth evaluation during the past decade. For example, Oermann et al. (2003) assess the quality of the ten best websites for patient and parent education on asthma. Seventy websites were evaluated based on the criteria set by the Health Information Technology Institute (HITI), namely, credibility, content, disclosure, links, design, interactivity, caveats, and readability. Dansky et al. (2006) also address four dimensions of eHealth evaluation as follows: (1) design and methodology issues; (2) challenges related to the technology itself; (3) environmental issues which are not specific to eHealth but pose special problems for eHealth researchers; and (4) logistical or administrative concerns of the evaluation methodology selected. Hsu & Chang (2007) set up the following evaluation guidelines for eHealth design from the perspective of users' demand: (1) items of operating interface: layout design, clear links, visual identification, interactive process, easy to control, clearly presentation, fast feedback, user-friendly, repeat practice, search confusion; (2) items of valuable results: useful information, whole concept, multi-search path, easy interactive function, reduction of search time, decrease of articles with no demand, clear results, explanatory accompanying text, helps understanding, ease of learning new information. Nevertheless, the researches related to the evaluation of children eHealth design are seldom seen. Health in childhood is regarded as the foundation of lifelong well-being. Many parents search for health information online to manage their children's health. Before seeing a doctor, they often search for related medical information in advance and try to acquire the opinions of other patients with the same disease. Internet-based health information seems to have a positive effect on their health knowledge, treatment decisions, and attitude toward maintaining health. How to design an effective children's health website to enhance parents' cognition study, to promote their active processing, and to increase their interaction frequency, is still very much a question that remains unanswered.

Purpose of this Study. A good developing model of children's health could reduce health care costs and improve quality of life across the children life span. What are the key communication issues and technology concerns involved in the design of children's health websites? When parents evaluate a children health website, they always have some concerns: Is the health information credible? Is the interpretation clear and adequate? Is the media application suitable? Is the interface design user-friendly? With recent advances in computer technology, its impact on health communication is continually increasing. What strategies, media, and forms of communication are the most effective for health promotion and patient education initiatives? Evaluation is the crucial part of developing a healthcare application. It motivates the designer, and explains the guidelines with reference to concrete projects and problem-solving. The purpose of this study is to determine the critical category and develop evaluation guidelines for a children's health website, and further to compare the differences between children's eHealth design in the East and the West. In consideration of the issues of concern mentioned above, the primary research objectives in this paper are as follows: to explore the strategies, media, and forms of communication of current children's health care websites; to survey current strategies, methodologies, and tools for evaluating children's health care website design; to evaluate the success of designs of children's eHealth websites in the East (China & Taiwan) and the West (UK & US).

2 Literature Review

2.1 eHealth Evaluation

Since health care website are the popular source of health information, a thorough evaluation of these sites should be made to ensure that they successfully achieve their goals. In the East, the Quality Healthcare Websites awards in Taiwan, organized by the Department of Health, Executive Yuan from 2002~2006, declared the general criteria for eHealth design as follows: (1) Credibility of the website: author's detailed data, author's professional title, modified instantly; (2) Interaction of the website: offering on-line consultation, users' feedback; (3) Maintenance management: website governor's name, website contact data, personal privacy protected; (4)Ease of browsing: ease of understanding the content, system stability; and (5) Compartment: advertisements and content are obviously compartmentalized.

In the West, the Web Health Awards, now in its 12th year in the US, organized by the Health Information Resource Center™ (HIRC), states that a health website design should contain the following elements: (1) Quality, accuracy and timeliness of online content; (2) Relevance of online information for the target audience; (3) Overall assessment of site layout and ease of use; (4) Would this online resource be something the targeted audience would bookmark for frequent review? (5) Is the online resource sufficiently interactive for the targeted audience? In addition, The Health On the Net Foundation (HON) ,which is established by ten countries and sixty professional medical institutions, promotes the Certificate of HON Code of Conduct for excellent medical and health websites, and their principles of judging are as follows: (1) Authoritative: indicates the qualifications of the authors; (2) Complementarity: information should support, not replace, the doctor-patient relationship; (3) Privacy Respect: the personal data submitted to the site by the visitor should be kept completely private and confidential; (4) Attribution: the source(s) of published information, date and medical and health pages should be clearly cited; (5) Justifiability: site must back up claims relating to benefits and performance; (6)Transparency: presentation must be accessible, and email contact accurate; (7) Financial disclosure: funding sources should be identified; and (8) Advertising policy: advertising should be clearly distinguishable from editorial content.

2.2 Information Design

Jacobson (1999) mentions that information design is about managing the relationship between users and information. Ideally the designer constructs an information platform which can be easily understood and used by most people, designs an interactive system which can be easily accessed and controlled by users, and builds a virtual space within which users can find the path quickly and will not get lost. By amalgamating the above recommendations, a set of criteria can be established under a general heading called ‘Information Design’, the focus of which can be the content of these websites, particularly the text-based content.

There is a communication revolution brewing in the delivery of health care by the growth of powerful new health information technologies. For example, Lucas (2008) assesses the potential benefits of a diverse range of information and communication technology (ICT) innovations. The following four broad areas are considered: (1) Improvements in traditional health information systems; (2)Computer-aided diagnosis and treatment monitoring; (3)A range of applications generically labeled ‘telemedicine’; and (4) The use of ICT to inform the general population of health and healthcare. Yusuf et al. (2008) also present an overview of the evaluation of health informatics and information systems. They undertake a critical appraisal of selected HIS and IS evaluation frameworks in order to identify HIS evaluation dimensions and measures. The frameworks are compared based on their inclusion of human, organizational and technological factor, and the results indicate that an increasing number of evaluation studies deal with two distinct trends of HIS, one of which considers human and organizational issues, while the other is concerned with the employment of a subjectivist approach.

2.3 Multimedia Design

With multimedia technology, the health care application can be produced in a very interesting, entertaining, and lifelike manner. Especially, the features of internet multimedia can contribute to reinforcing visualization, arousing attention and feedback, emphasizing intensification, showcasing information, and developing visual cues. Nevertheless, what are the design modules or guidelines for a successful educational multimedia design? The guidelines provided by Huang (2005) on best practice consist of five phases: (1) Understanding the learning problem and the users’ needs; (2) Designing the content to harness the enabling technologies; (3) Building multimedia materials with web-style standards and human factor principles; (4) User testing; and (5) Evaluating and improving the design. Indeed, choosing the appropriate media is critical for designing an efficient web-based learning system.

Designers make use of pictures, animations, music, and video clips to replace a great deal of text-based information. Mayer, R. E. (2005) conducted a review of research on the design of multimedia information and concluded that multimedia could have 10 beneficial effects if used correctly. These are outlined as follows: multimedia effect, modality effect, coherence effect, segmentation effect, signaling effect, spatial ability effect, temporal contiguity effect, redundancy effect, worked example effect and personalisation effect.

2.4 Interface Design

What are the key issues for effective Human-Computer Interaction (HCI)? Alison J. Head. (1999) suggests that the following three seminal HCI basics are conceptual anchors in a design evaluation template: (1) Task support: audience, user goals, functionality, control; (2) Usability: learnability, navigation, assistance; and (3) Aesthetics: appearance, interaction, enjoyment. Rajiv et al.(1997) mention that interactive technologies share many properties with other traditional media, and they propose the key interactive technology attributes in health promotion as follows: multimodality, networkability, temporal flexibility, segmentation capability, interactivity, sensory vividness, modifiability, availability, cost, and ease of use.

On the other hand, what points should interactive designer and program developer focus on? Yamamoto & Nakakoji (2005) discuss the following four issues in support of the early stages of design based on theories in design and human–computer interaction: (1) The available means of externalisation influence designers in deciding which courses of actions to take; (2) Designers generate and interact, not only with a partial representation of the final artefact, but also various external representations; (3) Designers produce externalisations to express a solution as well as to interpret the situation; and (4)A design task proceeds as a hermeneutic circle—that is, designers proceed with projected meanings of representations and gradually revise and confirm those meanings.

3 Methods

3.1 Research Methods

This research was implemented in three stages. Firstly, the Chinese keywords, "

" and the English keywords, "children's health website" were entered into Google to search for the 20 most popular Chinese and English-speaking websites. Secondly, existing literature was reviewed to ascertain the critical category and evaluation guidelines for designing children's eHealth. Thirdly and finally, a selection of these websites from China, Taiwan, the UK, and the US were evaluated by using a content analysis methodology, applying the criteria developed from the literature review.(re-shown below).

Before undertaking the formal coding, this research was implemented by performing a pre-test with two encoders, which randomly drew five samples from each nation. A total of 20 websites were reviewed and critiqued in advance, and having completed the pre-test, uncommon information elements, media effects and interface elements were discussed and deleted, and critical categories and definitions were revised. In addition, the two encoders carried on formally coding, reading the 40 effective samples of the selected websites separately, and conducted the formal review, critique, and logging.

3.2 Research Criteria

The general criteria used in information design are as follows (1) Authoritative: management data, such as the website governor's name, website contact address, website contact telephone number and the E-mail address of the managing person should be clearly recorded on the website; (2) Attribution: articles published on the website should clearly note the author's name, author's professional title, and author's service organization; (3) Advertising policy: advertising should be clearly distinguishable from the editorial content of the website; (4) Maintenance: articles published on the website should note their publication date or recently modified date to prove that they are current and up-to-date; (5) Recognition: information provided on the website should be concise for reading and understanding; (6) Personalisation: to meet the target audience's needs, the information content should be divided into several unique classifications; (7) Discussion: the website should provide a discussion area for users to communicate with each other; (8) On-line consultation: the website should cooperate with related medical institutions or hospitals to provide professional health consultations on-line.

The general criteria used in multimedia design are as follows (1) Modality effect: users learn more effectively from different media synchronously; (2) Temporal Contiguity Effect: users learn more effectively when the related picture and text are presented on the screen; (3) Segmentation effect: users learn more effectively from divided sections rather than complete information; (4) Spatial ability effect: users learn more effectively when printed words are placed near to, rather than far away from, corresponding pictures; (5) Signal effect: users learn more effectively from metaphoric signs rather than explanatory text; (6) Conversational effect: users learn more effectively when words are presented in conversational rather than formal style; (7) Coherence effect: users learn more effectively when extraneous material is excluded rather than included; (8) Redundancy effect: users learn more effectively from one medium instead of numerous media.

The general criteria used in interface design are as follows (1) Visualisation: the appearance of the website should be aesthetic to attract the attention of potential users; (2) Cognitive Load: the classification of the content of the website should be easy to search to save users' browsing time; (3) Consistency: the style of subject, colour and background should be designed consistently on the same page to avoid users getting lost; (4) Clear links: the selection buttons should be clearly designed and aligned so that users can see where they have come from and where they are going at a glance; (5)User control: to satisfy the user's desire for control, different processing paths should be designed so that users can choose their own operation; (6) Fast feedback: the website should download quickly and recover efficiently after users' interaction to ensure that they do not give up searching; (7) Operating note: an explanation of the selection buttons should be given beside the buttons to direct users where to go; (8) Advance technology: the operating functions should use recent advances in computer technology to help users to recognise the fast-growing electronic health field.

3.3 Reliability Analysis

Scholars, Wimmer & Dominick (2000), indicate that if mutual agreement is created when independent encoders use the same encoding tools to encode the same contents, this means reliability among encoders. Kassarjian (1997) proposes that, if the reliability coefficient of the content analysis reaches 0.85, the standard is acceptable. In cases where it is less than 0.8, the reliability of the research will be doubted. This study uses the method of reliability analysis proposed by communication scholar, Yang (1993), who develops a reliability formula of content analysis from two encoders as follows:

Reliability = 2 × Mutual Agreeableness / [1 + (2-1) Mutual Agreeableness]

Mutual Agreeableness = 2 × two encoders are in agreement / [the numbers of encoder 1 should agree + the numbers of encoder 2 should agree]

There are 40 effective samples of the selected websites, which is the total number coded. 36 number two encoders agree with the testing of the information design. Therefore, Mutual Agreeableness = 2×36/ (40+40) = 0.9, reliability = 2×0.9 / [1+(2-1)×0.9] = 0.95 ; 32 number two encoders are in agreement with the testing of the multimedia design. Therefore, Mutual Agreeableness =2×32 / (40+40) = 0.80, reliability = 2×0.80 / [1+(2-1)×0.80] = 0.89 ; 33 number two encoders are in agreement with the testing of the narrative style. Therefore, Mutual Agreeableness =2×33/ (40+40) = 0.83, reliability = 2×0.83 / [1+(2-1)×0.83] = 0.91. Thus, all three kinds of testing reliability are more than 0.85, which means that the reliability of this research is confirmed.

3.4 Data Analysis

The results reflected in Table 1 indicate that, in the East, 'Authoritative' is ranked first, with a 75% frequency of use, followed by 'Advertising Policy', 'Recognition', 'Personalisation 'and 'Online Consultation', which are evenly dispersed across various websites. Nevertheless, the other information design elements are not popular, with frequencies below 50%. In the West, 'Authoritative' and 'Advertising Policy' are ranked first, with the highest frequencies of use reaching 100%. These are followed by 'Attribution', 'Maintenance', 'Recognition' and 'Personalisation', all of which have a frequency of more than 60%. However, 'Discussion' and 'Online Consultation' are never seen.

Table 1. Information Design

Category	Elements	East		West	
		Unit	Average	Unit	Average
Credibility	Authoritative	15 (75 %)	50 %	20 (100%)	90%
	Attribution	4 (20 %)		14 (80 %)	
	Advertising Policy	12 (60 %)		20 (100%)	
	Maintenance	9 (45 %)		14 (80 %)	
Users' Needs	Recognition	12 (60 %)	50 %	14 (80%)	35 %
	Personalisation	10 (50 %)		12 (60 %)	
	Discussion	8 (40 %)		0 (0 %)	
	Online Consultation	10 (50 %)		0 (0 %)	

The results reflected in Table 2 indicate that, in the East, 'Segmentation' is the most welcome effect, with the highest frequency of use reaching 100%. Nevertheless, other multimedia design effects are not popular, and have a frequency almost below 50%. In the West, 'Segmentation' is the most welcome effect, with the highest frequency of use reaching 100%, and this is closely followed by 'Signal' and 'Spatial ability', with frequencies of use of 90% and 80% respectively. Then 'Modality' and 'Temporal Contiguity' are also familiar, since their frequency of use reaches 60%. However, 'Conversational', 'Coherence' and 'Redundancy' are uncommon, since their frequencies of use are no more than 40%.

Table 2. Multimedia Design

Category	Effects	East		West	
		Unit	Average	Unit	Average
Demonstration	Modality	8 (40 %)	55%	12 (60%)	75%
	Temporal Contiguity	8 (40 %)		12 (60%)	
	Segmentation	20(100 %)		20 (100%)	
	Spatial ability	8 (40 %)		16 (80%)	
Humanity	Signal	10 (50 %)	40%	18 (90%)	50%
	Conversational	8 (40%)		6 (30%)	
	Coherence	7 (35 %)		8 (40%)	
	Redundancy	7 (35 %)		8 (40%)	

The results reflected in Table 3 indicate that, in the East, ‘User Control’ and ‘Fast Feedback’ are the winners, with the same frequency of use reaching 75%. Then ‘Visualisation’ and ‘Consistency’ are also familiar, since their frequency of use reaches 50%. Nevertheless, the other interface design elements are not popular, with frequencies below 50%. In the West, ‘Consistency’ and ‘User Control’ are the winners, with the highest frequency of use reaching 100%, and these are closely followed by ‘Cognitive Load’ and ‘Clear links’, with the same frequency of use of 90%. Therefore, ‘Visualisation’, ‘Fast Feedback’ and ‘Advance technology’ are evenly dispersed across various websites, while ‘Operating Note’ is seldom used.

Table 3. Interface Design

Category	Elements	East		West	
		Unit	Average	Unit	Average
Appearance	Visualisation	10 (50%)	45%	16 (80%)	90%
	Cognitive Load	8 (40%)		18 (90%)	
	Consistency	10 (50%)		20 (100%)	
	Clear links	8 (40%)		18 (90%)	
Methodology	User Control	15 (75%)	50%	20 (100%)	60 %
	Fast Feedback	15 (75%)		12 (60%)	
	Operating Note	6 (30%)		4 (20%)	
	Advance technology	5 (20%)		12 (60%)	

4 Discussion and Conclusion

This study finds that the content of children’s health websites can change with the different motives of health councils and clinical services, strategies, and the media, and the formats of children’s health websites in the East and West are different. In terms of information design, credibility is better presented in the West than in the East, since the difference between frequency of use reaches 40%. On the other hand, users’ needs are better presented in the East than in the West, with a 15% higher frequency of use. In terms of multimedia design, demonstrations and humanity are better presented in the West than in the East, with a higher frequency of use of 20% and 10% respectively, and the segmentation of demonstrations is valued by the East and the West, since their frequency of use both reach 100%. In terms of interface design, the West presents a better appearance than the East, since the difference of frequency of use reaches 45%. Methodology is valued by both the East and the West, and user control is especially ranked as the most popular methodology, both in the East and the West.

Further differences between the East and West were observed, the information and design interface produced in the East has obviously fallen behind that presented in the West because of the development of scientific technology and economic circumstances. For example, advertising text occupies almost the whole layout in China, which may increase users' cognition load and mislead patients' treatment decisions. On the other hand, Hi-Tec multimedia design also occupies the whole screen of a site from Taiwan, which may decrease the amount of explanatory text and increase the cognitive load. Also, health information on both sides similarly lacks periodic renewal, and in the West, it is probably because of concern for ethical policies and cultural competence, that the substantial evidence and on-line consultation apparently neglects users' needs. For example, the medical or health information provided in the US is too professional for the ordinary user to understand, and too much space is devoted to answering patients' questions, whereas the medical or health information given in the UK is too complex, and concentrates too much on responding to the race problem. On-line consultations and solid examples are similarly not offered by these two countries. Thus, this research recommends improvements, such as the reduction of on-line advertising space in China, and the reduction of Hi-Tec multimedia design in Taiwan. Also, general terms should replace the professional terms in the US, and simplified text-based content should be used in the UK rather than the current complex content.

The eHealth Design is included in the fields of cognitive psychology, information science, health education, mass communication, and computer science. However, this study is limited to the factors of manpower, time and resources, and simply seeks to analyze the data from the most popular 20 Chinese and English-speaking websites from the provider's perspective, in order to explore the strategies, media, and forms of children's health websites. In order to present a holistic picture of children's eHealth design, perhaps future research could be extended to different issues from the user's perspective, such as a usability evaluation of children's health care websites, the ethical policies of health care application, and literacy competence in terms of children's health information. These are subjects which may benefit from an in-depth discussion in the future.

References

1. Head, A.J.: Design Wise: A guide for evaluating the interface design of information resources. Information Today, Medford (1999)
2. Brubken, R., Plass, J.L., Leutner, D.: Direct Measurement of cognitive load in multimedia learning. Educational Psychology 38(1), 53–61 (2003)
3. Dansky, K.H., Thompson, D., Sanner, T.: A framework for evaluating eHealth research. Evaluation and Program Planning 29(4), 397–404 (2006)
4. Horn, R.E.: Information design: Emergence of a new profession. In: Jacobson, R. (ed.) Information Design, pp. 15–33. MIT Press, MA (1999)

5. Hsu, C.J., Chang, P.C.: Applying the graphical relational representation technique to represent healthcare web information: taking the query and representation of SARS web information as an example. The Journal of Taiwan Association for Medical Informatics 16(3), 21–34 (2007)
6. Huang, C.: Designing high-quality interactive multimedia learning modules. Computerized Medical Imaging and Graphics 29(2-3), 223–233 (2005)
7. Jacobson, R.: Introduction: Why information design matters. In: Jacobson, R. (ed.) Information Design, pp. 1–10. MIT Press, MA (1999)
8. Kassarjian, H.H.: Content Analysis in Consumer Research. Journal of Consumer Research 1(4), 8–18 (1997)
9. Lee, Q.R., Wei, P.X., Shi, Y.F.: Human-Computer Interface Design. National Open University press, Taipei (1998)
10. Mayer, R.E., Moreno, R.: Nine ways to reduce cognitive load in multimedia learning. Educational Psychology 38(1), 43–52 (2003)
11. Mayer, R.E.: Cognitive theory of multimedia learning. The Cambridge handbook of multimedia learning. Cambridge University Press, Cambridge (2005)
12. Oermann, M.H., Gerich, J., Ostosh, L., Zaleski, S.: Evaluation of asthma websites for patient and parent education. Jour. of Pediatric Nursing 18(6), 389–396 (2003)
13. Rajiv, N.R., Flora, J.A.: Interactive technology attributes in health promotion: practical and theoretical issues. In: Health Promotion and Interactive Technology: Theoretical Applications and Future Directions, pp. 19–37. Lawrence Erlbaum Associates, London (1997)
14. Wyatt, J.C., Wyatt, S.M.: When and how to evaluate health information systems? International Journal of Medical Informatics 69(2-3), 251–259 (2003)
15. Yusof, M.M., Kuljis, J., Papazafeiropoulou, A., Stergioulas, L.K.: An evaluation framework for Health Information Systems: human, organization and technology-fit factors (HOT-fit). International Journal of Medical Informatics 77(6), 386–398 (2008)
16. Yamamoto, Y., Nakakoji, K.: Interaction design of tools for fostering creativity in the early stages of information design. International Journal of Human-Computer Studies 63(4-5), 513–535 (2005)
17. Yang, X.R.: Communication Research Methods. San-min, Taipei (1991)
18. Fox, S., Jones, S.: The social life of health information, Pew Internet & American Life Project (2009), `http://www.pewinternet.org/Reports/2009/8-The-Social-Life-of-Health-Information.aspx?` (retrieved)

Visually Exploring Multivariate Trends in Patient Cohorts Using Animated Scatter Plots

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Abstract. The effectiveness of animation in visualization is an interesting research topic that led to contradicting results in the past. On top of that, we are facing three additional challenges when exploring patient cohorts: irregular sampling, data wear, and data sets covering different portions of time. We present TimeRider, an improved animated scatter plot for cohorts of diabetes patients that tackles these challenges along with its evaluation with physicians. Results show that animation does support physicians in their work and provide further domain-specific evidence in the discussion on the effectiveness of animation.

Keywords: Information Visualization, animation, time, medical data.

1 Introduction

In health care, analyzing and exploring data of patient cohorts are important tasks, especially in quality control for healthcare providers or clinical research. Here, it is not only important to show the developments of one or more variables over time individually but also to explore relationships of variables and the dynamics thereof over time. This substantially increases the complexity of the task and demands sophisticated methods, such as correlation analysis. However, following the concept of exploratory data analysis, visual methods can be a valuable aid for getting an overview of the data and its relationships as well as for generating hypotheses or discovering surprising insights that would have possibly been overlooked by using statistical methods only. Furthermore, visualization can help in presenting findings to non-experts that might have a hard time interpreting computational results. For example, a physician might be interested in an overall view of how the conditions of patients develop over time. This could reveal that a certain group of patients is behaving differently from the rest. More specifically, a possible question would be to examine whether this is caused by a certain treatment method, the patients' lifestyle, or a combination of both.

Probably the most popular visual method to explore relationships between variables is the *scatter plot*. However, each individual scatter plot is a static snapshot of the relationship of two variables only and developments over time

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cannot be seen. There are basically two possibilities for visualizing dynamics over time: *static* representations that use spatial features such as a time axis, or *dynamic* representations that map time to time (i.e., animation or slideshows) [1]. For scatter plots, both axes are already used for data variables. Therefore, we use animation for showing developments over time. Animated scatter plots were prominently used by Rosling [16] in his famous presentations where he effectively communicates how complex socio-economic relationships develop over time. However, this approach is not applicable straightforwardly in other situations. Particularly, three challenges arise in handling the dynamics of patient cohort data: 1) irregularly sampled data, 2) data wear, 3) comparing datasets that cover different portions of time. First, data of different patients are usually sampled independently of each other, which is in contrast to, e.g., Rosling who shows data gathered on a yearly basis. Second, the validity of a medical parameter is usually decreasing over time and simply interpolating between two readings would hide this fact. Third, also patients that have been treated sequentially should be visually comparable in parallel.

Next, we discuss related work followed by an introduction to the application domain of diabetes care. In Sect. 4, we present our improved animated scatter plot and how the mentioned challenges are met. To examine our method, a usability evaluation with domain users has been conducted and is presented in Sect. 5. Evaluation feedback has been applied, so that we can present an updated software version in Sect. 4. Finally, we provide a conclusion and pointers for future work in Sect. 6.

2 Related Work

Considering animation in visualization, contradicting results can be found in research. Bartram [2] elaborates about potential advantages and uses of animation whereas a main motivation is that animation is an additional display dimension easing the representation of large amounts of multivariate dynamic data. She discusses five main factors that are potential benefits of using motion: 1) perceptually efficient, 2) rich interpretative scope, 3) still relatively underused, 4) more potential coding bandwidth, and 5) it gets technologically easier to implement. Nakakoji et al. [11] conducted two user studies to investigate cognitive effects as well as interactivity of animated visualizations for exploratory analysis. Their results support the arguments of Bartram and find animation a powerful instrument. In a more recent study Griffin et al. [8] investigated the effectiveness of animation for detecting moving clusters on a 2D representation considering the effects of timing (i.e., frame rate). Both error rate and task completion time consistently show advantages for the animated conditions in comparison to a small multiples display. The authors refer to the perceptually efficient Gestalt principle of *common fate* as possible explanation.

However, there are also critical voices on using animation. One argument against animation is the perceptual effect of *change blindness*, which can lead to an unnoticed miss of important changes. Nowell et al. [13] take up this argument and investigate potential causes as well as solutions for two visualization systems they developed. Tversky et al. [17] conducted a critical survey of evaluations that compared static and animated representations, many of which saw animation as beneficial. The authors argue that these experiments suffered from several flaws, most importantly that the static and animated cases were not comparable (e.g., less or more information presented or different representations). Their main concerns on animation are threefold: 1) may be hard to perceive, 2) may be comprehended discretely, and 3) there is a lack of interactivity. Especially, concerning the last issue the authors point out that interactivity may be the key to overcoming the drawbacks of animation. Most importantly, users should be able to control the speed, view, review, start, stop, zoom in and out, and change orientation of parts or the whole animation.

Animation has been applied to scatter plots most prominently by Rosling [16] and his publicly available Gapminder Trendalyzer. Robertson et al. [15] conducted a study on the effectiveness of trend analysis comparing animated scatter plot, static representation of traces for all variables in one display, and static small multiples representations with traces individually for each variable. Their results show that the static variants were better suited for analysis tasks and the animated scatter plot was better suited for presentation tasks.

Overall, it can be noted, that no clear view on animation in visualization exists. Contradictory views have been presented in prior research suggesting for example that animation is well suited for identifying moving clusters [8] whereas others argue that static views are better suited for analysis tasks [15]. This suggests that further research is needed to investigate animation in visualization.

3 Medical Scenario

Our research on exploration of patient cohorts was conducted in cooperation with a diabetes outpatient clinic. Diabetes mellitus is a widespread chronic condition in which the human body is no longer capable of managing its glucose (blood sugar). Patients need to change their lifestyle, take oral medication, and/or inject insulin. Otherwise, they are at risk of many complications, e.g., diabetic coma or cardiovascular disease. The choice of treatment depends on many factors including diabetes type, comorbid diseases, and the patient's experience.

The data set was collected during checkup examinations at the clinic, which were scheduled in intervals between six weeks to three months, depending on the patient's condition. Consequently, the data set is sampled irregularly. It encompasses 35 patients (anonymized), ten quantitative variables (e.g., fasting blood glucose level), and 22 binary variables (e.g., insulin therapy).

Physicians plan to use TimeRider for quality control and clinical research in connection to their work in the clinic, for example to find out whether some therapies are more effective than others. They are interested in whether their patients' conditions improve or worsen. They want to relate an improvement of some variables to the development of other variables, for example, lower glucose and gaining weight. They also need to compare and filter the patient cohorts.

4 Visual Encoding and Interaction Design

In this section, we describe how TimeRider meets the challenges of visualizing the dynamics of patient cohort data[1]. It has been argued that rich interaction is essential to take full advantage of the benefits of animation [17]. Fig. 1 shows an annotated screenshot of our highly interactive prototype. The scatter plot is its central component. It represents patients as marks in a Cartesian coordinate system and maps two variables to the two axes. Since position is the most accurate visual variable, scatter plots allow for an expressive and effective processing by the human visual system [9]. Users can select variables from two combo boxes next to the respective axes. Further variables may be mapped to color, shape, and size of the marks. Thus, users may encode up to five variables visually.

Animation is used to explore the dynamics of cohorts. For tackling irregularly sampled data, we establish a common time unit (e.g., one day) that we use for frames in the animation. At each frame, we draw the patient mark on a linear trajectory between its previous and the next known position. To account for data wear and maintaining temporal context, we propose two techniques of enriching the visual encoding of time: transparency and traces. In *transparency* mode, marks fade out more and more as they move away from a known location. They have their full opacity only in a frame for which data exists. After that, their opacity linearly degrades. This makes patients with current data clearly stand out. In *trace* mode, a line starts from the previous known location and iteratively grows to the next location. The marks and traces of all past observations stay visible with trace diameter increasing over time. Thus, at the end of the animation complete patient histories can be seen (Fig. 2). However, this static view only tells about the direction of change or the existence of local extrema. Animation is needed to understand the timing and co-occurrence of these developments. To *navigate in time*, users may hit the play button and watch the events unfold. Alternatively, they can jump from frame to frame using the media player buttons or drag the time slider manually. In order to compare patient histories that cover different portions of time, our method allows users to *synchronize* the data set. Currently, it provides four synchronization options: 1) calendar date, 2) patient age, 3) start of treatment, and 4) end of treatment. For example, if users synchronize by calendar date, the animation will start with only one or a few patients and over time patients will appear and then disappear from the scatter plot. Each frame will show the probably interpolated patient state of the corresponding date. If they synchronize by start of treatment, the animation will start with all patients at once and each frame will show the patient state n time units after their first treatment.

Most variables in medicine have important *value ranges*. For example, glycated hemoglobin HbA1c has a normal range of 4 % to 6 %. If HbA1c is higher, the patient will be at risk of diabetes induced organ damages. Highlighting this information already in the visualization allows for a faster recognition of, for

[1] Supplemental material and a Java Web Start application can be found at `http://ieg.ifs.tuwien.ac.at/research/timerider/`

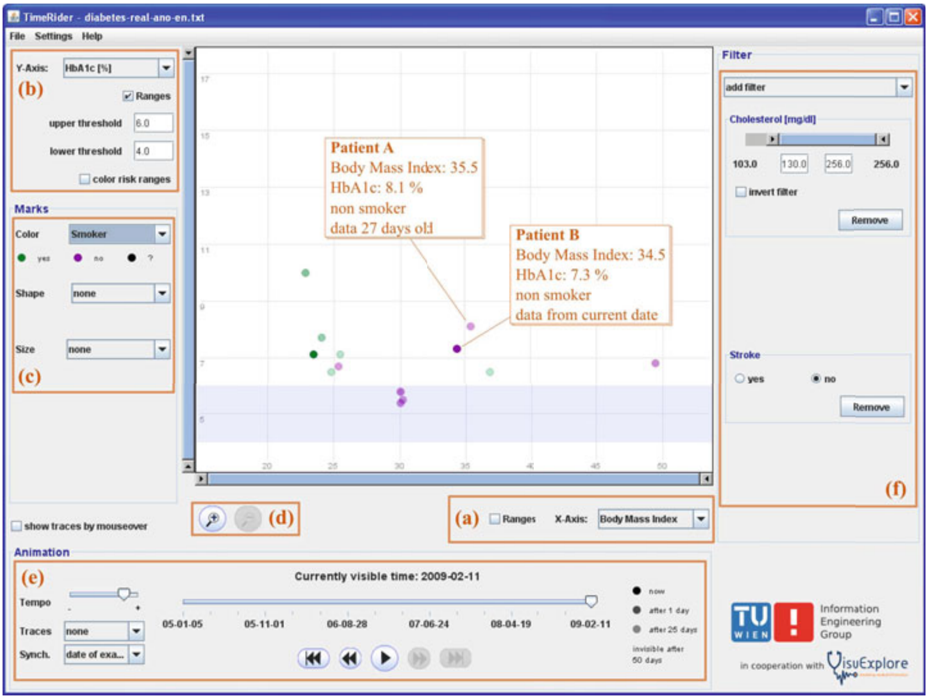

Fig. 1. TimeRider user interface: Patients are shown as marks in the scatter plot. Users may choose to map variables to (a) the x-axis, (b) the y-axis, (c) color, shape, and size of the marks. They may (d) zoom to show patients in more detail, (e) use animation to explore development over time, or (f) apply dynamic queries to filter patients. Here the normal range of HbA1c (y-axis) is represented by a light blue background. Two patients A and B demonstrate how transparency encodes the age of data values.

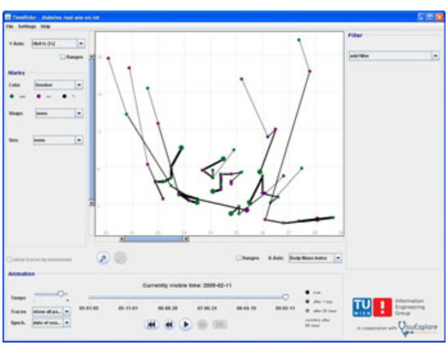

Fig. 2. TimeRider with traces shows the development over time for all patients

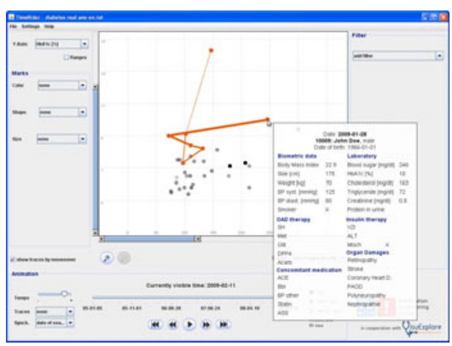

Fig. 3. On hovering the mouse over a patient mark, a trace shows its history and a pop-up window shows all current values

example, episodes with critical values. TimeRider represents these ranges using a light blue background in the scatter plot. Users can activate ranges for each axis (cp. Fig. 1 (b)) and choose whether they want to emphasize the normal range or the “risk” range, which is outside the normal range. They may also adapt range thresholds, though common thresholds are predefined via meta data.

TimeRider supports common interactions for select, pan, zoom, filter, and detail on demand (Fig. 3). Furthermore, it allows users to take a snapshot of the exploration state by *saving all settings* to a file. They can keep it for later reference, restore it with a different data set, or share it with colleagues. Alternatively, they may export a screenshot of the exploration state as an image file. A reset function will restore the initial program state, if they want to start over.

5 Evaluation

In the following evaluation we assessed the usability of TimeRider. Though we tested an earlier version than described above, results are still valid, because the visual mapping has not changed. Our subjects were physicians (in contrast to many studies using students). This investigation was guided by the following research questions: 1) Does animation, specifically in TimeRider, support physicians in getting insights from time-dependent data? 2) Is the mapping (e.g., color, traces) we developed appropriate for the task? 3) Are there any general usability/utility problems that might also occur in similar systems?

5.1 Research Methods

To answer our research questions we adopted the following methodologies:

Thinking aloud [6,3] has been occasionally used to evaluate Information Visualizations (see e.g., [10], [4]). Despite its problems, thinking aloud is a valuable research methodology yielding interesting insights into human reasoning processes [5].

We combined the thinking aloud methodology with *screen capture*. Preece et al. [14] point out that any observation method based on video is rather time-consuming and should be based on some kind of criteria for the interpretation and categorization of the users’ actions.

We used the *evaluation categories* developed by Forsell and Johannssen [7] to interpret the data. Their system of categories is based on other well-known heuristics (e.g., Nielsen [12]). They derived empirically the most important usability heuristics for Information Visualization: information coding (mapping), minimal actions, flexibility (number of possible ways to achieve a goal), orientation and help, spatial organization (e.g., distribution of elements on the screen), consistency, recognition rather than recall, prompting (all means to support the users to find alternative ways of doing things), remove the extraneous (distraction through unnecessary information), data set reduction (features for reducing data sets) [7, p. 203]. Even if these categories are mainly meant for heuristic evaluation, we think they can also form a valuable framework for the interpretation of user actions when working with Information Visualizations. We categorized self-contained events or activities as, e.g., that the users started the animation to go forward or backward in time or that they applied the filter mechanism. When users engaged in such activities several times in a row these activities were categorized as one activity, but on the categorization sheet a comment was made how often it was repeated.

5.2 Description of the Investigation

The evaluation consisted of three parts: an introduction into the domain and the software (about 15 minutes), the solving of four tasks by the participants while thinking aloud, and, in the last part, a short interview was conducted. The dataset used was the same as described in Sect. 3. For the evaluation we used version 3.4 of the TimeRider software, which is a predecessor version of the prototype described in Sect. 4. Windows Media Encoder 9, a video and audio encoding software, was used to capture the participants' activities on the screen (not the participants themselves) and record their comments while working with the software. The following interview was recorded separately.

Ten physicians (four women and six men with the age ranging between 26 and 35 and a single person about 50) participated in the evaluation. The physicians had not previously been involved in the development and saw the software for the first time. The duration of the evaluation varied between one and two hours. This difference is due to the fact that tasks and interview were open ended, and some of the participants spent considerably more time on these activities. Four tasks, developed with the help of physicians, had to be solved independently by the participants. For tasks one to three concrete parameters for the x-axis and y-axis were given; task one was designed to let the participants familiarize themselves with the software, task two and three had concrete questions to answer. The fourth task allowed the participants to freely experiment and interact with the software[2]. In general, the tasks were exploratory in nature and no predefined solution existed. Below, as an example of such a task, is task three as it was given to the participants:

Parameters: x-axis: NBZ (fasting blood glucose level);
y-axis: RR diast [mmHG] (diastolic blood pressure)

Task description: Limit the data set to NBZ $\leq$ 100; RR diast $\leq$ 80. Choose a setting that gives a good overview over the trends of the patients. Which patients show a favorable trend? What is the general trend of the group? Experiment at will. Describe your findings.

In addition to the tasks participants were given a list of variables and abbreviations used in the software (e.g., RR diast = blood pressure diastolic). As all participants were physicians, they were aware of correlations between certain parameters (e.g., some types of insulin cause a weight gain). Participants were also asked to experiment with all of the interaction possibilities (traces, color/size encoding), which they all did.

[2] Due to space restrictions, the full list of tasks cannot be listed here but can be found at `http://ieg.ifs.tuwien.ac.at/research/timerider/`

5.3 Results

All participants were able to solve the tasks and were able to predict trends. Solving the tasks seemed to be quite easy, but the participants were slightly hesitant about predicting trends. An example for an insight a participant got is: "When people started treatment they had a high HbA1c (indication for plasma glucose concentration) value at the beginning, and then this value decreased until the next measurement rather quickly. This indicates that at the beginning patients were diagnosed with diabetes, then the therapy started and the HbA1c went down."

More than 50 usability problems were detected, and additionally, a number of interesting remarks regarding the software were made. The most serious problems are listed below. The number in brackets indicates the number of participants having that specific problem once or several times during the evaluation. Also added is the categorization according to the heuristic of Forsell and Johanssen [7]:

dropdown lists: Participants could not find entries because the order of variables was neither consistent nor clearly communicated (9, prompting).

filter function: The range sliders were unfamiliar and it was not possible to edit the thresholds by keyboard (7, data set reduction).

traces: It was often impossible to follow traces, even a single one (4, information coding/mapping), and the traces were confusing when all of them were activated (5, information coding/mapping).

overlapping values: There was no way to tell if and how many values (marks on the screen) are overlapping (5, information coding/mapping).

risk levels: Value ranges were not correctly identified because the normal range was highlighted but the user interface referred to "risk range" (4, information coding/mapping). When both risk levels (x-axis, y-axis) were active, participants could not match them to the corresponding x-axis or y-axis (4, information coding/mapping).

zoom bar: While using the zoom bar the scatter plot was empty which confused the participants (3, spatial organization).

colors: Color changes of the values over time confused the participants and drew their attention to these points (4, information coding/mapping). The yellow color used to distinguish values was difficult to discern (2, spatial organization).

5.4 Discussion

In summary, the user study identified many ways to improve TimeRider's ease of use. We tackled many of the problems and iteratively developed a new version, which we present in Sect. 4 of this work. The main improvements are: 1) Value range controls are located next to the respective axes and wording has been improved, also users may now explicitly "color risk ranges". 2) Filter controls allow keyboard editing. 3) During zoom the scatter plot is continuously updated and buttons were added to make the zoom feature more visible. Furthermore, we added features to synchronize patient histories, select patients, and save settings.

However, the methods to represent irregularly sampled data and data wear were kept unchanged.

Some of the innovative approaches presented obstacles to the users. E.g., it took minutes for the participants to understand the control of filter settings because range sliders were unknown to them. After getting familiar, they were able to use them without problems. All participants were able to detect trends, clusters, and correlations in the data, though it should be noted that prior to this learning all participants had problems with the navigation or control of TimeRider. At the end of the evaluation some participants worked easily with it while others were slightly frustrated.

As far as our research questions are concerned, the following results can be derived from the study: Previous research [17,15] indicated that subjects were often confused by animations and could not derive any insights. In addition, it is often difficult to understand trends from static visualizations. This was not the case in our study. Therefore, we assume that the animation we developed supports physicians in their work. More research is necessary to clarify why animation in our case was more successful than in other contexts. With the modifications indicated by our study, the system can be learned fairly easily. Some of the mappings posed problems to the subjects, especially the risk levels, overlapping values and traces. These problems will also occur in other, similar visualizations. They can be described as generic problems. Specific usability problems found in this visualization were problems with filters and dropdown lists. Most of the usability/utility problems belong to the category of information coding/mapping. This is probably to be expected in Information Visualizations.

6 Conclusions and Future Work

TimeRider is an improved animated scatter plot that provides solutions to three challenges arising when visually exploring patient cohort data: irregular sampling, data wear, and data sets covering different portions of time. For this, it enriches the visual encoding of time with transparency or traces. The evaluation showed that physicians using our method successfully gained insights. More generally speaking, our work provides evidence for the effectiveness of animation in visualization acquired in a domain-driven study.

Additionally, the evaluation yielded valuable input for the iterative improvement of TimeRider and animated scatter plots in general. The version presented in Sect. 4 accounts for much of this input. Furthermore, there are several directions for future research: Overlap in general is a persistent problem in visualization. Overlapping marks may be avoided through jittering, though that needs to play together with animation. Traces seem to be most effective when they do not overlap, but even then, they are sometimes difficult to interpret. No easy solutions seem to be possible for more than a few traces. The mapping of value ranges could also account for the patient heterogeneity, e.g., different thresholds depending on demographics or therapy. We plan to examine the strategies that physicians chose to solve the tasks in our study. Finally, more user studies are needed to investigate animation and specifically the enriched visual encodings we provided for patient cohort data.

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References

1. Aigner, W., Miksch, S., Müller, W., Schumann, H., Tominski, C.: Visualizing time-oriented data—a systematic view. Computers & Graphics 31(3), 401–409 (2007)
2. Bartram, L.: Perceptual and interpretative properties of motion for information visualization. In: Proc. Workshop New Paradigms in Information Visualization and Manipulation, pp. 3–7. ACM, New York (1997)
3. Boren, T.M., Ramey, J.: Thinking aloud: Reconciling theory and practice. IEEE Trans. Professional Communication 43(3), 261–278 (2000)
4. Burmester, M., Mast, M., Tille, R., Weber, W.: How users perceive and use interactive information graphics: An exploratory study. In: Proc. IEEE Conf. Information Visualization (IV), pp. 361–368 (2010)
5. Carpendale, S.: Evaluating information visualizations. In: Kerren, A., Stasko, J.T., Fekete, J.-D., North, C. (eds.) Information Visualization. LNCS, vol. 4950, pp. 19–45. Springer, Heidelberg (2008)
6. Ericsson, K.A., Simon, H.A.: Protocol Analysis, 2nd edn. MIT Press, Cambridge (1993)
7. Forsell, C., Johansson, J.: An heuristic set for evaluation in information visualization. In: Proc. Int. Conf. Advanced Visual Interfaces, pp. 199–206. ACM, New York (2010)
8. Griffin, A.L., MacEachren, A.M., Hardisty, F., Steiner, E., Li, B.: A comparison of animated with static small multiple maps for visually identifying space-time clusters. Annals of the Association of American Geographers 96(4), 740–753 (2006)
9. Mackinlay, J.: Automating the design of graphical presentations of relational information. ACM Trans. Graphics 5(2), 110–141 (1986)
10. Marsh, S.L., Dykes, J., Attilakou, F.: Evaluating a geovisualization prototype with two approaches: Remote instructional vs. face-to-face exploratory. In: Proc. IEEE Conf. Information Visualization (IV), pp. 310–315 (2006)
11. Nakakoji, K., Takashima, A., Yamamoto, Y.: Cognitive effects of animated visualization in exploratory visual data analysis. In: Proc. IEEE Conf. Information Visualization (IV), pp. 77–84 (2001)
12. Nielsen, J.: Usability Engineering. Morgan Kaufmann, San Francisco (1993)
13. Nowell, L., Hetzler, E., Tanasse, T.: Change blindness in information visualization: A case study. In: Proc. IEEE Symp. Information Visualization, pp. 15–22 (2001)
14. Preece, J., Rogers, Y., Sharp, H.: Interaction Design: Beyond Human-Computer Interaction. John Wiley & Sons, New York (2002)
15. Robertson, G., Fernandez, R., Fisher, D., Lee, B., Stasko, J.: Effectiveness of animation in trend visualization. IEEE Trans. Visualization and Computer Graphics 14(6), 1325–1332 (2008)
16. Rosling, H.: Visual technology unveils the beauty of statistics and swaps policy from dissemination to access. IAOS Statistical Journal 24(1-2), 103–104 (2007)
17. Tversky, B., Morrison, J.B., Betrancourt, M.: Animation: can it facilitate? Int. J. Human-Computer Studies 57, 247–262 (2002)

Emerging Triage Support Environment for Dementia Care with Camera System

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Abstract. This study proposes a new concept called a Triage Support Environment based on the authors' research at three care homes. We believe that this study will help develop information and communication technology (ICT) systems for caring for people with dementia (PWD). We installed a video monitoring system for caregivers in three homes and observed the positive and negative effects of applying the system to caregiving. In terms of positive effects, the video monitoring system enabled caregivers to optimize their work and helped them concentrate on their tasks at hand, reducing both mental and physical stresses. On the other hand, some caregivers expressed concerns over being watched by other caregivers through the monitor, especially when their activities were recorded. We discuss these issues and explain how the concept of a Triage Support Environment may lead to a solution for these problems.

Keywords: triage, group home, persons with dementia, camera system.

1 Introduction

A growing number of people are now entering the *elderly* age category in Japan; this category is defined as those over sixty-five years old. Consequently, the demand for qualified caregivers is increasing, but most care homes for the elderly are short-staffed and caregivers' workloads are increasing. This has resulted in numerous caregivers burning out from overwork. Japan is not the only country facing this challenge; many developed countries like Germany, Italy, and the Republic of Korea face the same problem. According to a report from the United Nations [1], many countries are expected to become super-aged societies around the year 2050, when more than twenty percent of the population will be over sixty-five years or older.

The growing number of elderly persons also raises the issue of dementia, because the probability of becoming cognitively impaired increases with age. Care for elderly people with dementia requires particular attention because they are vulnerable to environmental irregularities and become uncomfortable when they do not recognize their surroundings. Thus, caregivers must take many things into consideration to assure peaceful lives for those with dementia.

To keep things under control, caregivers need to know be aware of what is going on in a care home, including which residents are where, with whom, and for what. However, this creates a dilemma. The privacy of the residents is violated to some extent if a care house is designed to allow caregivers to observe every corner. The

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residents' wellbeing, however, is put at risk if the house is designed like a normal house, because most corners are unobservable from a distance. There must be a tradeoff between privacy and safety. If we value privacy over safety, we can make the house cozy, but caregivers will have to run from corner to corner to prevent possible accidents. Accordingly, most care houses have one large common room in the center with bedrooms adjoining it, allowing caregivers to observe all residents from the common room.

We take another approach to adjusting the balance between privacy and safety. We place the highest value on residents' privacy and believe that a normal house is the best place for those with dementia to live their lives peacefully. However, converting a normal house into a care home inevitably increases the risk of some residents being harmed by accidents while they are unattended by caregivers. We resort to technological solutions to solve the problem of blind spots. That is, we install a video monitoring system into care homes.

It is not particularly innovative to introduce a camera and a monitor into a care home for persons with dementia. Several existing monitoring systems have been developed by researchers such as [2-9]. In this study, we emphasize the system's usage by and effects on caregivers to clarify how well such monitoring systems are utilized and to consider how to design a better system. Thus far, little attention has been paid to how ICT augments caregivers' ability to administer care; most efforts have focused solely on developing useful systems. In this study, we focus on caregivers instead of particular technologies or systems.

We believe that monitoring systems not only help caregivers care for people with dementia but also reduce the physical and mental stresses that come from caregiving. If we respect the concept of personhood [10-11] as advocated by the pioneer, we must consider both patient and caregiver equally; that is, it is not particularly fair to ask caregivers to sacrifice their lives for caregiving. The basic human rights of person with dementia must be observed.

We installed camera systems into three care homes for our field study and analyzed the systems' effects on caregivers by employing a qualitative method with the hope that our research would lead to useful systems for them [12-13]. We conducted a series of interviews with sixteen caregivers and three managers, in addition to a video observation of their caregiving. In the remainder of the document, we refer to care homes as *group homes* according to the custom in Japan.

2 Related Work

The ENABLE project, conducted across several countries in Europe, namely, the U.K., Norway, and Finland, investigated issues involved in monitoring and supporting people with dementia [7, 14-15]. They developed several useful devices for people with dementia, such as gas cooker monitors and automatic nightlights, and were instrumental in establishing guidelines for the use of assistive technologies based on the results of their field studies [14]. They also considered ethical issues related to the use of technology on people with dementia [15]. The project is regarded as a pioneering study in this area of research with respect to both the scale and depth of the investigations.

Several monitoring systems have been developed with the intent of ensuring the safety of people with dementia. Such systems focus on preventing residents from wandering without any specific purpose. For example, Masuda et al. developed a system to detect wandering in bedrooms using a step sensor [3]. A four-week clinical trial at a hospital showed that their system detected thirty cases of wandering. Miskelly developed two (independent) systems for tracking people with dementia, one of which consists of bracelet-type tags and a monitoring station [4], and the other uses a GPS-enabled mobile phone [5]. Other researchers have adopted GPS technology as well [8-9].

Lin et al. integrated several technologies into a tracking system (radio frequency identification, a global positioning system, a global system for mobile communications, and a geographic information system) that did not interfere with the activities of people with dementia [2].

More generally, research on smart homes can be seen as an area that is closely related to ours. A smart home with a sensor network installed in it enables caregivers to monitor the whereabouts of residents. When a smart home is inhabited by people with dementia, the home can help caregivers sense the risks involved in residents' unusual behaviors, wandering, agitation, and so on [6, 16-17].

3 Research Design

3.1 Overview of the Camera System and System Installation

The installed monitoring systems were slightly different in the three group homes (Table 1). Hereafter, the three homes will be referred to as GH-A, -B, and -C. The system installed in GH-A allowed for video recording and its devices were wired. The systems installed in GH-B and GH-C used wireless devices and did not allow video recording. In this section, we focus on the system installed in GH-C.

We designed the system as simply as we could because the caregivers in GH-C were not familiar with computers. The system consisted of four wireless cameras, a portable monitor, and a laptop PC functioning as server. Visual data from the cameras were gathered on the server and were displayed on a Web browser. A down-scan converter was employed to turn the information displayed on the Web browser into TV signals, which were emitted to a portable monitor. Possible malfunctions due to mishandling by the caregivers or residents were reduced to the minimum because it was impossible for them to operate the system through the monitor. The cameras and the monitor were placed as shown in Figure 1.

Before the installation, a preliminary investigation was carried out to identify blind spots in the group home and to identify the system's requirements. The manager and the caregivers were concerned with invasion of privacy and were especially keen to avoid any unwanted effects that might be caused by video recording, so we paid the most attention to preserving residents' privacy. Thus, we decided to set the cameras in common spaces only, such as the entrance hall, entrance hall corridor, and living room (the positions noted as Z1 to Z5 in Figure 1). Furthermore, we decided not to include any video recording functionality in the system. In our discussion with the manager of GH-C, we discovered that spots Z1 to Z5 were often difficult to observe.

Table 1. Overview of the group homes and the study

		GH-A	GH-B	GH-C
Figuration		renovated		purpose-designed and newly established
Number of residents		9	6	9
Total of caregivers		9	5	8
Number of informants		6	5	5
Caregivers in daytime		2 or 3	2	2 or 3
Caregivers in nighttime		1	1	1
Residential areas		first and second floor	first floor	first floor
Start of operation		December 2006	January 2005	March 2008
Time of interview	before	—	—	November and December 2007
	after	June 2007		May 2008
Time of video	before	—	—	March 2008
observation	after	—	—	December 2008

3.2 Interview

A series of semi-structured interviews were carried out after systems had been installed in GH-A and GH-B. As for GH-C, we carried out the interviews before and after the installation. We interviewed the caregivers, asking them what they thought of the system and which aspects they regarded as the most valuable in terms of dementia care. Specifically, we asked the caregivers the following questions:

Q1. What is the burden of dementia care? (before)
Q2. What is/are the most important factor(s) for dementia care? (before)
Q3. How do you use the video monitoring system? (after)
Q4. What do you think of the system? (after)
Q5. How has the system affected your work stress? (after)

Table 2. Profiles of interviewees

Intervewees	Level of expertise	Qualification of nursing
a1	moderate	eligible
a2	moderate	
a3	high	eligible
a4	low	
a5	moderate	
a6	low	eligible
b1	moderate	
b2	low	
b3	moderate	
b4	low	
b5	low	
c1	high	eligible
c2	moderate	
c3	high	eligible
c4	moderate	
c5	moderate	

Table 1 gives an overview of our field study. The group homes accommodated either six or nine residents at full capacity, and the number of caregivers present at the homes was as required by law. The profiles of the interviewees are illustrated in Table 2. We graded the caregivers of the three groups according to their work experience: the *low* group had less than three years experience; the *moderate* group had three to seven years experience; and the *high* group had more than seven years experience.

All the interviews were recorded with an IC recorder and were fully transcribed for ease of reference. The constant comparative method was used to analyze the transcriptions. The transcriptions were repeatedly read as many times as possible to identify any commonalities and differences among the data.

3.3 Video Observation and Analysis

We recorded and observed the behavior of caregivers and residents. The caregivers and the managers allowed us to record their activities with two extra video cameras that were not part of the video monitoring system. We carried out the data collection for two days before installation and another two days after installation. We analyzed their behaviors in the corridor (V1 in Figure 1) and in the living room (V2) to focus our investigation on the events that were closely related to daily activities such as assistance in the washroom.

Every ninety minutes from four o'clock in the afternoon to half past five in the early morning (16:00 to 5:30), we counted how often each resident performed an action and how the caregiver responded to it. We studied the behaviors observed in the evening and at night because we assumed that the effects of the system could be best evaluated during that period. The number of caregivers was limited to one at night, and the camera system was expected to be most effective then. Previous studies also suggest that caregivers receive the most benefit from monitoring systems at night [12-13].

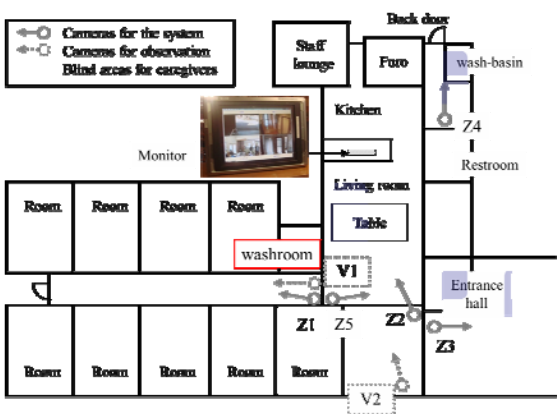

Fig. 1. Camera arrangement at the group home and its outlooks

3.4 Ethical Considerations

In this study, we strictly observed informed consent guidelines in asking individual caregivers and managers of the group homes for data collection. Likewise, a letter of consent was obtained from the residents' families.

Video cameras were never set in private residential areas such as inside a resident's room, the washroom, *furo* (Japanese-styled bathroom), etc., to maintain privacy.

The ethics committee of the Japan Advanced Institute of Science and Technology approved the data collection method used in our study.

4 Results

4.1 Results of Interview: Alleviating Caregivers' Stress

The series of interviews revealed that the system reduced caregivers' physical and mental stress, as previously reported (the details were reported in [12-13]). Caregivers reported that some areas became blind spots at night because fewer caregivers are available to work overnight. The video monitoring system was most effective during nighttime, in particular, the time from midnight to early morning. Caregivers who worked during the night were very anxious about blind spots. They were afraid that some residents might be seriously injured, for example, suffer from bone fracture, if they fell down. Such accidents are always a possibility, but they must be avoided because being injured and confined to a bed may further cognitively impair the person. Caregivers were so worried of accidents that they would get anxious in the evenings.

After the video monitoring system was installed, they felt that the system alleviated their stress and improved their work styles significantly because it enabled them to focus on the tasks at hand, such as writing residents' daily records, washing dishes, or cooking, without experiencing excessive strain.

As previously reported [12-13], video cameras raise concerns about the violation of privacy, which becomes a source of stress for caregivers. However, our research and a separate investigation on technology acceptance [18] indicate that caregivers can accept ICT after they acknowledge the benefits of the devices; however, ICT usually gave rise to feelings of rejection during the initial phase of operation.

4.2 Results of Interview: Release from Restrictions

During both the daytime and nighttime shifts, caregivers reported that the camera system helped them make decisions. For instance, when a resident appears from his/her room and walks toward the washroom (depicted in the center of Figure 1) at night, caregivers in the kitchen may not be aware of the event. If they notice that a resident is heading toward the washroom, they leave their work and take any necessary action.

Even if two or three caregivers are working during the daytime, blind spots are an unavoidable issue in group homes. In addition to the limitations that caregivers have regarding resources for observing residents, caregivers also have an obligation to ensure residents' safety. To maintain PWD's physical safety, caregivers often disturbed residents' activities before system operation. A veteran caregiver (a3) noted that she always asked residents about where he/she wanted to go when they stood up and/or showed signs of heading in some direction. She felt apologetic for this behavior and felt that it became a source of stress. Another caregiver (a6) related how she used the system to take preemptive actions. When she noticed a resident going out to take a walk, she rushed to the back door and walked toward the resident to greet them from the front. In the case of GH-C, two caregivers (c4 and c5) and a manager said that it was easy for them to observe residents entering or exiting the washroom during both the day and night.

Before the introduction of the monitoring system, residents' activities were limited in order to secure their physical safety. On the other hand, both PWDs and caregivers were under fewer restrictions while the system was in place. A veteran caregiver (c3) reported that the elderly residents' peace of mind improved in response to the increased level of caregiver attention.

4.3 Results of Video Observation: Changing Work Style

Figure 2 shows the behaviors of two caregivers. This figure indicates that the caregivers' responses to the residents' behaviors were optimized. Despite the fact that the total number of responsive actions is slightly different, the proportion of actions changed: caregivers could adequately judge whether they needed to take action and assist residents. In fact, the system helped the caregivers adjust their efforts to the residents' demands and allowed caregivers to wait until residents truly needed help.

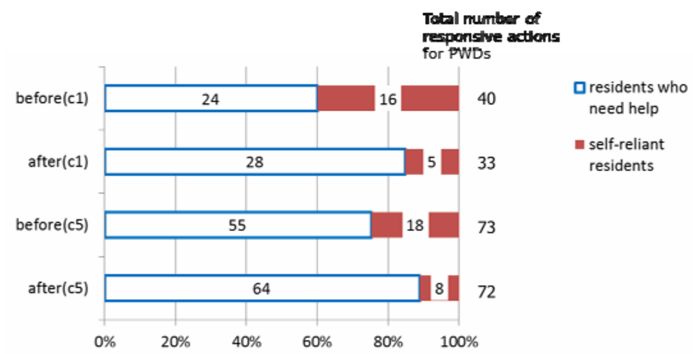

Fig. 2. Change in responsive action for PWDs

5 Discussion

Figure 3 is a summary of the results, and it illustrates the proposed concept of a *triage support environment*. The group homes we investigated were strained due to a lack of resources and fatigue. Caregivers always had to observe residents to maintain their safety. Whenever they detected certain behaviors, especially when residents attempted to go outside, caregivers had to ask the resident to confirm where he/she wants to go and what they want to do; in order to do so, the caregiver had to suspend their task at hand, such as cooking, cleaning, or toiletry assistance. They did not have enough time to evaluate a resident's actions. If caregivers were late in noticing a resident's action, they stopped their task immediately and headed to the scene. It is quite difficult to take the right decision under stressful conditions. Furthermore, the lack of redundant force to response residents' accidental actions was ascribed as a cause of stress.

However, caregivers were more at peace and were able to effectively respond to residents' needs while the system was in use. These benefits were the result of increased time for waiting, judging, and preparing that came from the system. The time that caregivers need to determine who needs help and to prioritize their actions is an important factor in their job performance.

Triage refers to the prioritization of the allocation of resources for medical treatment according to the severity of a patient's condition. The term is used in computer science to categorize vast information [19], documents [20], and e-mail [21].

When using the camera system, caregivers could observe residents and take action according to the urgency of their need. In other words, the camera system helped create a triage support environment. It should be noted, however, that the most important aspect of the triage support environment in this study is the time it allows caregivers to *wait* until action is necessary, which enhances the independence of PWDs, as opposed to the original meaning of triage, which is to treat aggressively based on severity.

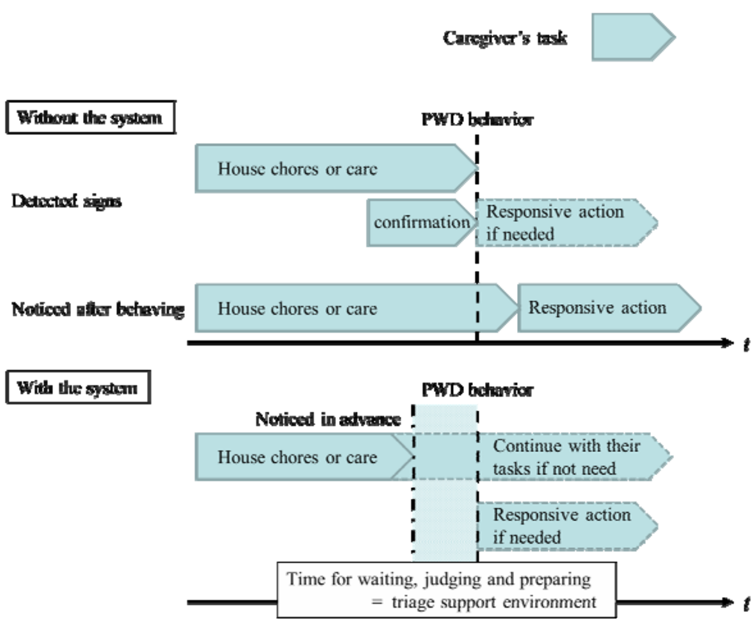

Fig. 3. Emerging triage support environment

6 Conclusion

We analyzed how the camera system affected caregivers in terms of how the system could contribute to the field of caregiving. The results of interviews showed that the stress caregivers felt was decreased. The reason for this stress reduction is most likely the increased control they had over observing the residents' behaviors with the camera system. Ironically, the camera system liberated both PWDs and caregivers from oppressive surveillance. The video observation allowed caregivers to efficiently respond to PWD activity. Finally, we established the concept of a "triage support environment," which can augment dementia care.

Because we only carried out our experiments, further data collection is required to verify our findings. We also need to improve the camera system by investigating the caregivers' needs with additional field studies.

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References

1. United Nations: World Population Prospects: The 2008 Revision Population Database, `http://www.esa.un.org/unpp/index.asp?panel=2` (accessed January 27, 2011)
2. Lin, C.-C., Chiu, M.-J., Hsiao, C.-C., Lee, R.-G., Tsai, Y.-S.: Wireless Health Care Service System for Elderly with Dementia. IEEE Transactions on Information Technology in Biomedicine 10, 696–704 (2006)
3. Masuda, Y., Yoshimura, T., Nakajima, K., Nambu, M., Hayakawa, T., Tamura, T.: Unconstrained Monitoring of Prevention of Wandering the Elderly. In: Proc. of the Second Joint EMBS/BMES Conference and the 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society, pp. 1906–1907 (2002)
4. Miskelly, F.: A Novel System of Electronic Tagging in Patients with Dementia and Wandering. Age and Ageing 33, 304–306 (2004)
5. Miskelly, F.: Electronic Tracking of Patients with Dementia and Wandering using Mobile Phone Technology. Age and Ageing 34, 497–499 (2005)
6. Miura, M., Ito, S., Takatsuka, R., Sugihara, T., Kunifuji, S.: An Empirical Study of an RFID Mat Sensor System in a Group Home. Journal of Networks (JNW) 4(2), 133–139 (2009)
7. Orpwood, R., Gibbs, C., Adlam, T., Faulkner, R.: The Design of Smart Homes for People with Dementia—User-interface Aspects. Universal Access in the Information Society 4, 156–164 (2005)
8. Shimizu, K., Kawamura, K., Yamamoto, K.: Location System for Dementia Wandering. In: Proceedings of the 22nd Annual International Conference of the IEEE EMBS, pp. 1556–1559 (2000)
9. Shoval, N., Auslander, G.K., Freytag, T., Landau, R., Oswald, F., Seidl, U., Wahl, H.-W., Werner, S., Heinik, J.: The Use of Advanced Tracking Technologies for the Analysis of Mobility in Alzheimer's Disease and Related Cognitive Diseases. BMC Geriatrics 8, 1–12 (2008)

10. Kitwood, T.: Dementia Reconsidered. Open University Press, Buckingham (1997)
11. Takatsuka, R., Fujinami, T.: Aware Group Home: Person-Centered Care as Creative Problem Solving. In: Khosla, R., Howlett, R.J., Jain, L.C. (eds.) KES 2005. LNCS (LNAI), vol. 3684, pp. 451–457. Springer, Heidelberg (2005)
12. Sugihara, T., Nakagawa, K., Fujinami, T., Takatsuka, R.: Evaluation of a Prototype of the Mimamori-care System for Persons with Dementia. In: Lovrek, I., Howlett, R.J., Jain, L.C. (eds.) KES 2008, Part II. LNCS (LNAI), vol. 5178, pp. 839–846. Springer, Heidelberg (2008)
13. Sugihara, T., Nakagawa, K., Liu, X., Fujinami, T.: The effects of camera system on caregivers' behaviors to persons with dementia. In: Stephanidis, C. (ed.) UAHCI 2009. LNCS, vol. 5614, pp. 297–303. Springer, Heidelberg (2009)
14. Adlam, T., Faulkner, R., Orpwood, R., Jones, K., Macijauskiene, J., Budraitiene, A.: The Installation and Support of Internationally Distributed Equipment for People with Dementia. IEEE Transactions on Information Technology in Biomedicine 8, 253–257 (2004)
15. Bjorneby, S., Topo, P., Cahill, S., Begley, E., Jones, K., Hagen, I., Macijauskiene, J., Holthe, T.: Ethical Considerations in the ENABLE Project. Dementia 3, 297–312 (2004)
16. Arcelus, A., Jones, M.H., Goubran, R., Knoefel, F.: Integration of Smart Home Technologies in a Health Monitoring System for the Elderly. In: Proc. of 21st International Conference on Advanced Information Networking and Applications Workshops (AINAW 2007), pp. 820–825 (2007)
17. Helal, S., Giraldo, C., Kaddoura, Y., Lee, C., El Zabadani, H., Mann, W.: Smart Phone Based Cognitive Assistant. In: Proc. of the 2nd International Workshop on Ubiquitous Computing for Pervasive Healthcare Applications, UbiHealth 2003 (2003)
18. Engström, M., Lindqvist, R., Ljunggren, B., Carlsson, M.: Staff Members' Perceptions of a ICT Support Package in Dementia Care during the Process of Implementation. Journal of Nursing Management 17, 781–789 (2009)
19. Marshall, C.C., Shipman III, F.M.: Spatial Hypertext and the Practice of Information Triage. In: Proc. of the Eighth ACM Conference on Hypertext, pp. 124–133 (1997)
20. Badi, R., Bae, S., Moore, J.M., Meintanis, K., Zacchi, A., Hsieh, H., Shipman, F., Marshall, C.C.: Recognizing User Interest and Document Value from Reading and Organizing Activities in Document Triage. In: Proc. of IUI 2006, pp. 218–225 (2006)
21. Neustaedter, C., Brush, A.J.B., Smith. M.A.: Beyond "From" and "Received": Exploring the Dynamics of Email Triage. In: Proc. of CHI 2005, pp. 1977– 980 (2005)

Nonvisual Effects of Led Coloured Ambient Lighting on Well-Being and Cardiac Reactivity: Preliminary Findings

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Abstract. This study examined the immediate nonvisual effects of ambient lighting colours and illuminance on momentary wellbeing and physiology during daytime. As reported in recent literature, the effects of lighting extend beyond comfort and safety issues. Illuminance level and ambient colours appear to have differing effects on perception and to some degree on physiological parameters. In the present study, LED lighting was used in a mock-up office to expose 37 participants to two levels of illuminance, being 45 lx and 195 lx on the eye, and four ambient colour combinations, being Red-Green, Red-Blue, Green-Blue, Red-Green-Blue. Overall, the results showed interactions between lighting condition and illuminance levels on the currently investigated subjective and objective parameters. The expected arousing impact of colour combinations with a blue component was only partially observed in the current study. The results may have implications for future office design in which coloured lighting takes a central role.

Keywords: Nonvisual effects, LED, illuminance, colour lighting, well-being, cardiac reactivity.

1 Introduction

Lighting conditions in most buildings are often inadequate with regard to the biological need of light (Veitch, 2002). The quality of lighting should not only be considered in terms of visual comfort and safety, but should also be thought of in terms of health and wellbeing (Ariës, Veitch, & Newsham, 2010). In a work environment, the advantages of improved health and wellbeing are important for the workers, and might also lead to better work performance, fewer errors, more safety, and lower absenteeism (Bommel and Beld, 2004; Edwards, 2002). Although poor lighting has been associated with mental health problems numerous times, the direct effects of lighting on psychological wellbeing and mental stress is not yet fully understood.

The strongest indications for the beneficial qualities of light stem from controlled laboratory research, in which typically the level of illuminance is the only experimental factor. In general, the direct effects of experimental, short-term

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elevations in illuminance (<3h) have been shown to involve increases in subjective alertness and physiological measures of arousal (Cajochen, 2007; Myers & Badia, 1993; Scheer, Doornen, & Buijs, 1999; Vandewalle et al., 2007). Yet, not all studies found consistent findings. Some studies partially confirmed these results (Knez, 1995; Rüger, Gordijn, Beersma, Vries, & Daan, 2005), or not at all (Knez, 2001). An explanation might be sought in both the timing of lighting exposure and the laboratory protocol.

Despite widespread belief, there is no clear evidence that lighting colour affects mood, emotions, or psychological wellbeing in any systematic manner. Ambient colour is frequently used by interior designers to influence the workers' mood and creativeness. Indeed, some evidence was shown for a better mood when the office space is experienced as colourful (Küller et al., 2006). Again, most evidence emerges from chronobiological studies, which have explored the direct effects of colour lighting typically during the nighttime period, and showing the arousing quality of blue light as compared to other light conditions (Cajochen et al., 2004; Gordijn et al. (2005). These effects can be attributed to a recently discovered photoreceptor that is particularly sensitive to the blue regions and primarily projects information to non-sensory brain areas, such as the suprachiasmatic nucleus where the biological clock is situated (Berson et al., 2002; Brainard et al., 2001).

In the current study both dimensions –illuminance and colour– of lighting were taken into account, to address mental stress and wellbeing issues after a short period of demanding tasks in an office mock-up environment. Mental stress has been shown a determinant to health complaints, among which is the sick building syndrome (Ooi & Goh, 1997). To further increase the practical relevance of the current study, light-emitting diode (LED) lighting was used, which has gradually become a serious competitor to traditional lighting, such as incandescent light bulbs.

2 Methods

2.1 Participants

Thirty-seven healthy students from the TU Delft (19 male, 18 female; age 21.3 ± 2.6 [SD] years, range 17-27 years) were included in this study. Participants with a personal or family history of psychopathology and/or cardiovascular disorders were excluded from the study. All participants were paid for participation, and were required to give written consent. The study was approved by the Ethics Committee of the TU Delft.

2.2 Setting

The experiment took place in the Studio Home/Office laboratory facility of the TU Delft, Department of Industrial Design Engineering. For the present experiment two LED bars (LED Pixel Track MKII, Showtec Inc., USA) were included. To avoid glare, light of the LED bars was emitted on a reflective white screen providing a bright area of app. 0.9mx0.7m (height x width) on a surface of app. 1.4m x 1.1m (Figure 1). All windows were completely covered to shut out natural daylight. At all times during the experiment individuals were exposed to warm white light (app.

3000K) produced by a fluorescent bar (Osram L58W/31-830) fixed in an overhead luminaire with an illuminance level (at eye level) of 20 lx.

2.3 Subjective Ratings

Momentary wellbeing included one-item probes for tension, fatigue, motivation, and annoyance. These were assessed on a five-point Likert scale (1=very little – 5=very much) and have been found sensitive for momentary and circadian effects (Varkevisser et al., 2005, 2007). Perceived arousal and valence were measured with the self-assessment manikin (SAM, Figure 1) (Bradley and Lang, 1994).

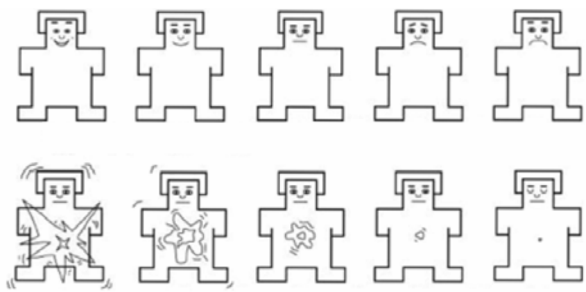

Fig. 1. Self-Assessment Maniken (SAM): mood valence and arousal

2.4 Physiology

The physiological parameters were derived from electrocardiograph and skin conductance measures (Mobi8 polygraph, TMSi, The Netherlands). Heart rate has been shown sensitive to lighting in some studies (Cajochen et al, 2004; Scheer et al., 1999). Heart rate variability appears to be a sensitive measure for mental load (Backs and Seljos 1994; Veltman and Gaillard 1996). The following physiologic output indexes were calculated: heart rate average (HRA), heart rate variability (HRV; root mean square of successive differences).

2.5 Experimental Procedures

Upon arrival in the laboratory the participants started with a 5-min baseline measurement: sitting quietly in front of the computer screen in an upright position (in 20 lux white light), after which they had to fill out the momentary wellbeing questionnaire. This was followed by the first 12-min test bout (performance results not reported here), during which they were exposed to one of the colour light conditions. Finally, the individuals were allowed a 5-min rest period. After this period the LED tubes were turned off and the participants had to fill out the momentary wellbeing, SAM, and RSME questionnaires. Then they engaged in the next test bout during which they were exposed to a novel colour condition. The participants were assigned randomly to a low illuminance or a high illuminance condition. The low-illuminance group received app. 45 lux in the direction of gaze, while the high-illuminance group received app. 195 lux in the direction of gaze. In both illuminance conditions (195 and 45 lux at eye level) participants were randomly exposed to four different Red-Green-Blue (RGB) lighting combinations: RG, RB, GB, and RGB.

2.6 Data Reduction & Analyses

Thirty second averages were calculated for HRA and HRV. Except for the mental effort values, individual baseline values were subtracted from values obtained during the experimental protocol. All parameters were subjected to a repeated measures analysis of variance (repeated covariance type: Diagonal) (rmANOVA) to test for effects across colours and illuminance level, with Colour (4 levels) and Illuminance (2 levels) set as fixed effects, and Participants set as a random effect. A fixed Intercept effect was included to test against baseline. Post-hoc comparisons with Bonferroni correction were included to compare the main effects.

3 Results

3.1 Momentary Wellbeing

Table 1 shows the rmANOVA outcomes for the momentary wellbeing parameters. Overall, no main effects were found for Colour or Group, except for a group difference in Tension, showing a higher level of tension in the low illuminance group (0.1±0.2; baseline subtracted) as compared to the high illuminance group (-0.5±0.2; baseline subtracted). Fatigue, and Annoyance differed from baseline values (Intercept test) with relatively higher scores in all colour conditions. A Colour x Group interaction was found for Fatigue, with a trend for an effect for Motivation. Figure 2 shows that the level of fatigue was rated higher in the high illuminance group when exposed to RB, GB, and RGB, whereas the low illuminance group showed higher scores in the RG condition. Motivation showed relatively higher scores in all lighting conditions for the low illuminance group (highest in RG), except for the RB condition, in which the high illuminance group scored higher. Results on Annoyance showed a significant main effect of colour, with the highest values in the RG (1.0±0.3) and RB (1.1±0.3) conditions as compared to the GB (0.0±0.2) and RGB conditions (0.0±0.2).

3.2 Arousal and Mood Valence

Analysis yielded a significant Colour x Group interaction for mood valence, showing that mood valence was rated as being relatively worse in the low illuminance group when exposed to RG and RGB colours, whereas valence was relatively worse for the high illuminance group when exposed to the GB condition (Fig. 2). Mood valence levels were significantly higher in all lighting conditions as compared to baseline (Intercept test). No statistical effects were found for experienced arousal.

Table 1. F-values of the Main and Interaction effects derived by the Mixed Model ANOVA

	Colour	*Group*	*CxG*
Well-being			
Tension	0.5	5.1^{*}	0.3
Fatigue	$2.5^{\dagger}$	1.8	4.9^{*}
Motivation	$2.3^{\dagger}$	0.1	$2.7^{\dagger}$
Annoyance	12.2^{**}	0.2	1.2
SAM			
Valence (1-9)	0.9	0.2	3.0^{*}
Arousal (1-9)	0.1	0.7	1.0
Cardiac Activity			
HRA	1.0	0.2	3.0^{*}
RMSSD	1.6	1.1	0.5

3.3 Cardiac Activity

Figure 2 shows a higher level of HRA for the low illuminance group in the RB and RGB conditions, whereas a higher level for the high illuminance group can be observed in the RG and GB conditions. This was corroborated by a significant Colour x Group effect for HRA. RMSSD only reached statistical significance when tested against baseline, showing lower values for rMSSD throughout the experimental period.

4 Discussion

The present study explored the impact of ambient LED colour light and illuminance level on momentary wellbeing, and cardiac reactivity after relatively short, repeated periods of mental stress. Overall, the results showed the most robust effects in momentary wellbeing. Most significant effects were due to the influence of colour light in interaction with illuminance level. In particular, magenta (RB) and yellow (RG) elicited relatively strong negative effects across these measures. Based on the literature we expected that illuminance level would strengthen certain effects, in particular on parameters related to alertness. This was partially supported by the results as the effect was only apparent in interaction with colour condition.

With respect to momentary wellbeing, the RG and RB colours in the present study elicited strong reactions on fatigue. Yet, this was also dependent on illuminance condition. In the low illuminance condition the RG colour elicited a stronger negative effect on fatigue, whereas in the high illuminance condition this was true for the RB colour. Although the strength of the blue light component might not have been sufficient to increase arousal (Berson et al., 2002; Brainard et al., 2001; Mills et al., 2007), it does not explain the increase in for instance fatigue. The participants indicated annoyance –a more perceptual/visual quality compared to the other well-being paremeters– in the RG and RB conditions. More specifically, subjectively reported levels of fatigue and mood valency increased when exposed to RG light with low illuminance levels, and when exposed to RB light with high illuminance levels. Thus, it might have been more tiresome/straining to work in the RG and RB light conditions leading to decreased feelings of wellbeing.

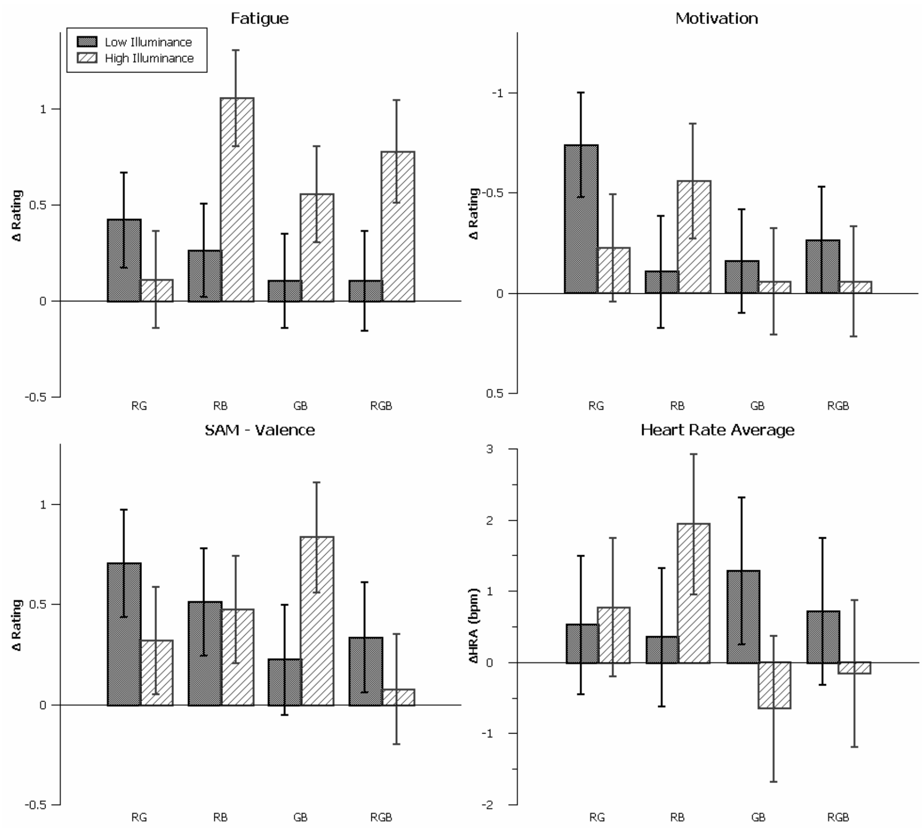

Fig. 2. Estimated Marginal Means ± SEM of Fatigue, Motivation, Mood Valence, and Heart Rate Average. Note that the axis for Motivation is inverted: a higher negative score denotes less motivation

Mood valency showed equivocal results with the highest negative mood for the high illuminance RG condition, and also the low illuminance RG condition. Note, however, that compared to baseline all mood valence values were elevated, so compared to office lighting (fluorescent light; 20 lx) the colours generally evoked more negative feelings. Consequently, the data suggest that yellow (RG) and magenta (RB) colours induce stronger negative mood effect as compared to cyan (GB) and white (RGB), but not to a dim office lighting condition.

Heart rate showed a partly similar pattern, with an increase in the high illuminance RB, yet also in the low illuminance GB colour condition. This corroborates to a certain extent with the wellbeing parameters, i.e. an elevation in fatigue and demotivation in the RB colour condition with high illuminance levels. In contrast to the other findings heart rate was elevated in the GB colour condition under low illuminance levels. This is in contradiction with our expectation that a colour combination with a blue component would elicit the highest physiological responses only in the high illuminance condition, an effect that has been shown in previous studies (Berson et al., 2002; Brainard et al., 2001). The present results showed this effect for the RB condition, but not for the GB condition (also with a blue component). An explanation might be sought in the observed increases in annoyance and negative mood valence which are know to influence cardiac reactivity (Al'Absi et al., 1997), although this effect was not constituted by heart rate variability.

The experimental conditions seemed to have evoked aspecific vagal withdrawal, most likely related to the mental stressors and not to the different lighting conditions. The overall absence of heart rate variability under different illuminance levels has been observed in earlier studies in which physiological reactivity was independent of illuminance level (Küller & Wetterberg, 1993; Leproult et al., 2001; Noguchi and Sakaguchi, 1999; Rüger et al., 2005; Scheer et al., 1999) and might be explained by the fact that (1) relatively low illuminance levels were administered in the current study (2) the study was performed during daytime. Other studies in which dose-dependence in cardiac parameters indeed was found, used illuminance levels far exceeding the current levels (>1000 lx) and were conducted during nighttime, thus evoking stronger responses..

Thus, the alerting and arousing effect, commonly found in chronobiological studies either appears to be mainly related to circadian processes coinciding with the circadian trough, or to illuminance levels much higher than commonly found in office spaces.

The present study, to our knowledge, is one of the first to explore direct nonvisual effects of LED colour lighting and illuminance levels on wellbeing and cardiac reactivity. The results added to previous results by a) showing colour and illuminance dependency in the wellbeing and cardiac parameters, b) refuting predictions of alerting/arousing effects due to illuminance and blue light during daytime. Further research is strongly encouraged in this novel field to ensure optimal office conditions, both biologically and aesthetically. In the future, smart lighting systems might be able to detect mental stress and respond accordingly by adapting the immediate office surroundings to the user's current mental state.

References

Al'Absi, M., Bongard, S., Buchanan, T., Pincomb, G.A., Licinio, J., Lovallo, W.R.: Cardiovascular and neuroendocrine adjustment to public speaking and mental arithmetic stressors. Psychophysiology 34, 266–275 (1997)

Aries, M.B.C., Veitch, J.A., Newsham, G.R.: Windows, view, and office characteristics predict physical and psychological discomfort. Journal of Environmental Psychology (2010), doi:10.1016/j.jenvp.2009.12.004

Backs, R.W., Seljos, K.A.: Metabolic and cardiorespiratory measures of mental efforts: the effects of level of difficulty in a working memory tasks. International Journal of Psychophysiology 16, 57–68 (1994)

Berson, D.M., Dunn, F.A., Takao, M.: Phototransduction by retinal ganglion cells that set the circadian clock. Science 295, 1070–1072 (2002)

van Bommel, W.J.M., van den Beld, G.J.: Lighting for work: a review of visual and biological effects. Lighting Research Technology 36, 255–269 (2004)

Bradley, M.M., Lang, P.J.: Measuring emotion: the Self-Assessment Manikin and the Semantic Differential. Journal of Behavioral Therapy and Experimental Psychiatry 25, 49–59 (1994)

Brainard, G.C., Hanifin, J.P., Greeson, J.M., Byrne, B., Glickman, G., Gerner, E., Rollag, M.D.: Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. Journal of Neuroscience 21, 6405–6412 (2001)

Cajochen, C.: Alerting effects of light. Sleep Medicine Reviews 11, 453–464 (2007)

Cajochen, C., Münch, M., Kobialka, S., Kräuchi, K., Steiner, R., Oelhafen, P., Orgül, S., Wirz-Justice, A.: High sensitivity of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light. Journal of Clinical Endocrinology & Metabolism 90, 1311–1316 (2004)

Edwards, L., Torcellini, P.: A Literature Review of the Effects of Natural Light on Building Occupants. Technical Report, National Renewable Energy Laboratory, U.S. Department of Energy, Golden, Colorado, US (2002)

Gordijn, M.C.M., Beersma, D.G.M., Rüger, M., Daan, S.: The effects of blue light on sleepiness. Annual Proceedings of the Dutch Sleep-Wake Society 16, 67–70 (2005)

Knez, I.: Effects of infoor lighting on mood and cognition. Journal of Environmental Psychology 15, 39–51 (1995)

Knez, I.: Effects of colour of light on nonvisual psychological processes. Environmental Psychology 21, 201–208 (2001)

Küller, R., Ballal, S., Laike, T., Mikellides, B., Tonello, G.: The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments. Ergonomics 14, 1496–1507 (2006)

Küller, R., Wetterberg, L.: Melatonin, cortisol, EEG, ECG and subjective comfort in healthy humans: impact of two fluorescent lamp types at two light intensities. Lighting Research and Technology 25, 71–81 (1993)

Leproult, R., Colecchia, E.F., L'Hermite-Balériaux, Van Cauter, E.: Transition from dim to bright light in the morning induces an immediate elevation of cortisol levels. Journal of Clinical Endocrinology & Metabolism 86, 151–157 (2001)

Mills, P.R., Tomkins, S.C., Schlangen, L.J.M.: The effect of high correlated colour temperature office lighting on employee wellbeing and work performance. Journal of Circadian Rhythms 5, 2 (2007)

Myers, B.L., Badia, P.: Immediate effects of different light intensities on body temperature and alertness. Physiology & Behavior 54, 199–202 (1993)

Noguchi, H., Sakaguchi, T.: Effect of illuminance and color temperature on lowering of physiological activity. Applied Human Science 18, 117–123 (1999)

Ooi, P.L., Goh, K.T.: Sick building syndrome: an emerging stress-related disorder? International Journal of Epidemiology 26, 1243–1249 (1997)

Phipps-Nelson, J., Redman, J.R., Dijk, D.J., Rajaratnam, S.M.W.: Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance. Sleep 26, 695–700 (2003)

Rüger, M., Gordijn, M.C.M., Beersma, D.G.M., de Vries, B., Daan, S.: Time-of-day-dependent effects of bright light exposure on human psychophysiology: comparison of daytime and nighttime exposure. American Journal of Physiology - Regulatory, Integrative and Comparative Physiology 290, R1413–R1420 (2005)

Scheer, F.A.J.L., van Doornen, L.J.P., Buijs, R.M.: Light and diurnal cycle affect autonomic cardiac balance in human; possible role for the biological clock. Autonomic Neuroscience: Basic and Clinical 110, 44–48 (1999)

Vandewalle, G., Schmidt, C., Albouy, G., Sterpenich, V., Darsaud, A., Rauchs, G., Berken, P.Y., Balteau, E., Degueldre, C., Luxen, A., Maquet, P., Dijk, D.J.: Brain Responses to Violet, Blue, and Green Monochromatic Light Exposures in Humans: Prominent Role of Blue Light and the Brainstem. PLoS ONE 2(11), 1247 (2007)

Varkevisser, M., Van Dongen, H.P.A., Van Amsterdam, J.G.C., Kerkhof, G.A.: Chronic insomnia and daytime functioning: a field assessment. Behavioral Sleep Medicine 5, 279–296 (2007)

Veitch, J.A.: Principles of healthy lighting: highlights of IE TC6-11's forthcoming report. In: Proceedings of the International LRO Lighting Research Symposium – Light and Human Health 2002 (Report No.1009370). Electric Power Research Institute, Palo Alto (2002)

Veltman, J.A., Gaillard, A.W.K.: Physiological workload reactions to increasing levels of task difficulty. Ergonomics 41, 656–669 (1998)

Warm, J.S., Parasuraman, R., Matthews, G.: Vigilance requires hard mental work and is stressful. Human Factors 50, 433–441 (2008)

The Effect of Vibrotactile Feedback on Novice Older Adults in Target Selection Tasks

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Abstract. In this study, older adults are examined as computer users, their characteristics and problems they are facing with computer systems are described; utilization of vibrotactile feedback mouse in graphical user interfaces is proposed to enhance their computer usability experience. An original Fitts experiment variation with 9 participants (mean age 69.67), who are novice computer users without any health related issues which may interfere with performance, has been done and the results of 2880 trials were analyzed. Results indicated that in vibrotactile mode, subjects completed the tasks faster (60%) and increased their target selection performances measured by Fitts' index of performance (43%, $p<0.05$).

Keywords: Human computer interaction, older adults, Fitts' Law, vibrotactile feedback.

1 Introduction

As relative population of elderly citizens is steadily rising particularly in developed countries [1, 2], governments indicate a strong tendency to transfer public services to the electronic platforms, to be accessed through computers, as much as possible to reduce operational public service costs and to increase accessibility to services offered [3]. Since the segment of older computer users are broadening fast [4] and most of the computer systems are not suitable for the older computer users [5], we directed our focus towards senior adults as computer users and identified their barriers in computer usability. To enhance their usability experience, we have revisited and implemented a vibrotactile feedback solution.

1.1 Older People

Examining older people in a scientific way has been a tough issue since population is highly heterogeneous. Besides, it is not always possible to find significant correlation between age, mental condition and physical condition [6]. On the other hand, older people are very likely to have at least one chronic disease such as hypertension, arthritis, diabetes, various cancer types and all kinds of heart problems [7]. Health problems developed as years past can cause elderly to run into various problems, impairing or blocking their daily life activities such as accessing communication tools, going for shopping etc.

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Specified characteristics of older users can be listed as follows: They are less experienced compared to younger ones [8]. They are not quick learners [9]. They have weak working memory and motor skills [10]. They experience vision loss [11]. They feel hesitation when it comes using technology [12]. On the other hand, if the technological tool they are to use is not expensive and is highly usable, they can overcome this hesitation in time [13]. Senior users are members of the fastest growing computer user segment [4].

1.2 Computer Usability Problems of Older Adults

The loss of flexibility, limited motor skills, vision problems, weak memory and cognition compose a grup of barriers against older people when they are considered as computer users. Mead et al. [14] compared the performances of young and older users with different experience levels on a university library on-line search application and stated that young ones had better performance than olders. Mead et al. also reported that computer experience is a significant factor affecting the task completion success of olders in a positive way. Fisk et al. [15] reported that older users spend more time than younger ones do during the visual display processing. The cause of this relatively slow processing may be attributed to age related defects on sight and cognition. Due to impaired manual dexterity through normal aging process, older users usually have difficulties with standart input devices such as keyboard and mouse [16]. Being away from common computer concepts is a primary obstacle for the senior adults. They face problems in comprehension of user interface conventions due to their lack of contextual knowledge [15]. Janicki concluded that older users have difficulties when it comes to understanding technical terminology [17].

Understanding task model and, even it is understood, translating the model into the sequential activities is usually problematic for older users [18], since information processing ability declines through the years [19]. Hanson [20] examined older subjects regarding to their accessibility levels to Internet and reported obstacles that are possible to be overcomed by re-designing browsers and web applications for elderly. Several design principles are strongly recommended by government agencies for making computer applications more usable by seniors [21]. Those principles are clearly addressing age related deficiencies on vision, perception, cognition and motor functions. Some studies made it clear that special design for older users is absolutely beneficial. Worden et al. [22] conducted a study with experienced and novice group of older and young subjects, and mesured their performance on pointing tasks by using specially designed mouse area-cursor and sticky icons and reported that olders are slower than youngers but older people got 50% faster in completing the tasks by using area-cursor and sticky icons compared to their timings with standard cursor and icons. In Cybrarian project [6], *user sensitive inclusive design* principles are used for developing a special web browser and an e-mail client for older people and it is reported that seniors performed better with specially designed tools.

Using the mouse is a major barrier for older people. The users with motor skill problems produced 10% more error rates in pointing tasks [23]. Keates and Trewin [24] measured the effect of age and Parkinson disease on pointing and clicking tasks with 24 subjects and reported that olders and subjects with Parkinson disease recorded much longer task completion times than younger ones. Furthermore, it was revealed that older ones were moving the mouse in a very special way as they were drawing the cursor near target haltingly and they wait significantly longer for target validation before clicking. Those strategies developed are showing that seniors are likely to make effort for being able to use the mouse successfully. After a three years long broad study, Sayago and Blat [25] stated that older people experience difficulties while using the mouse and they use keyboard for assisting the mouse on pointing and selection tasks. As using the mouse requires sensitive muscle coordination and agile actions like clicking, which require strong motor abilites and clear vision, olders are likely to have difficulties in pointing and selection tasks by using that tool.

The literature on the computer usability problems of older people emphasize that mouse is a very problematic device for them. Interpreting and processing the standard visual positional feedback from the mouse is a challenging issue for older people due to usual aging problems on motor skills, sight and perception. According to the multiple resource theory by Wickens [26], producing feedback to be processed by different cognitive resources may result in enhanced performance due to the parallelism. Using the mouse with multi modal feedback is examined well by several parties. Akamatsu and MacKenzie [27] measured the effect of tactile, force feedback and combination of tactile and force feedbacks with 12 subjects. It is stated that using tactile feedback and the combination of tactile and force feedbacks are beneficial for subjects compared to normal feedback mode. Jacko et al. [28] showed that having multi modal feedback results in performance gain on drag and drop tasks assigned to older adults. Emery et al. [29] examined the multi modal feedback effects on drag and drop tasks designed for the older adults and they noted that haptic feedback must be combined with other feedback modes since “the age dependent degeneration of the peripheral nervous system common in individuals 40 years and older, older adults may be less sensitive to haptic feedback”. The subjects of this experiment were grouped into three levels of computer experience so that the interrelations between the feedback modes and experience could be isolated. Results revealed that experienced group performed well with double and triple feedback modes but less experienced groups could not take the advantage of triple feedback mode. The automation of motor skills [30] may result in the higher cognitive resources left for processing new and extra ordinary feedback signals coming from the mouse as experienced users are completing most of the actions taken for task completion without making any effort but novices are not. Fraser and Gutwin [31] indicated that “redundant targeting feedback can improve the usability of graphical interfaces, both for low-vision users and also for normally sighted users in visually stressed environments”. Cockburn and Brewster studied the effect of different combinations of multi modal feedback modes [32] and they stated that “all feedback modes reduce targeting times” after examining non-speech audio; tactile; and pseudo-haptic sticky feedback on small target acquisition tasks.

2 Hypothesis

In the same direction with previous research, suggesting a positive effect of multi modal feedback on pointing tasks, it is proposed that the novice older computer users would show better performance in completing the target selection tasks while they are using the pointing device in vibrotactile feedback mode.

3 Method

3.1 Subjects

The experiment took place with the participation of 9 right handed male volunteers who were living in the nursing home belonging to the Social Services Department of Istanbul. Volunteers' ages were ranging from 63 to 81 (Mean Age=69.67, σ=5.12). Only 2 out of 9 subjects were familiar with computers: First was using his laptop for 2 years and the latter was experiencing computer usage for 18 months on his personal computer. This experiment was the first contact with computers for the rest of the participants. None of the participants was having any chronic mental or physical diseases that may affect their computer usage in a negative way; they all were considered as normal, healthy older persons by the responsible specialists of the nursing house.

3.2 Design

Participants were asked to complete a simple target selection task by using the mouse in normal and vibrotactile feedback modes after a warming up session of 5 minutes. 4 different blocks of clicking tasks in 2 different axes (horizontal & vertical) were prepared. Each block was having 20 repeating clicks. It was a within subject repeated measures design. The levels of the design were given in Table 1:

Table 1. Design levels of the experiment

Block	Index of Difficulty (bits)	Axis	Feedback
1	3.87	Horizontal	Normal
2	2.81	Horizontal	Normal
3	1.81	Horizontal	Normal
4	2.67	Horizontal	Normal
5	3.87	Vertical	Normal
6	3.48	Vertical	Normal
7	2.48	Vertical	Normal
8	2.87	Vertical	Normal
9	3.87	Horizontal	Vibrotactile
10	2.81	Horizontal	Vibrotactile
11	1.81	Horizontal	Vibrotactile
12	2.67	Horizontal	Vibrotactile
13	3.87	Vertical	Vibrotactile
14	3.48	Vertical	Vibrotactile
15	2.48	Vertical	Vibrotactile
16	2.87	Vertical	Vibrotactile

The number of trials to be collected from 9 participants, in 2 axes, 2 feedback modes, 4 blocks in each axis, 20 clicks in each block was 2880 (9×2×2×4×20).

Each subject was given a red target bar on the screen which was appearing in the right and left or top and bottom of the screen in a sequential order regarding to the task block's direction. Once the bar was clicked, it was disappearing from its latest location and appearing in the opposite side of the screen. In each block, the width of the bar and/or the distance between 2 opposite bar locations was changing so that each block was yielding a different task difficulty.

In the vibrotactile mode the feedback rules were as follows:

1. The mouse vibrates for 500 milliseconds when the cursor located on the target bar.
2. If the cursor leaves the target before 500 milliseconds past, the mouse stops vibration.
3. If the cursor re-enters in the target area, the mouse vibrates for 500 milliseconds again.

According to the Fitts' law [33], movement time (*MT*) to a target of width (*W*), at a distance (*A*) is as follows:

$$MT = a + b \ \log_2(\frac{2A}{W}) \tag{1}$$

Where a and b are experimental constants of linear regression. Shannon formulation [34] was used in this experiment:

$$MT = a + b \ \log_2(\frac{A}{W} + 1) \tag{2}$$

Shannon variation has been chosen because it is known that [35] it mimics the information theorem underlying Fitts' law, it produces always positive results and it provides better fits with observations. The log term in the equation 2 is defined as index of difficulty (*ID*). Index of difficulty is measured in terms of "bits", which comes from the analogy with Shannon's information theorem. In addition to the index of difficulty, Fitts also defined a measure for the performance, named index of performance (*IP*) which is as follows:

$$IP = 1/b \tag{3}$$

IP is measured in bits/seconds which is analogous to throughput indices of electronic communication devices such as modems. In this experiment, the performance difference between normal and vibrotactile feedback modes of the pointing device was measured by using *IP* derived from the collected data from the task designed. Movement time, target width, target distance and clicking offset data were collected for each clicking action.

3.3 Apparatus

Vibrotactile Feedback Mouse. An electronic circuit that activates an eccentric micro electric motor with the digital control signal, is designed and produced. The control signal is designed to be received from the serial port of the computer. After having the physical circuit produced, a standard A4 Tech™ PS/2 optical mouse is modified to encapsulate the circuit and became a vibrotactile mouse.

Software and the Computer. A computer program with a graphical user interface that is implementing a variation of the original Fitts' experiment, explained in the design section, was developed by using Microsoft Visual Basic 6™. The standard

Microsoft ™ serial port controller component (Mscomm32.ocx) is used to send control signal to the mouse for activating the vibrator when the cursor moves in the target area and for deactivating the vibrator when the cursor is out of the current target. A standard desktop computer with a 2.8 GHz CPU, 2 GB of main memory and 1024×768 pixels of LCD display was used to run the software.

4 Results

After the experiment, the data collected was analyzed and refined from the outliers. The data belonging to the subject 2 was discarded due to the measurement defects so that it was not fitting into the Fitts' model. The obtained facts from 8 subjects are as follows:

Whole experiment took 3.5 hours. The average movement time (MT) to target was decreased at a proportion of 60% in vibrotactile feedback mode.

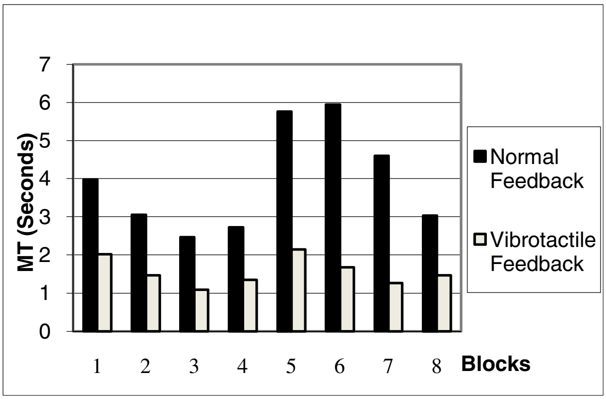

Fig. 1. Average task block timings compared

Especially subject 8, who has got no visual or motor function impairments, has acquired the target 85% faster in vibrotactile feedback mode compared to the normal feedback mode. The result on movement times showed that subject became faster in completing the task in vibrotactile feedback mode.

Table 2. *IP* scores compared in normal and vibrotactile modes

Subject#	IP Normal	IP Vibrotactile
1	9.21659	14.30615
3	12.48439	9.442871
4	2.893519	11.29944
5	10.83424	13.73626
6	5.78369	5.24109
7	3.067485	5.813953
8	0.628417	2.554931
9	5.260389	9.21659
T-Test	0.032	(p<0.05)
Average	6.27	8.95
σ	4.19	4.17

The average index of performance increased 43% in vibrotactile feedback mode and the resulting array of IP values between two modes are moderately significant statistically (p=0.032; σ_{normal}=4.19, $\sigma_{vibrotactile}$=4.17, see Table 2).

The results suggested that non impaired older computer users were performing better at completing the target selection tasks while they were using mouse in vibrotactile feedback mode.

As stated in the method section, this experiment was the first contact with a computer for 7 out of 9 subjects. In the warm up sessions, the mouse as "the pointing device" and the terms like "pointing" and "clicking" were introduced to the participants. During the experiment, most of them intuitively succeeded to use the mouse in both modes. On the other hand, in some cases, the subjects were forgetting to click the target although the pointer was located on the right place. In those cases, the benefit of vibrotactile feedback to the users was sharper: They immediately clicked the target after the mouse had vibrated.

Most of the subjects considered the experiment as a joyful and competitive game so that, they were trying to be faster than their predecessors to win the "game".

5 Conclusion

As the target selection and pointing tasks are the majority of activities when users are dealing with the graphical interfaces [36], any enhancements on these tasks may result in better computer usability experiences.

In this study, we examined the effect of using vibrotactile feedback mouse on selecting targets at different difficulty levels of tasks. The results show that older adults performed better significantly in the case of using vibrotactile mouse. Since there is an elevated threshold, for a novice adult to start using a computer than an experienced one. We can conclude that, barriers that prevent older novice users from effectively using computers can be significantly reduced through introduction to multimodal feedback input devices such as vibrotactile mouse.

References

1. Federal Interagency Forum on Aging-Related Statistics: Older Americans (2010)
2. European Commission: The 2009 Ageing Report: economic and budgetary projections for the EU-27 Member States (2008-2060) (2009)
3. United Nations: E-Government Survey 2010 (2010)
4. Mayhorn, C.B., Stronge, A.J., McLaughlin, A.C., Rogers, W.A.: Older Adults, Computer Training, And The Systems Approach: A Formula For Success. Educational Gerontology 30(3), 185–203 (2004)
5. Czaja, S., Lee, C.C.: The impact of aging on access to technology. Univ. Access Inf. Soc. 5, 341–349 (2007)
6. Newell, A., Dickinson, A., Gregor, P., Smith, M.J.: Designing a Portal for Older Users: A Case Study of an Industrial/Academic Collaboration. ACM Transactions on Computer-Human Interaction 13(3), 347–375 (2006)
7. Administration on Aging: A profile of older Americans: 2009, U. S. Department of Health and Human Services, Washington. D.C. (2009)

8. Chen, Y., Persson, A.: Internet use among young and older adult: Relation to psychological well-being. Educational Gerontology 28, 731–744 (2002)
9. Schneider, B.A., Pichora-Fuller, M.K., Craik, F.I.M., Salthouse, T.A.: Implications of perceptual deterioration for cognitive aging research, 2nd edn. The handbook of aging and cognition, pp. 155–219. Erlbaum, Mahwah (2000)
10. Vercruyssen, M., Fisk, A.D., Rogers, W.A. (eds.): Movement control and speed of behavior. Handbook of human factors and the older adult, pp. 55–86. Academic Press, San Diego (1997)
11. American Foundation for the Blind: Normal changes in the aging eye (2010), http://www.afb.org/Section.asp?SectionID=35&TopicID=212&SubTopicID=39
12. Morrell, R.W., Dailey, S.R., Stoltz-Loike, M., Feldman, C., Mayhorn, C.B., Echt, K.V., Podany, K.I.: Older Adults and Information Technology: A Compendium of Scientific Research and Web Site Accessibility Guidelines, The National Institute on Aging (2004)
13. Rosenthal, R.L.: Older Computer-Literate Women: Their Motivations, Obstacles, and Paths to Success. Educational Gerontology 34(7), 610–626 (2008)
14. Mead, S.E., Sit, R.A., Rogers, W.A., Jamieson, B.A., Rousseau, G.K.: Influences of general computer experience and age on library database search performance. Behaviour & Information Technology 19(2), 107–123 (2000)
15. Fisk, A.D., Rogers, W.A., Charness, N., Czaja, S.J., Sharit, J.: Designing for Older Adults: Principles and Creative Human Factors Approaches. CRC Press, Boca Raton (2004)
16. Czaja, S., Lee, C.C.: Designing computer systems for older adults. In: Jacko, J.A., Sears, A. (eds.) The Human-Computer Interaction Handbook: Fundamentals, EvolvingTechnologies and Emerging Applications, pp. 413–427. Lawrence Erlbaum Associates, Mahwah (2003)
17. Janicki, K.: A hindrance to communication: The use of difficult and incomprehensible language. Int. J. Appl. Linguist. 12(2), 94–217 (2002)
18. Hollinworth, N., Hwang, F.: Learning How Older Adults Undertake Computer Tasks. In: ACM SIGACCESS Conference on Computers and Accessibility, pp. 245–246 (2009)
19. Salthouse, T.A.: The processing speed theory of adult age differences in cognition. Psychological Review 103(3), 403–442 (1996)
20. Hanson, V.L.: Age and web access: the next generation. In: W4A 2009 Proceedings of the 2009 International Cross-Disciplinary Conference on Web Accessibililty (W4A), pp. 7–15 (2009)
21. National Institute on Aging and National Library of Medicine: Making your web site senior friendly-A checklist, http://www.nlm.nih.gov/pubs/checklist.pdf
22. Worden, A., Walker, N., Bharat, K., Hudson, S.: Making computers easier for older adults to use: area cursors and sticky icons. In: Proceedings of the SIGCHI Conf. on Human Factors in Computing Systems, pp. 266–271 (1997)
23. Trewin, S., Pain, H.: Keyboard and mouse errors due to motor disabilities. International Journal of Human-Computer Studies 50, 109–144 (1999)
24. Keates, S., Trewin, S.: Effect of Age and Parkinson's Disease on Cursor Positioning Using a Mouse. In: ASSETS 2005, Baltimore, MD, USA, October 9-12 (2005)
25. Sayago, S., Blat, J.: About the relevance of accessibility barriers in the everyday interactions of older people with the web. In: International Cross-disciplinary Conference on Web Accessibility (W4A-ACM), Madrid, Spain, April 20-21, pp. 104–113 (2009)
26. Wickens, C.D.: Engineering Psychology and Human Performance. HarperCollins, New York (1992)

27. Akamatsu, M., MacKenzie, I.S.: Movement characteristics using a mouse with tactile and force feedback. Int. J. Human–Computer Studies 45, 483–493 (1996)
28. Jacko, J.A., Scott, I.U., Sainfort, F., Barnard, L., Edwards, P.J., Emery, V.K., Kongnakorn, T., Moloney, K.P., Zorich, B.S.: Older adults and visual impairment: what do exposure times and accuracy tell us about performance gains associated with multimodal feedback? In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 33–40 (2003)
29. Emery, V.K., Edwards, P.J., Jacko, J.A., Moloney, K.P., Barnard, L., Kongnakorn, T., Sainfort, F., Scott, I.U.: Toward achieving universal usability for older adults through multimodal feedback. In: Proceedings of the 2003 ACM Conference on Universal Usability, pp. 46–53 (2003)
30. Schmidt, R.A., Lee, T.D.: Motor control and learning: a behavioral emphasis, 4th edn (2005) ISBN:0-7360-4258
31. Fraser, J., Gutwin, C.: The Effects of Feedback on Targeting Performance in Visually Stressed Conditions. In: Proceedings of Graphics Interface 2000, pp. 15–17 (2000)
32. Cockburn, A., Brewster, S.: Multimodal feedback for the acquisition of small targets. Ergonomics 48(9), 1129–1150 (2005)
33. Fitts, P.M.: The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology 47, 381–391 (1954)
34. MacKenzie, I.S.: A note on the information-theoretic basis for Fitts' law. Journal of Motor Behavior 21, 323–330 (1989)
35. MacKenzie, I.S., Buxton, W.: A tool for the rapid evaluation of input devices using Fitts' law models. ACM SIGCHI Bulletin 25(3), 58–63 (1993)
36. Johnson, P., Hewes, J., Dropkin, J., Rempel, D.: Office ergonomics: Motion analysis of computer mouse usage. In: Proceedings of the American Industrial Hygiene Association, pp. 12–13. AIHA Press, Fairfax (1993)

Multi-Resolution-Display System for Virtual Reality Setups

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Abstract. Most large-area video projection systems offer only limited spacial resolution. Consequently, images of detailed scenery cannot be displayed at full fidelity. A possible but significantly more costly strategy is a tiled projection display. If this solution is not feasible then either aliasing occurs or some anti-aliasing method is used at the cost of reduced scene quality.

In this paper we describe a novel cost effective multi-resolution display system. It allows users to select any part of a stereoscopic projection and view it in significantly higher resolution than possible with the standard projection alone. To achieve this, a pair of video projectors, which can be moved by stepper motors, project a high-resolution inset into a small portion of the low-resolution image. To avoid crosstalk between the low and high resolution projections, a mask is rendered into the low resolution scene to black out the area on the screen that is covered by the inlay.

To demonstrate the effectiveness of our multi-resolution display setup it has been integrated into a number of real life scenarios: a virtual factory, an airplane cabin simulation, and a focus and context volume visualization application (see Figure 1).

Keywords: projection, virtual reality, multi-resolution.

1 Introduction

In a number of computing areas today, like simulation or graphic design, image data is provided that contains far more detail than computer screens are able to display. Even very common data such as a digital photographs made with cheap consumer cameras can exceed the resolution of most high definition displays. If those or even lower resolution images are used as detail textures in a three dimensional scene the problem becomes even more obvious as those regions normally do not cover the entire display, further reducing the effective resolution (see Figure 1 A & B). Especially in visualizations of highly detailed scientific datasets (such as the visible human [1] in Figure 1C) this is an undesired effect.

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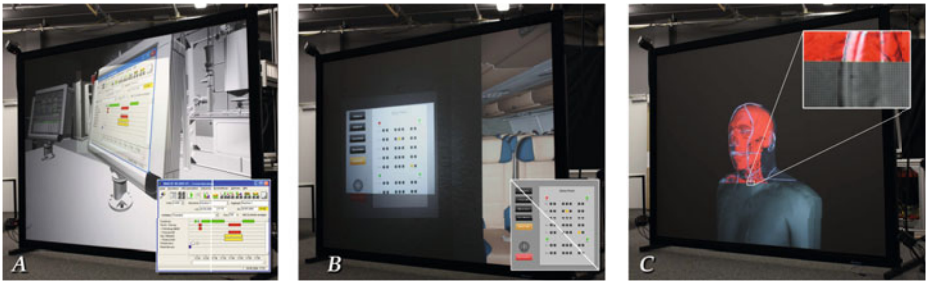

Fig. 1. The three scenarios for the multi-resolution display. Image A shows a virtual factory scene, were the inlay is placed such that the program output on the virtual screen becomes readable. The small image demonstrates the difference between the two resolutions. In image B the inlay is used to improve the usability of a virtual control panel, again the effect of the resolution increase is shown in a small image. In image C the inlay is used in a focus and context volume visualization system [5,11]. In this case the small image is a closeup photo that shows the pixel size on the projection screen at the transition between the inlay and context region.

In most cases, it is not sufficient to simply zoom into a specific region of the data until the screen provides adequate resolution to display the data, as this causes the context information to be lost. Often, however, it is possible to separate the dataset into a number of scales such that a low resolution version of the dataset exists (e.g. a down-sampled version of an image) that gives an overview over the data while finer details can be displayed when in a focus region. These types of data or documents are referred to as “multi-scale” documents [3,6].

The multi-scale problem also applies to stereoscopic virtual reality (VR) systems. Especially projection-based systems, in which large projection screens and limited projector resolutions are common, show a low level of detail. In extreme cases even the wiring on the projector LCDs are visible in the stereoscopic image which disrupts the feeling of immersion. To counter this, we have developed a multi-resolution stereo display system consisting of a pair of video projectors controlled by stepper motors. These projectors display a high-resolution inset into a small portion of the low-resolution image. To avoid crosstalk between the low and high resolution projections, we use a mask to prevent the low resolution projection from appearing in the area where the high resolution inlay appears.

This setup allows users to display a region of the projection screen in significantly higher resolution. In our proposed setup we achieve resolutions in the inlay that are close to the maximum resolution of the average human eye, at normal working distance. As our system only adds a few components to an existing stereo projection setup it can be installed as an upgrade for many existing projection-based VR systems.

2 Related Work

Projection-based systems allow the setup of wall-size stereoscopic displays without disrupting effects like display borders. Due to the projection of the image the pixel density decreases with distance as mentioned before. A straight forward solution to this issue would be the use of higher resolution projectors. Therefore, commercial projectors e.g. for digital cinemas, provide horizontal resolutions of up to 4096 pixels [8] which would offer enough resolution to drive a 2.5 meters projection screen near the maximum resolution of the human eye at a working distance of 1.5 meters (which is approximately 39-58ppi). The projectors, however, are extremely costly (currently about $50,000 per unit). Tiling of images from lower resolution projectors is another way to increase the overall resolution, but the complexity of the calibration process increases rapidly with the amount of projectors [10,4]. Another solution to achieve high resolution of large images without the calibration issues are tiled displays made up of a number of LCD screens. However the unavoidable display bezels inevitably interrupt the image. The extent to which this disturbs the stereo perception has been mostly unexplored thus far.

A completely different approach to achieve high resolution images that cover the entire field of view are head mounted displays (HMDs). Nowadays, commercial HMDs are available [9] that offer resolutions close to eye resolution (viewing angle between pixels $\approx \frac{1}{30}^{\circ}$). To even further increase the resolution of HMDs, Yoshida et al. [18] built a low cost head mounted display system that used two liquid crystal displays and fixed optics to place a high-resolution insert into a contextual view at the gaze point of the user. Using HMDs for multi-user environments, however, requires everyone to wear such a device, multiplying the costs of such a system with the number of simultaneous users.

Focusing on immersive video communication, Naemura et al. [13] proposed a multi-resolution stereoscopic system based on a setup of four cameras. For each eye, one camera recorded a wide angle view while the second camera captured a close-up of the central part. An additional compositing step combines these images. After enlarging the central high-resolution area only for the left eye, users reported that they see a "triple resolution" image, in which the high-resolution from the left eye overlapped with the already low-resolution image of the right eye created a sensation of a medium-resolution boundary.

Most closely related to our work is a setup by Baudisch et al. [3]. They describe a system which they refer to as "foveal display". It consists of a projector to display a large contextual view on a projection surface in which they placed a LCD screen with a significantly higher resolution to display the focal view. Similar setups were developed for 2D [17] and even 3D stereoscopic projections [7]. The latter system consisted of four projectors that are aligned to each other and did not include the correction of the increased inset brightness which was seen as an advantage of foveal displays.

We also base some of of our setup parameters on the recently work by Ogawa et al. [15]. They presented a study targeting the perception of multi-resolution images. They demonstrated that reducing the resolution of an image to $\frac{1}{4}$ at

20°angle and $\frac{1}{10}$ at 40°angle from the center of gaze results in images indistinguishable from the full resolution imagery.

2.1 Contribution

In this paper we present an extension to the work presented by Baudisch et al. [3]. We extend their idea in that we developed a hardware and software environment to move the high resolution inlay to any position on the projection. This extension allows for a number of novel applications. First of all the users are not restricted to moving the area of interest into the center of the projection — they can select an arbitrary region on the projection to be shown in high resolution. They can also dynamically move this high resolution area like a lens, following and exploring parts of the scene or data.

The remainder of this paper is structured as follows: In the following section we first present the conceptual design of our setup followed by a more detailed description of the components used. In Section 5 we give a detailed analysis of the performance of our system. We conclude the paper with a summary and give directions for further research.

3 Concept

To achieve the goal of a dynamic "foveal display" system we propose a setup with four identical projectors: Two equipped with wide angle lenses for the context and two with zoom lenses for the focus/inlay region. The focus projectors are mounted on a movable rig that is driven by two stepper motors (see Figure 2). This rig consist of two main parts: the basic rectangular, box-like horizontal moving-unit, and the vertical moving-unit, containing the two projectors and a counterweight to balance out their weight and minimize the stress on the stepper motor. This allows a 2D motion parallel to the projection screen resulting in no image distortion while moving the high resolution inset to different parts of the contextual image. To avoid overlapping of the contextual image and the inset image, the area covered by the inset has to be masked out. If needed, image correction has to be applied to the inset image to correct the higher brightness and color differences due to the smaller projection area of the inset projectors in comparison to the contextual image.

4 Setup

Our multi-resolution display setup consists of four *projectiondesign F20 sx+ projectors* [16], each with a resolution of 1400x1050 pixels. Two of these projectors are fixed and serve as context projectors for the entire wall (see C in Figure 3) . Two others are mounted on a moving rig made of aluminum profiles (see F in Figure 3). Two Nanotec Plug&Drive PD6-I89 stepper motors [14] drive the rig vertically and horizontally (see M_x and M_y in Figure 3).

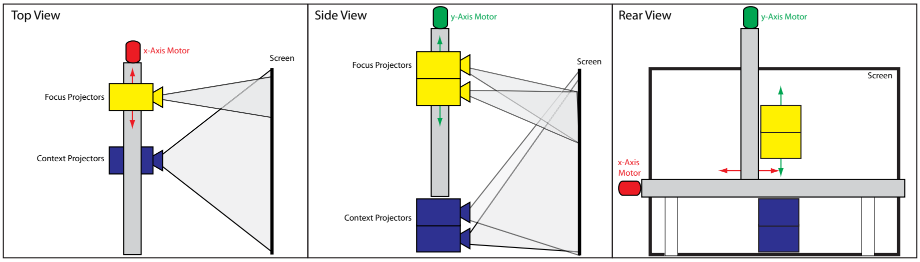

Fig. 2. Conceptual overview of our proposed multi-resolution display system

The four projectors are connected to two commodity PCs, each equipped with an Intel Q6600 2.4GHz quad-core CPU with 4GB DDR2 RAM and two NVidia GeForce GTX285 graphics cards. The motors are also connected to one of these PCs via a serial RS485 interface [2]. To issue motor commands we developed a custom driver that sends commands directly to the serial interface. This driver runs as a server on the PC to allow for multiple connections from different machines to control the inlay.

To render the VR environment both computers are using the VR-software "Lightning" [12]. To synchronize them we use Lightning's built in cluster protocol. To ensure that the context projectors do not render any low-resolution imagery into the inlay region covered by the focus projectors we render a black rectangle of the size of the inlay on top of the context projection. The images for the focus region are generated from the same model but with different camera parameters, which are adjusted when the focus region is moved. To allow for a brightness compensation and edge blending we also render a semi-transparent full screen rectangle over the entire focus region. Tcl scripts running inside the Lighting software are used to control these additional objects and adjust the camera settings.

Normally, our VR system is controlled by various input devices (e.g. mouse, joystick, IR markers) that are directly connected to one of the computers that runs Lightning. Via the aforementioned Tcl scripts we could add interaction techniques for the inlay directly into Lightning and control the focus and context overlay rectangles and the focus camera parameters. Unfortunately, it is not possible to access the RS485 interface and thus the stepper motors from within the application. Consequently, we either need to change the source code of Lighting and add this functionality or develop an external solution. In order to have a general and re-usable setup we decided not to modify Lighting but to handle the user input from an application that sends control signals via the network and multiplexes VR commands to Lighting and motor commands to the RS485.

With this solution we can attach any given input device to the control computer which then forwards these commands. With the input devices available in our lab we performed an informal internal user study that favored our

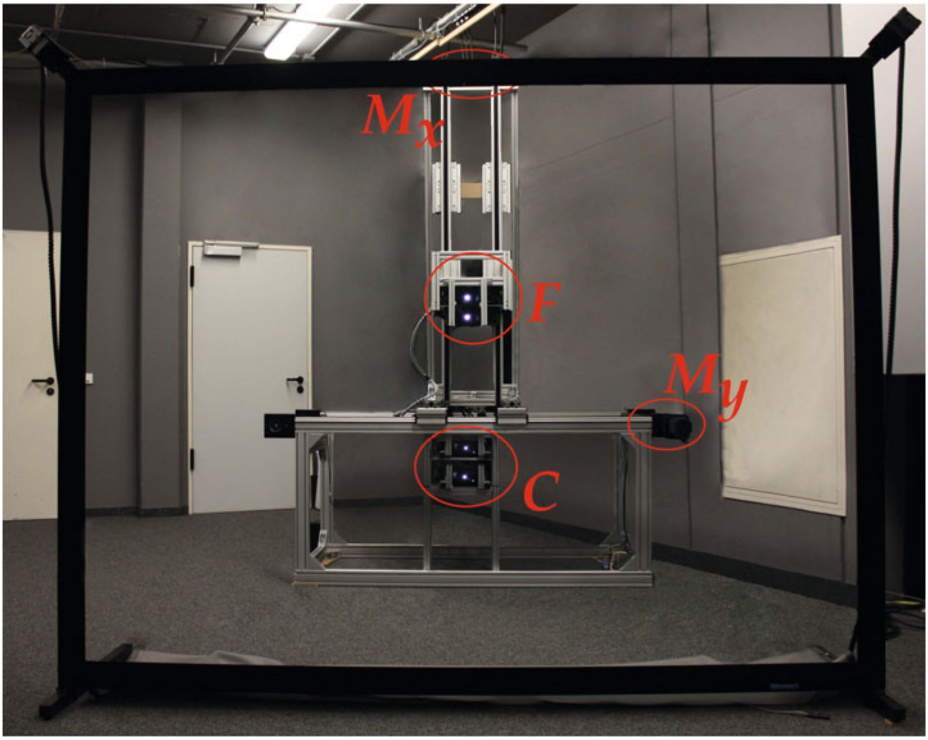

Fig. 3. Photograph of the actual setup of our multi-resolution display. The stepper motors (M_x and M_y allow horizontal and vertical movement of the projectors (C: context region projectors, F: focus region projectors).

multi-touch input table (see Figure 4) as the most intuitive means of control for the inlay position. In addition the custom-developed multitouch framework software also allowed a quick integration of further functionality which made the multitouch the first choice of implementing a "proof of concept" interaction for the multi-resolution display system. To control the high resolution inset, a map-like graphical user interface (GUI) was added to the multitouch software, acting as a metaphor for the projection screen. A red rectangle shows the current inset position which can be modified by using drag & drop gestures. Additional sliders and checkboxes at the side of the GUI allow the manipulation of transparency and color values of the overlay used for inset image corrections (see Figure 4). The introduction of linear functions and "borders" to map the position of the red rectangle on the multitouch to a position on the projection screen allows the usage of the software for different sizes of multi-resolution display systems. This also allows fine scale movement of UI or other elements.

Once assembled, setup of the whole system is very simple. It is only necessary to align the projection screen plane parallel to the moving-units, adjust the projectors to the desired screen sizes, and calibrate the stepper motor control

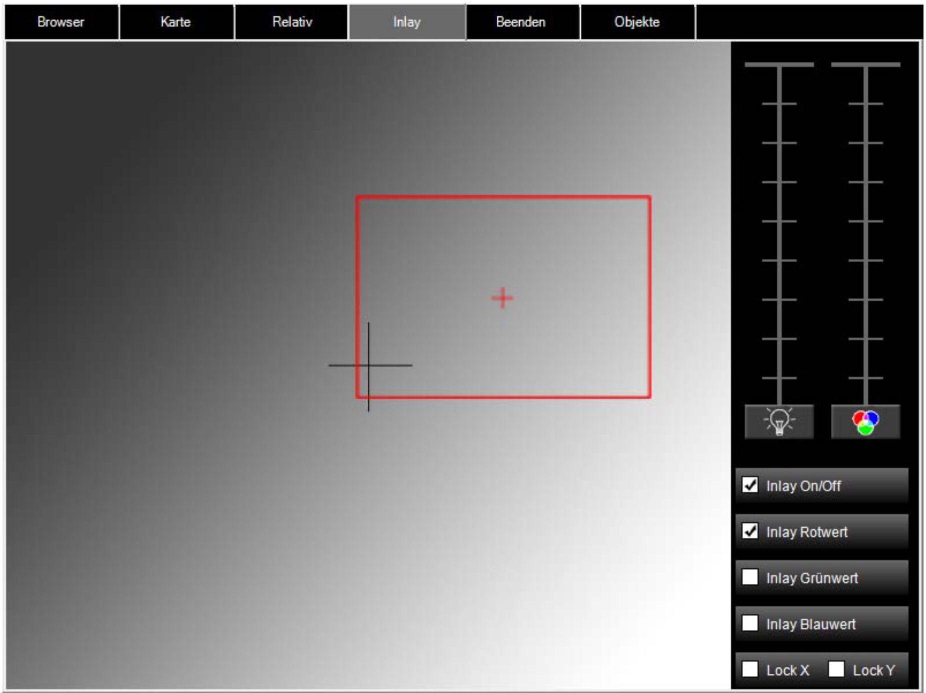

Fig. 4. The multitouch interface that controls the VR scene and the inlay

with the maximum steps possible (the number of steps needed to move the inset from the lower left corner to the upper right corner of the projection screen). The latter can be determined by using the Nanotec NANOPRO software. Using the administrative stepper motor control GUI, the sizes for the projection screen and the desired speeds for the motors have to be set. This initial setup of the whole system can be done in about 30-60 minutes. Later re-calibration, which may be necessary due to changes in the materials used to setup the rig, requires only about 5 minutes.

5 Results

The described moving-unit construction delivered satisfying results concerning resolution, speed and precision when applied to an already existing projector-based stereoscopic VR system. No formal user tests were conducted yet with this system so we give only measured timings of the setup itself.

Since identical projectors were used for the low-resolution context screen and for the high-resolution inset part, the increase of resolution is proportional to the decrease in size of the projected image. So decreasing the image size from 2.44 meters of the context area projection screen to an inset size of 1 meter yields a resolution increase by the factor 2.44. Given a working distance of 1.5 meters from the projection surface, the resulting 35.56ppi for the inset image is very close to the maximum resolution that the human eye can discern. Even by getting close (<30cm) to the projection screen, it is still hard to see the individual pixels in the inset, which is possible in the context part of the image even at working distance. The higher brightness and contrast of the inset with a switched off overlay also seems to add to the depth perception in stereoscopic scenes inside the inset. This "highlight" effect could also be used to guide the user's eye to a specific part of the image.

To measure the speeds the system can achieve, several movements with varying travel distance were conducted. The average time needed to adjust the inlay to a new position was 4 seconds with the minimum ramp-speed that could be achieved with the used stepper motors. Adjusting the ramp-speed and maximum moving speed of the stepper motors, this average time can be further reduced to about 2.5 seconds on our system. It is worth noting, that increasing these values also means an increase of forces affecting the projectors and consequently may reduce the projector lifetime. We found, however, that using values of about $0.07\frac{m}{s^2}$ for the acceleration-ramp and $0.2875\frac{m}{s}$ as maximum speed did not affect the performance of our projectors even after a several months of usage. To determine the precision of our proposed system, we moved the inlay by 3000 steps and measured how many pixels in the contextual image were covered. This test resulted in a covered distance of 601 pixels, which gives a sub-pixel precision of about 0.2 pixels per step.

6 Future Work

The proposed multi-resolution display system offers a cost effective way to increase the maximum resolution of a projection-based stereoscopic VR system. Being able to choose the size of the high resolution inset also offers the possibility to increase the resolution increase even further at the expense of projection area. Using a server-based application to steer the stepper motors, a multitude of interaction methods and software can be used.

Since the high resolution inset of the described multi-resolution display system is movable, there are a number of different use-cases for this system. So far we considered the three scenarios detailed in Figure 1. First, reading high resolution data in a virtual smart factory environment. Second, interacting with realistic control elements in a virtual scene. Third, using the inlay in a focus and context volume visualization system. For these scenarios we received very positive initial user feedback but we would like to verify and quantify the effectiveness of our system in a formal user study. In particular we are interested in a comparative study to both a standard low-resolution only projection as well as a high resolution projection with a very high resolution projector.

Finally, we will investigate novel interaction metaphors. Due to the server-based concept of controlling the inset, it is easy to use other novel devices, such as an Apple iPhone or iPad, to control the inlay.

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References

1. Ackerman, M.: The visible human project. Proceedings of the IEEE 86(3), 504–511 (1998), http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=662875
2. Association, T.I.: Electrical characteristics of generators and receivers for use in balanced digital multipoint systems (ansi/tia/eia-485-a-98) (2003), http://www.tiaonline.org/standards/catalog/search.cfm?standards_criteria=TIA-485-A
3. Baudisch, P., Good, N., Bellotti, V., Schraedley, P.: Keeping things in context. In: Proc. CHI 2002, pp. 259–266 (April 2002), http://portal.acm.org/citation.cfm?id=503423
4. Bresnahan, G., Gasser, R., Abaravichyus, A., Brisson, E., Walterman, M.: Building a large scale, high-resolution, tiled, rear projected, passive stereo display system based on commodity components. In: SPIE Proc. of Stereoscopic Displays and Virtual Reality Systems X (2003), http://spie.org/x648.html?product_id=474149
5. Fogal, T., Krüger, J.: Tuvok - an architecture for large scale volume rendering. In: Proceedings of the 15th Vision, Modeling and Visualization Workshop 2010 (2010), http://www.ivda.uni-saarland.de/fileadmin/publications/2010/VMV2010a.pdf
6. Furnas, G.W., Bederson, B.B.: Space-scale diagrams: understanding multiscale interfaces. In: CHI 1995: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 234–241. ACM Press/Addison-Wesley Publishing Co., New York, NY, USA (1995), http://www.sigchi.org/chi95/proceedings/papers/gwf_bdy.htm
7. Godin, G., Lalonde, J.F., Borgeat, L.: Projector-based dual-resolution stereoscopic display. In: Proceedings of the IEEE Virtual Reality 2004, p. 223. IEEE Computer Society, Washington, DC, USA (2004), http://www.ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1310080
8. Digital Cinema Initiatives: Dci system requirements and specifications for digital cinema - dci specification, version 1.2. Website (2008), http://www.dcimovies.com/specification/index.html
9. Inition: Comparison table for binocular head mounted displays. Website (2011), http://www.inition.co.uk/inition/compare.php?SubCatID=16
10. Kresse, W., Reiners, D., Knöpfle, C.: Color consistency for digital multi-projector stereo display systems: the heyewall and the digital cave. In: Proceedings of the Workshop on Virtual Environments, EGVE 2003, pp. 271–279. ACM, New York (2003), http://doi.acm.org/10.1145/769953.769985, http://doi.acm.org/10.1145/769953.769985
11. Krüger, J., Schneider, J., Westermann, R.: ClearView: An interactive context preserving hotspot visualization technique. IEEE Transactions on Visualization and Computer Graphics (Proceedings Visualization Information Visualization 2006) 12(5) (September-October 2006), http://wwwcg.in.tum.de/Research/data/Publications/vis06_clear.pdf

12. Landauer, J., Blach, R., Bues, M., Rsch, A., Simon, A.: Toward next generation virtual reality systems. In: International Conference on Multimedia Computing and Systems, p. 581 (1997), http://doi.ieeecomputersociety.org/10.1109/MMCS.1997.609772
13. Naemura, T., Sugita, K., Takano, T., Harashima, H.: Multi-resolution stereoscopic immersive communication using a set of four cameras. In: Proceedings of Stereoscopic Displays and Applications XI of the International Society for Optical Engineering: Stereoscopic Displays and Virtual Reality Systems VII, vol. 3957, pp. 271–282 (2000), graphics.stanford.edu/~naemura/publication/2000/MultiStereo-SPIE.pdf
14. NANOTEC: Pd6-i89 product webpage (2010), http://de.nanotec.com/page_product_archive__schrittmotor_pd6i_closedloop__de.html
15. Ogawa, M., Shidoji, K., Matsuki, Y.: Assessment of stereoscopic multi-resolution images for a virtual reality system. The International Journal of Virtual Reality 9(2), 31–37 (2010), http://portal.acm.org/citation.cfm?id=1079808
16. Projectiondesign: F20 sx+ product webpage. Website (2010), http://www.projectiondesign.com/Default.asp?CatID=1522
17. Staadt, O.G., Ahlborn, B.A., Kreylos, O., Hamann, B.: A foveal inset for large display environments. In: VRCIA 2006: Proceedings of the 2006 ACM International Conference on Virtual Reality Continuum and its Applications, pp. 281–288. ACM, New York (2006), http://doi.acm.org/10.1145/1128923.1128971
18. Yoshida, A., Rolland, J.P., Reif, J.H.: Design and applications of a high-resolution insert head-mounted-display. In: Proceedings of the Virtual Reality Annual International Symposium (VRAIS 1995), p. 84. IEEE Computer Society, Washington, DC, USA (1995), http://portal.acm.org/citation.cfm?id=527216.836018, http://portal.acm.org/citation.cfm?id=527216.836018

Alternative Workstations May Be New But Are They Better?

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Abstract. An ergonomics survey of 84 employees who moved to an alternative workspace with smaller workstations equipped with various ergonomic products is reported. Half of the employees received some ergonomics training. Results showed that 25-40% reported the ergonomic products were somewhat or much less comfortable to use, and around the same proportion found them somewhat or much more comfortable to use. Between 25-40% of employees reported frequent neck, shoulder, back and right wrist discomfort and many reported that these symptoms interfered with work activities. There was clear evidence that levels of discomfort increased over the course of the work day. Employees were equally split on whether the office changes helped or hindered their work productivity. Comparison of the trained versus untrained employees showed that training reduced the problems associated with their new workstations. Overall, the results suggest that ergonomic products alone may not compensate for problems associated with smaller workstations.

Keywords: ergonomics training, alternative workspaces, musculoskeletal injuries, keyboard tray, ergonomic chair, productivity.

1 Introduction

In the U.S.A. a majority of office workers sit in cubicle workspaces (cubes). The size of these cubes often was a function of the size of the computer technology that had to be accommodated, for example, the depth of the horizontal work surface needed to be sufficient to accommodate a desktop, conventional CRT, keyboard and mouse, and a deep corner location was needed to accommodate the depth of a large CRT displays. But those technology requirements have changed. Recently, computer technology has becomes smaller: thin-screen LCDs have replaced CRTs, small form factor desktops have replaced towers, notebooks and netbooks have replaced desktops altogether and keyboards have become sleeker. Smaller technology footprints along with wireless networks have allowed workers to become more mobile. Smaller desktop and laptop computer form factors, reductions in paper storage requirements and a desire for increased spatial variety and flexibility are some of the factors leading many companies to experiment with alternative workplace strategies. Invariably the most obvious impact for employees is a smaller spatial workstation footprint. To compensate for any possible

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adverse effects of reducing workspace, increasing emphasis is being placed on the use of ergonomic products, chairs, keyboards and mice, keyboard trays, task lights etc.

A walk around a U.S. office typically reveals around 50% of cubes are empty because their occupants are elsewhere, e.g., in meetings, traveling or working elsewhere in the building etc. Organizations are responding to these changes by testing alternative workplace strategies that provide smaller cubes, more flexible furniture and a greater variety of types of spaces where work can be done. However, as the cube shrinks there is a need to focus on ergonomic designs to comfortably accommodate the diversity of workers. Often it is assumed that merely giving workers ergonomically designed products is a sufficient strategy, however, providing appropriate ergonomics training can also be a requirement for success.

Korunka et al. (2010) investigated how the successful implementation of an ergonomics program was affected by job, organizational and personal factors for 116 employees in a production company. Results showed that psycho-social resistance attitudes and management support were the most important predictors of the number of ergonomic measures successfully implemented, whereas job, organizational and personal factors accounted for only 35% of the learning transfer variance in the implementation of ergonomic measures. Of importance is the finding that ergonomics training resulted in the implementation of ergonomic measures to decrease injury risks.

Other studies of office workplaces have found that ergonomics training can improve the adjustment and set-up of the workstation and the worker's posture which results in a decrease in reports of musculoskeletal discomfort. Brisson et al. (1999) studied 627 University computer workers who worked >5 hours per day at a computer. Workers were randomly assigned to a training (284 workers) or reference (343 workers) group. Measures were taken in parallel in both groups 2 weeks before and 6 months after the training. The effect of the ergonomics training program on 3 postural stressors (twisted neck, inappropriate screen height and bent hand-wrist line), workstation adjustments and musculoskeletal disorders was tested. The prevalence of all 3 of the postural stressors decreased for those receiving the training whereas 2 of the 3 stressors decreased slightly in the reference group, and this benefit of training was especially pronounced for workers <40 years old.

The effect of an intensive ergonomic approach and education on workstation changes and musculoskeletal was evaluated in a study of 124 video display unit workers were assigned to each of 3 groups: intensive ergonomics, ergonomic education, reference (Ketola, et al., 2002). Evaluation measures (questionnaire, discomfort diary, workload measurement, and workstation ergonomics rating) were made 2 weeks before the intervention and after 2 and 10 months of follow-up. Starting at 2 months of follow-up there was less shoulder, neck, and upper back musculoskeletal discomfort in the intensive ergonomics and ergonomics education groups than the reference group.

Martimo et al., (2010) investigated the effectiveness of an ergonomic intervention at the worksite on lost productivity (decreased quality and quantity of the daily work output) among workers with medically verified upper-extremity disorders (UED). Differences were tested at baseline and 8 and 12 weeks post-intervention for 177 employees randomly allocated to intervention and control groups. Results showed that at baseline, 54% of the intervention group and 58% of the control group reported a productivity loss of 17% and 20%, respectively. At 8 weeks both the proportion and magnitude of productivity loss trended lower in the intervention group, and at 12 weeks the differences were statistically significant (proportion 25% versus 51%, magnitude 7% versus 18%, P=0.001 for both). However, the intervention only benefitted employees with 0–20% loss of productivity at baseline, not those with a higher initial productivity loss.

Solidaki et al., (2010) conducted a cross-sectional survey of 224 nurses, 200 office workers and 140 postal clerks in Crete, Greece to study the relative importance of work-related and psychological determinants of the number of anatomical sites affected by musculoskeletal pain in six body regions (low-back, neck, shoulder, elbow, wrist–hand, and knee). Two-thirds of the sample reported pain in ≥ 2 body sites during the past 12 months, and 23%, >3 body sites. The number of painful anatomical sites was strongly related to the physical work load and work-related psychosocial factors; somatization was the leading determinant of the number of painful body sites.

Robertson et al. (2009) examined the effects of office ergonomics training in a large-scale field intervention study. The ergonomics training accompanied the provision of a highly adjustable ergonomic task chair and the training also provided workers with information on work-related musculoskeletal risks. Three study groups of office workers were compared. One group received both the training and the ergonomic adjustable chair, one group only received the ergonomics training, and one group served as a control receiving neither training nor the chair. Office worker ergonomics knowledge both pre/post-intervention was tested and body postures and workstation set-ups were observed before and after the intervention. Compared to workers in the control group both intervention groups reported higher perceived control over their workspace and greater overall ergonomic knowledge. Post-intervention musculoskeletal risks and work postures were improved for both intervention groups compared with the control group.

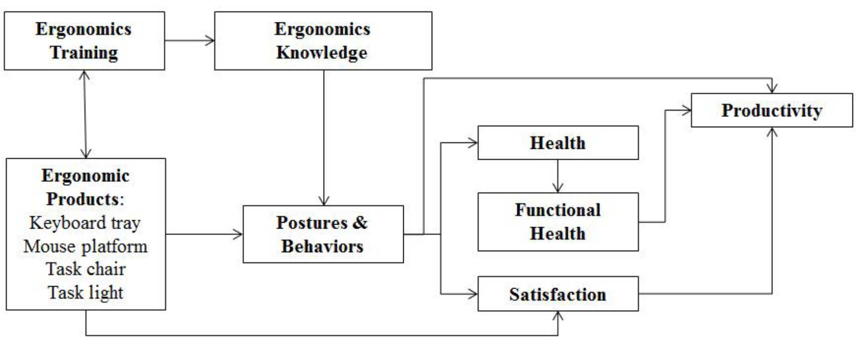

Fig. 1. Model of change as a result of an ergonomics intervention with products and training (adapted from Robertson et al., 2009)

This study extends previous work and tests the effects of a complete workstation makeover for a group of employees moving from conventional office cubes to an alternative workstation design on the levels of musculoskeletal discomfort and the opinions of workers before and after moving. Around 60% of the employees received some ergonomic training in additional to their ergonomic products. The model of change underpinning this work is shown in Figure 1 and was adapted from Robertson et al. (2009).

2 Method

2.1 Survey Sample

A sample of 300 office engineering employees in a large energy company participated in the study and complete data was obtained for 84 respondents (28% response rate). Forty of the respondents (47.6%) reported having attended the company's "ergonomics awareness for office workers annual training" and 9 (10.7%) reported having attended ergonomics training provided by the vendor. Forty one percent reported that they had not received any ergonomics training.

2.2 Survey Method

A retrospective web-based ergonomics survey that asked employees about comparative reactions to their new workstation cubes, the ergonomics equipment, ergonomics training, workspace conditions, opinions and levels of musculoskeletal discomfort in the new versus old workplaces was conducted. The research was approved by the Cornell University Institutional Review Board for Human Participants.

2.3 Alternative Workspace and Ergonomic Design Intervention

The new office workspace design provided employees with a smaller cube footprint. Corner work locations and straight-edge work surfaces were replaced with contoured and linear work surfaces. In an attempt to compensate for the smaller size all cubes in the new office were equipped with a height-adjustable downward tilt keyboard tray with mouse platform; a new ergonomic task chair and most also had an adjustable task light, and other ergonomic accessories, such as a footrest or document holder, were provided as required. Examples of the pre-move and post-move cubes are shown in Figures 2 and 3 respectively.

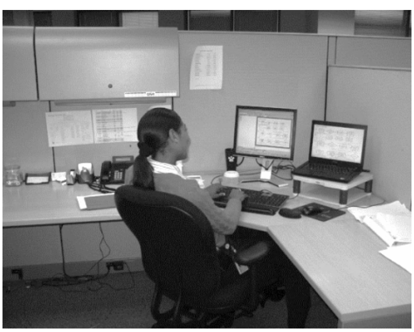

Fig. 2. A pre-move workspace cube

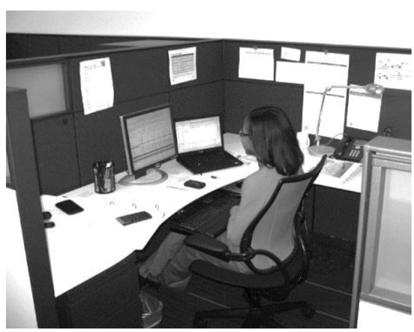

Fig. 3. A post-move workspace cube

3 Results

In this summary of the results all percentages are for the respondents who answered that question.

3.1 Workstation Components

Figure 4 shows employees ratings of their new workstations compared with their previous workstations. Responses were about equally split between those reporting that the new components were somewhat/much more comfortable or somewhat/much less comfortable.

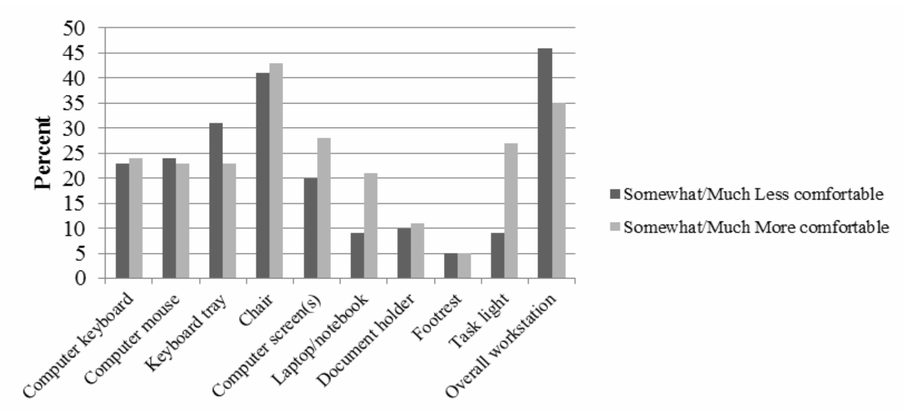

Fig. 4. Comparative ratings of old and new workstations

3.2 Postural Comfort

Figure 5 shows changes in the prevalence of musculoskeletal discomfort during a typical work week for the new and old offices. Neck, shoulder and lower back symptoms were the most prevalent and were more prevalent in the new cubes.

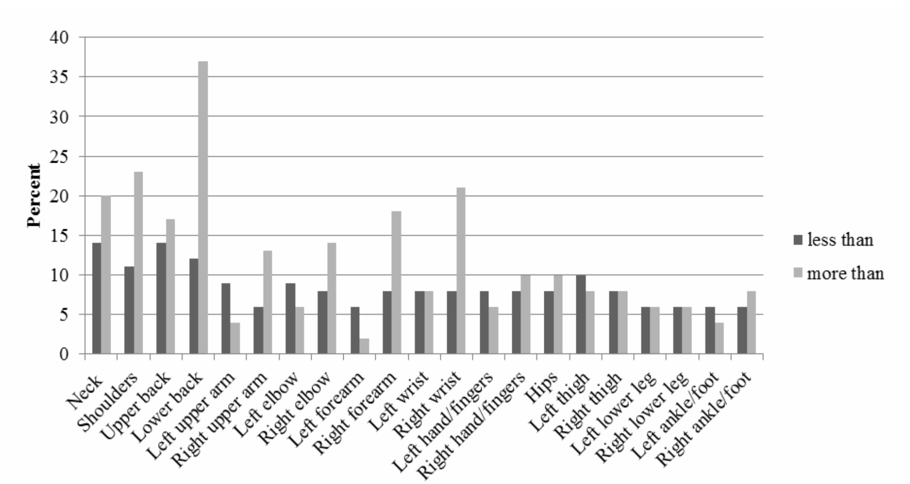

Fig. 5. Changes in the prevalence of musculoskeletal discomfort for the old and new offices

3.3 Work Interference and Musculoskeletal Discomfort

Figure 6 shows the extent to which musculoskeletal discomfort interfered with work in the new cubes: again neck, shoulders and back problems caused problems.

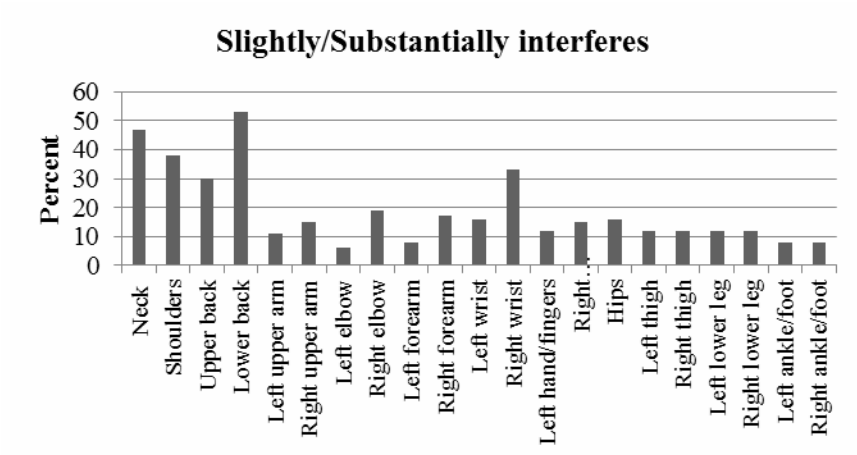

Fig. 6. Work interference effects from musculoskeletal discomfort

3.4 Time-of-Day Effects

Figure 7 shows how the pattern of musculoskeletal discomfort worsened over the course of the work day in the new cubes.

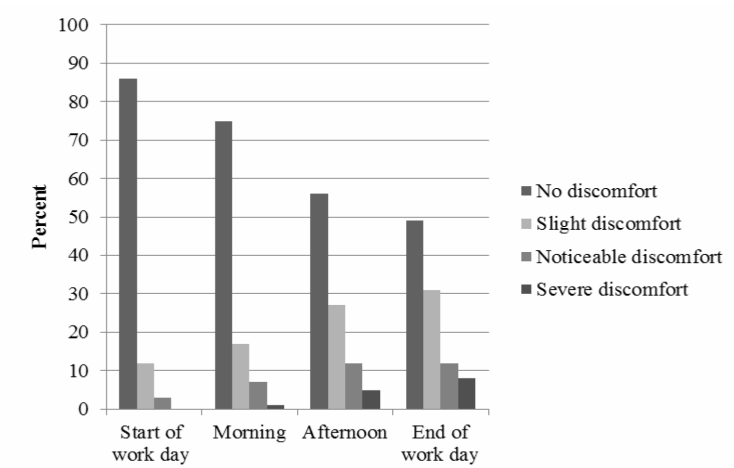

Fig. 7. Time-of-day effects on musculoskeletal discomfort for the new offices

3.5 Workstation Components and Productivity

Figure 8 shows the impact of workstation components on self-reported work productivity.

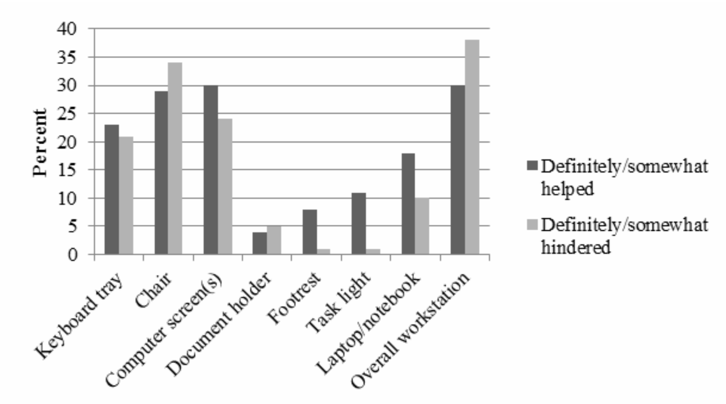

Fig. 8. Effect of workstation components on productivity for the new offices

3.6 Effect of Ergonomics Training on Musculoskeletal Discomfort

Figure 9 shows the effects of training on reports of musculoskeletal discomfort.

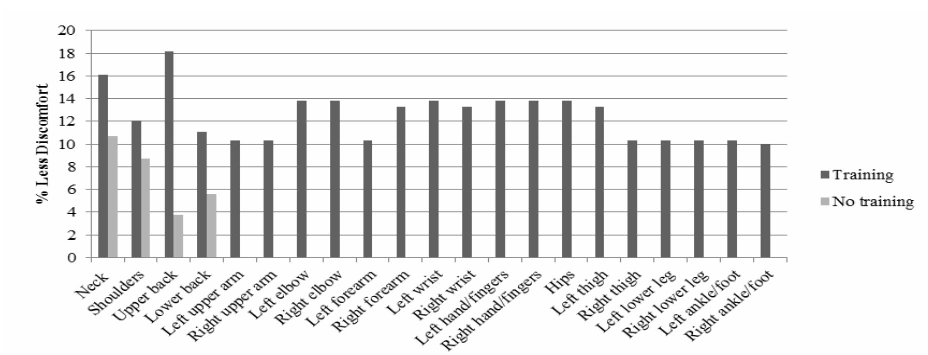

Fig. 9. Effect of training on reports of musculoskeletal discomfort for the new offices

3.7 Effect of Ergonomics Training on Time-of-Day Discomfort

Figure 10 shows the beneficial effect of ergonomics training on reports of musculoskeletal discomfort over the course of a work day.

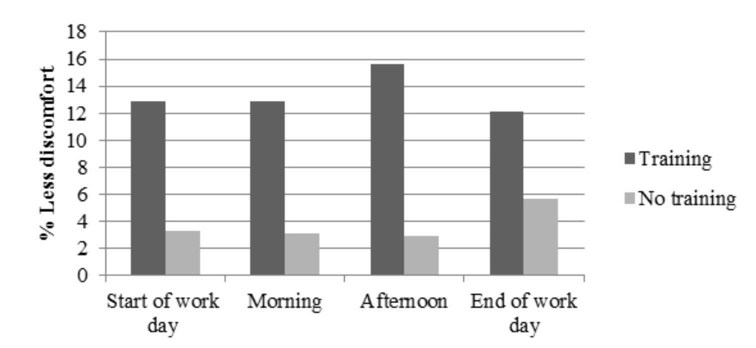

Fig. 10. Effect of training on musculoskeletal discomfort

3.8 Effects of Ergonomics Training on Productivity

Comparisons showed a higher percentage of reports of improved productivity associated with the keyboard tray, chair and computer screen among the trained respondents as shown in Figure 11. Training improved the benefits associated with using the ergonomic products (keyboard tray, chair and computer screen) but fif not affect the impact of the overall workstation.

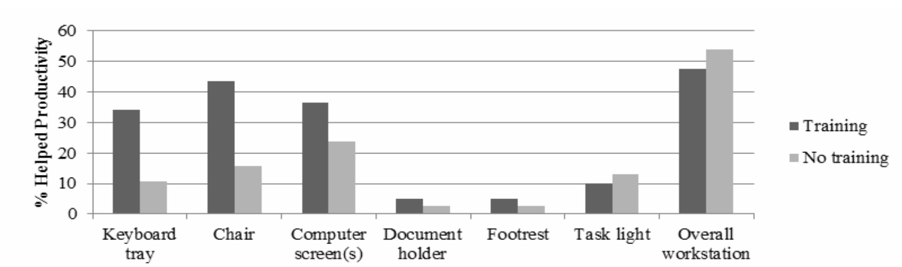

Fig. 11. Effect of training on musculoskeletal discomfort

4 Conclusions

There was an expectation that any adverse effects of moving employees from larger to smaller alternative workstation cubes would be offset by providing them with ergonomic products, whether or not they received adequate training on the adjustment and use of these products. This study clearly refutes that assumption. Following the move to the new offices the employees were consistently evenly split on whether their new workstation helped or hindered their work and their musculoskeletal experiences. Problems of discomfort were shown to increase over the course of the work day. Over half of the employees received some ergonomics training and comparison of those who had and had not received training showed a clear benefit of training in lowering levels of discomfort and improving work productivity associated with the various workstation components. Results from this study are consistent with previous studies that have demonstrated the benefits of ergonomics training (Brisson et al., 1999; Ketola et al., 2002; Korunka et al., 2010; Robertson et al., 2009; Solidaki et al., 2010).

Even though the findings are comparable to the previous studies cited this work suffered unavoidable limitations. This was a retrospective survey of employee experiences of their pre-move and post-move workstations and it was not possible to survey employees prior to their move, nor was it possible to study a control group of comparable employees.

Acknowledgements. I gratefully acknowledge the assistance of Barbara Peck, Global Ergonomics/ Office Safety Manager, GE Energy, in conducting this survey.

References

Brisson, C., Montreuil, S., Punnett, L.: Effects of an ergonomic training program on workers with video display units. Scand. J. Work Environ. Health 25, 255–263 (1999)

Ketola, R., Toivonen, R., Häkkänen, M., Luukkonen, R., Takala, E.-P., Viikari-Juntura, E.: Effects of ergonomic intervention in work with video display units. Scand. J. Work Environ. Health 28, 18–24 (2002)

Korunka, C., Dudak, E., Molnar, M., Hoonakker, P.: Predictors of a successful implementation of an ergonomic training program. App. Erg. 42, 98–105 (2010)

Martimo, K.-P., Shiri, R., Miranda, H., Ketola, R., Varonen, H., Viikari-Juntura, E.L.: Effectiveness of an ergonomic intervention on the productivity of workers with upper-extremity disorders – a randomized controlled trial. Scand. J. Work Environ. Health 36, 25–33 (2010)

Robertson, M., Amick III, B.C., DeRango, K., Rooney, T., Bazzani, L., Harrist, R., Moore, A.: The Effects of an Office Ergonomics Training and Chair Intervention on Worker Knowledge, Behavior and Musculoskeletal Risk. App. Erg. 40, 124–135 (2009)

Solidaki, E., Chatzi, L., Bitsios, P., Markatzi, I., Plana, E., Castro, F., Palmer, K.T., Coggon, D., Kogevinas, M.: Work-related and psychological determinants of multisite musculoskeletal pain. Scand. J. Work Environ. Health 36, 54–61 (2010)

Improving the Online Video Chat Experience

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Abstract. With the recent proliferation of netbooks and tablets with webcams transforming oneself virtually is easier than ever before. However, the software used for such devices like video chat programs and online role playing do little to enhance the connectedness of the users involved. In this paper, we present Touch Live Connect (TLC), a product concept for an enhanced video chat experience that is aimed towards improving the online shared experience. TLC enhances the online experience by enabling people to do activities together in video mode. Users watch online videos together, transform to different backgrounds and also perform multi-way chat. TLC can also detect user motions and appropriately enhance the environment of the chat. This helps people emulate the face to face experience beyond just chatting and makes them feel connected. We developed three prototypes of the product concept and tested them on sets of users, and conclude that (1) Users feel more connected by sharing experiences rather than just seeing visual representation of self, (2)Amplification of human gestures over video is an important feature to improve video communication and (3) Users find a handheld tablet as most useful device for video communication and television as least useful.

Keywords: Online collaboration, sharing, virtual relationships, video chat.

1 Introduction

An increasing number of people are choosing video chatting over e-mails and telephone calls to stay in touch with family and friends at a distance. Webcams are becoming ubiquitous on powerful computing platforms such as laptops and smart phones. Video chat programs provide a richer sense of presence than other forms of distant communication, yet a need still exists for a more enhanced video chat experience to make users feel more connected. Part of the problem with most existing video chat software is that users cannot partake in social activities together. In addition, users cannot physically touch while communicating via video chat, and facial expressions or body posture may be missed or misinterpreted. Users do not get the sense that they are present in the same environment and may not feel as though they are sharing the same space and experiences. Consequently, there is a need for a video chat program which can help bridge these gaps and make video chat users feel more connected.

Many studies have been performed on the use of video chat and video conferencing programs for informal and formal communication. According to

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IJsselsteijn et al., "videoconferencing or shared virtual environments are based on providing a mix of both the physical and social components, i.e., a sense of being there together" [1]. Aspects of virtual worlds (computer-based simulated environments were users can interact) could be applied to video chat programs to provide users with a greater sense of being present in the same environment [2]. Other studies have found that internet users enjoy sharing videos and watching content together [3, 4], and that media is more enjoyable when watching it synchronously with others [5]. Shamma et al. found evidence that video sharing online can help users feel closer and more connected to their peers [6]. These findings show that there is great potential for enhanced features to improve social communication and connectedness while video chatting.

Among the most popular video chat programs used today are Skype, Google Video Chat, TokBox, and iChat. Skype allows any PC-to-PC call to become a video chat as long as users have a webcam and has become a popular choice because of its high cross-platform compatibility. However, Skype does not have many additional enhanced video chat features like some other programs do. Google Video Chat has become a popular option because of its seamless integration with Gmail, but like Skype, does not have many additional enhanced video chat features. i-Chat is the default chat application for Mac OS X. This program does have enhanced features such as multi-user video chat and the ability to share and view files, but it can only be used on systems with Mac OS X. TokBox is a web-based application where users login and initiate video chats through their web browser. TokBox has become popular because it can be integrated with other services such as Facebook to start quick video calls. In addition, TokBox allows for up to 20 users to video chat at the same time [7]. While these video chat programs are widely used and provide useful services and features, there is still a lack of focus on shared experiences and increased connectedness.

The goal of this paper is to propose a solution to overcome the limitations of existing video chat software. We have designed a product concept, Touch Live Connect (TLC), a novel video chat software which makes users feel more connected though the addition of enhanced features. The features of TLC are aimed at increasing co-presence and connectedness and include multi-user chat, synchronously watching video, sharing a virtual environment, and emotion/motion detection. The emotion/motion feature captures user's simple emotions and gestures and adds them to the environment using smiley icons and other notations. Through this exercise, we are able to draw insight on requirements for a video chat solution.

In subsequent sections of this paper we will: describe the process used to design TLC, discuss the design elements and features of TLC in detail, share methods and results of user testing, provide insight into limitations of TLC, and finally summarize our conclusions.

2 Design Process

We followed the process of user interaction development to conceptualize a solution to improve the online sharing experience. We believe this concept also encompasses exchanging personal information and communicating emotions more effectively using technology since this is the basis of relationships. In this section, we describe the various stages of our design process and our insights and improvements to our concept from them.

2.1 Storyboarding

Our design process began with storyboarding, in which we created scenarios related to our product concept being a touch based software for video chat for a tablet PC or equivalent. We used the storyboarding technique to illustrate exactly why and how users would benefit from our software. The storyboards depicted the four major tasks including users watching a video online together, users interacting in the same background, users adding multiple friends to the video chat, and users sharing emotion/motion messages to one another. Figure 1 illustrates that by using the TLC interface to perform video chat and by applying the change background function, the users should potentially experience themselves video-chatting within a single new environment. This exercise helped us realize situations where shared experiences were amiss and helped us define features for our next step, the paper prototype.

Fig. 1. The image above shows part of a storyboard depicting users interacting on TLC

2.2 Paper Prototype

In order to get a better sense of how the product will look and how users will navigate the screens, we created a paper prototype of the TLC software. Our testing comprised of the user interacting with the paper interface to perform a video chat. This included the user logging in, browsing his/her friends list and placing a call. The major tasks included - (1) Watching a video with a friend while performing video chat, (2) Changing the background and environment of users in a video chat session, (3) Adding more people and performing multi-way video chat, and finally (4) Expressing emotions on video chat, and the camera detecting and enhancing the video chat experience.

Testing the prototype Before testing our paper prototype with users, we wrote up an instruction sheet that gave an introduction to the TLC software. The instruction sheet explained that the system was a touch screen interface and that the user could use his/her fingers to navigate the screen. A list of tasks for the user to perform was also included in the instruction sheet. For each task, we gave detailed information about what we wanted the user to do. For example, we gave the user a Username and Password to use when they log in.

We also told the user to find a specific friend to connect to (Figure 2) and a specific video to watch. By giving them detailed instructions such as this, we were able to have the screens we needed to show them the functionality of our product without having to have a screen for every single option that was available.

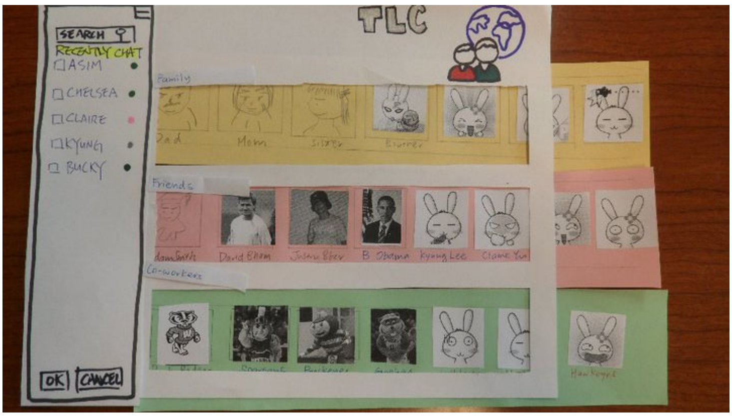

Fig. 2. Friend list page after log in of paper prototype. There are multiple friends categories and the user can search through friends by scrolling the screen to the left**.**

We recruited three participants for testing our initial paper prototype and gave them the instruction sheet to read over before they started. We placed the prototype in front of them and had them follow the instructions on the sheet. The participants were told to “Think Aloud” while they were testing the prototype so we would know what they were thinking as they were using the prototype. One member of the team took notes on what the participant did while interacting with the prototype and if there were areas where the participant struggled to use the prototype. After the participant completed the tasks, we gave them a short evaluation sheet that asked about usefulness, desirability of features, usability, layout, and ease of navigation.

After the preliminary testing of our paper prototype, several issues came to light that needed to be addressed during further design phases. The first and foremost of these issues was the question of general flow of screens and usability. To address this issue, we needed to reexamine our planned physical prototype concept from the ground up. In order to log in or use the text box function, we needed a touch-pad keyboard. Furthermore, we decided to create message windows asking the user for confirmation to proceed further, which would minimize mistakes made by the user. Also, we needed to have a way to transition better from one function to the next such as adding close buttons to the screens. We also added the log off function button in order to end the program from any of the intermittent screens.

2.3 Video Prototype

The next step in the design process was to create a video prototype to get a better sense of how users may actually use TLC in a realistic environment. The video prototype we created consisted of four main tasks: changing the background, watching a video, adding a friend, and performing Emotion-Motion. Our first step was to determine the sequence in which we wanted to show the tasks being performed. We then focused on the scenario to create a smooth transition between the different major tasks and show the distinct features of each task. We chose to show the users interacting with the product in a home environment because we felt this was the context that most users would be in while using TLC. We tried to show the touch screen capabilities and the navigation through the screens by showing a finger pressing the screen for each feature of the product. Through our prototype [8], we were clearly able to show the usage scenarios, brief interface navigation and video in video communication modes.

After creating the video prototype, we sent the video to multiple (four) participants to watch the video and fill out evaluation form. Through creating this video prototype and getting feedback from viewers, we learned that we want the product to be capable of working on a multitude of different devices from televisions to computers to iPads. Further, we learned a lot about how the screens will actually look to the users and where the videos will be placed. We created many of the TLC software screens (static) which helped us to plan what the menus in the interactive prototype will look like. We also brainstormed some additional features that would enhance the video chat experience even further. These features include 3D chat, using videos with background sounds for change background, and having an accessory device with a heat sensor or vibrating feature that would enhance Emotion-Motion.

2.4 Interactive Prototype

The next step in the design process was to create an interactive prototype. The interactive prototype allowed us to create a semi-functioning interface and navigational framework for TLC to see where design flaws may still lie. In the absence of actual video chat software developing realistic software was a challenge. Simulating the video chat was important to make the interactive prototype more realistic. Eventually, we found a program called Plays for Certain which could play live webcam feed during a PowerPoint presentation. Figure 3 shows the interactive prototype we made using PowerPoint. We inserted controls such as active text boxes and check boxes to make the prototype more interactive. We also assigned ‘actions’ to buttons to navigate from slide to slide. In addition, we embedded YouTube video for the ‘Watch a Video’ feature. Overall, the interactive prototype turned out very realistic and allowed users to perform the four major tasks: watch a video, change background, add a friend, and Emotion/Motion.

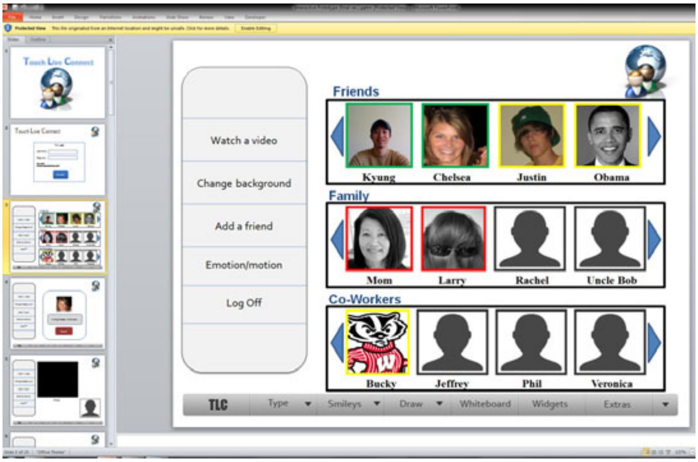

Fig. 3. Interactive prototype in PowerPoint

3 User Testing

The final step in our design process was to perform user testing of the final prototype on a set of participants in a controlled manner. Since this testing was more comprehensive than the testing of our previous two prototypes, we describe it in a separate section.

We performed two separate tests. The first test was a pre-testing performed on a nine users to understand the requirements of the video chatting solution without the bias of our software. The second test was performed on five users and was after testing with TLC interactive prototype. The main questions we wanted to answer during our user testing (post-testing) were:

1. Is the interface intuitive and easy to navigate?
2. Which features of TLC are novel and useful compared to other video chat software?
3. What is your device type preference to use video chat software on?

3.1 Participants

The target participants for TLC were people who were familiar with basic computer operation knowledge and interested in enhanced features for online video chatting. Participants were limited to individuals who use video chat software on a regular basis or at least several times a month. Before deciding who would be the participants, an online questionnaire was set up to gain a better understanding of how and why people use video chat programs, and we then chose participants who fulfilled our requirements of using online chatting software on regular basis.

3.2 Methods

We tested our interactive prototype with a small set (five) of users on a laptop and big projector screen (to simulate TV/home environment). The participants were given an instruction sheet with a list of tasks to perform and were asked to use the "Think Aloud" method. We filled out an observation form based on the feedback given by the participants using "Think Aloud" while performing the tasks. The participants then filled a second questionnaire after they finished testing the prototype. It was a detailed set of questions regarding preferences of features as well as questions regarding the interface and each of the tasks.

4 Results

4.1 Results from the Survey before Using the Prototype

The pre-testing results give us some insight on the usage patterns and requirements from modern video chatting software. The results show that users want to do more activities together online rather more than any other feature.

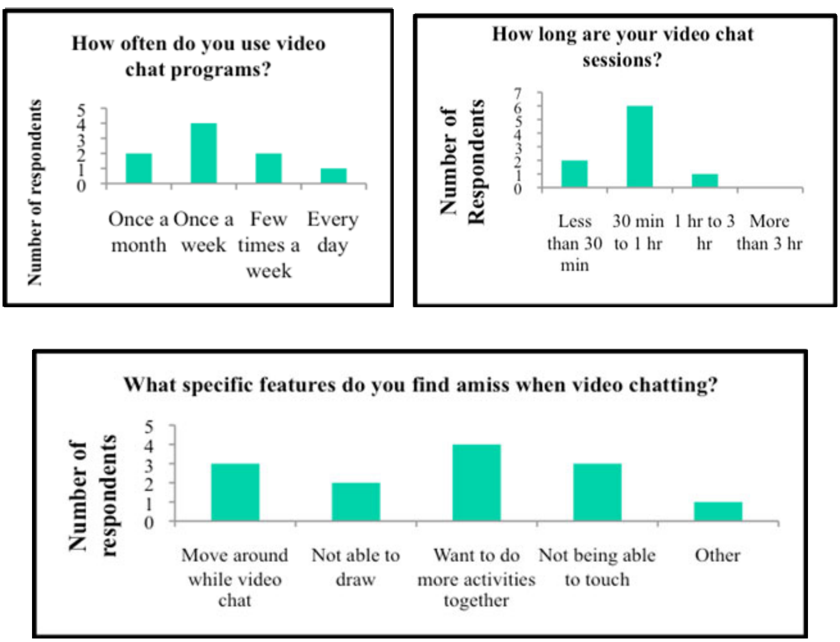

Fig. 4. Results

4.2 Results after Using the Prototype

To summarize our post-testing results, users found features of TLC novel and useful and agreed that a product like TLC will make the users feel more connected.

After having the five participants complete the assigned tasks on the TLC software interactive prototype, we had them complete an online post-user questionnaire. All of the participants were highly satisfied after using the software (average 8.4/10). The participants found the interface to be intuitive and easy to navigate (7.6/10). They also found the software to be responsive (average 8.6/10) and simple to use (average 8.6/10). The participants rated the four features they tested in the interactive prototype in terms of novelty and usefulness. The "Emotion/Motion" and "Watch a Video" features were rated as most novel (average 8.6/10 and 8.4/10, respectively). One participant commented, "The expression detector was very interesting, it adds another novel feature." The "Change Background" feature was rated as least novel (average 7/10). The "Multi-User" and "Watch a Video" features were also rated as the most useful (average 8.8/10 and 8.4/10, respectively). The "Change Background" feature was rated as least useful (average 5.8/10).

The post-user questionnaire also provided us with interesting comments. All of the participants felt the software will enhance the video chat experience. Three of the five participants would use this software with their family and friends. Four of the five participants thought that the flow of screens was in the right order. The participant who did not think the flow of screens was correct commented, "the back button from background page did not go back to regular video chat." All but one of the participants felt that touch screen navigation would be more effective than mouse/keystroke navigation. Three of the participants chose i-Pad or an equivalent device as their preferred platform, while two of the participants chose laptop. However, none of the users chose TV as their preferred platform. When asked how this software compared to their current video software, one participant commented, "this one is more fancy." Another commented, "similar to Tokbox but has more features." Other comments included, "most video chat software are integrated with keyboard chat like messenger or Google chat" and "interface is well put together and clear, has a lot of potential."

Discussion. One of our design goals is to allow users to easily navigate without confusion and maintain interoperability of different tasks using our software. Thinking about the product design, there are some aspects of the study that can be used to improve it. From our post-user evaluation testing, all five users mentioned that there should be a "tab" function on the login screen. They felt uncomfortable having to set the cursor each time to enter text for login information. In addition, the check boxes were not properly labeled on 'Emotion/Motion' task page for users to interact smoothly. This was fixed immediately during the study.

As for the change background feature, an advanced video chat would have been possible if we were able to have the appearance of the users outlined on the background for better visual effects and better feel of the feature. Lastly, the horizontal menu located at the bottom had no function features and we can extend our prototype to add some features from writing on the screen. Thus, the feedback from users was extremely valuable and we believe simplicity will be the key for the next generation technology.

5 Discussion

In this section, we discuss the design implications from our design process and its limitations. The process of designing TLC provided us with valuable feedback on the navigation, interface design and features for video chat software.

Navigation. Through our design process we observed that users significantly value unspoken norms for software navigation. For example, all five participants tried to use tab key to enter the password after they entered the login. Most users tried to close the windows for different screens by searching for close boxes on the top right side of the screens. These examples emphasize that software design for new platforms should incorporate these norms to avoid navigational "surprises" that may affect ease of navigation of the software. Following consistency of navigation styles through the series of tasks made the user more comfortable with the interface and generally they liked it better.

User Interface. Through our design process, we observed that users were barely able to remember information from previous screens. For example, for the Emotion/Motion feature, users were not able to recollect what emotions have been turned on. Having a system status visibility while enabling/disabling important features is useful. This also makes the "recognition rather than recall" design heuristic significant.

Features. Users wanted to use text based chatting while using these advanced features. We had similar feedback of adding text chatting feature in our early testing of the paper prototype, but we had decided to only focus on fewer/most novel features for our prototypes. We believe having additional screens for text chatting will be useful since users still like to associate traditional text based chatting with video chat. Throughout the design process, users stressed the interoperability of features. Many users wanted to use multiple features together like the changed background and watching videos.

Preferred Device. Users stressed mobility as an important issue while performing video chat and almost all users preferred a tablet-based device to perform video chat. Also, none of the users found television as a useful medium for video chatting.

Limitations. In this sub-section, we discuss the limitations of our prototype and our testing.

1. Our prototype was not tested on a touch-based device. This is because we were not able to arrange a touch based computer with a web camera.
2. We only tested the interactive prototype on a laptop and large screen (to emulate TV experience). We were unable to test the prototype across a variety of devices. This did not help users get a clear picture on what devices the user will prefer with the prototype although many users indicated that they will prefer a device that allows them mobility.
3. We were unable to insert more than one live webcam feed into the PowerPoint interactive prototype. Therefore, participants did not get as realistic of an experience as they could have if more web cam feeds could have been introduced.

6 Conclusion

In this paper, we presented TLC, a video-chatting product concept for enhanced video chat experience which makes users feel more connected. Through our design process, prototypes, and questionnaire results we show that there is scope for improvement and innovation in the current video chat programs and significant amount of improvements can be achieved by using simple software based improvements and feature additions. We were able to conclude that a favorable video chatting device should provide the users with mobility, amplify user gestures and signals and let users perform various activities online to make them feel more connected.

References

1. IJsselsteijn, W.A., de Ridder, H., Freeman, J., Avons, S.E.: Presence: Concept,determinants and measurement. In: Proceedings of the SPIE, Human Vision and Electronic Imaging V, pp. 3959–3976 (2000)
2. Albuquerque, A.L.P., Velho, L.: Togetherness through Virtual Worlds: How real can be that Presence? In: Proceedings of Presence (2002)
3. Huang, E.M., Harboe, G., Tullio, J., Novak, A., Massey, N., Metcalf, C.J., Romano, G.: Of social television comes home: a field study of communication choices and practices in tv-based text and voice chat. In: Proceedings of the 27th International Conference on Human Factors in Computing Systems (2009)
4. Motti, V.G., Faga, R., Catellan, R.G., Pimentel, M.G.C., Teixeira, C.A.C.: Collaborative synchronous video annotation via the watch-and-comment paradigm. In: Proceedings of the Seventh European Conference on European Interactive Television Conference (2009)
5. Weisz, J.D., Kiesler, S.: How text and audio chat change the online video experience. In: Proceeding of the 1st International Conference on Designing Interactive User Experiences for TV and Video (2008)
6. Shamma, D.A., Bastea-Forte, M., Joubert, N., Liu, Y.: Enhancing online personal connections through the synchronized sharing of online video. In: CHI 2008 Extended Abstracts on Human Factors in Computing Systems (2008)
7. Five Best Video Chat Applications, `http://lifehacker.com/5088083/five-best-video-chat-applications`
8. TLC Video prototype, `http://www.youtube.com/watch?v=jO3SfKLAQJQ`

DeskTop: A Design Guideline to Creating a Multi-touch Desk Prototype

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Abstract. In many multi-touch tables, a projector is used to project an image onto the surface and a camera is used to detect user touches. The optical paths for both the camera and projector limits the physical design of multi-touch tables. Our research focuses on the creation of a multi-touch desk that improves on the physical design of past multi-touch tables by using a combination of multiple cameras and a liquid crystal display to create a physical design that is ergonomic, mobile, collaborative/scalable and simplistic in design.

Keywords: Multi-touch tables , Ergonomic design.

1 Introduction and Motivation

The idea of tabletop computing has been around since the late 80's with Myron Krueger's invention of the Video Desk [14]. Revolutionary for its time, users could use their arms, hands, and fingers as input [14]. Whereas most systems during that time required users to input information using a keyboard, the Video Desk used a video camera stationed above the surface to capture the user's motions [14]. With Kruegar's system, users were allowed to draw and manipulate objects using a set of gestures similar to what we see in modern day multi-touch systems. Unlike modern day touch screen systems the Video Desk did not allow direct manipulation of objects [14]. The user did not directly touch the object they were to manipulate; instead, they looked at monitors positioned around the table for output while using the surface as input.

In 1991, Pierre Wellner expanded on the ideas of Kruegar, with the creation of his Digital Desk system. Unlike the Video Desk, monitors no longer sat around the table surface. The output was projected onto the surface of the table from a projector mounted above, allowing users to directly touch and manipulate objects appearing on the table, creating one of the first true multi-touch tables [19].

More research was done in the 80's and the 90's on multi-touch tables, but not until the 2000's did a significant surge in multi-touch table hardware and software

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emerge. The creation of devices like the Diamond Touch, Perspective Pixel, and Microsoft Surface exemplify this trend [7]. While these current systems have made significant progress in the area of finger/object tracking and collaboration, their physical design has kept them from having a significant impact on the consumer market [10], [8], [16] .

The physical design of many multi-touch tables requires that users stand beside the system, causing fatigue in the user's lower extremities. According to the National Health and Nutrition Examination Survey 2009-2010, approximately 18% of Americans 18 or older express that they experience physical discomfort when standing for two hours or more [3]. In respect to the physical design, this observation elucidates the need for a better approach, which will allow the user to sit in a comfortable position while using the table. Achieving such a design is complicated due to the systems heavy dependence on two hardware components, the projector and the camera.

Multi-touch tables use a projector to project an image onto the table surface and a camera to detect when a user has touched the surface [17]. The length of the optical path, i.e., the distance needed between the table surface and the lenses of both the projector and camera, determines the size of the display [7], [8]. One implication of this design is that it requires users to stand beside a large box to use the display.

Systems, such as the Microsoft Surface, use a short throw projector and multiple cameras to reduce the optical path of the camera and projector. This approach reduces the overall height of the table allowing users to sit down [1]. It also causes the users to bend over the table and sit awkwardly because of the bulky box needed to store the system components [9]. Research conducted in the area of occupational ergonomics recommends that, "The user work level should be at a height where the body takes up a natural posture, slightly inclined forwards, with the eyes at the best viewing distance from the work" [13]. Figure 1 illustrates the ideal sitting posture compared to, Figure 2 where the user is forced to lean more than "slightly forward" in order to use the multi-touch surface. This is because the height of the table along with the bulkiness of the box stops users from sitting with their legs underneath the system causing an unnatural posture for the user. Mapping the user's posture in Figure 2 to the Range of Motion Diagram in Figure 3, the user's posture would be placed in the *red zone*—meaning they are putting great strain on their muscles and joints [5].

One possible solution is to remove the box and use a front projected system where the camera and projector are positioned above the surface, thus allowing the user to sit at a regular table. The drawbacks to systems like these are that they are immobile. If the user wants to move the table then they would also have to reposition the projector and camera [4].

Our goal was to create a physical design that has a form factor that can be moved as easily as a regular table or desk and that allows a user to sit comfortably while interacting and collaborating with others on the surface of the table. In this paper, we will explain our design objectives through the prototyping of DeskTop, our mutli-touch desk system.

Fig. 1. Ideal posture

Fig. 2. User of multi-touch table

Fig. 3. Range of Motion [2]

2 Background

DeskTop is a prototype of a multi-touch desk system that is meant to improve on the physical design of multi-touch tables. In order to improve upon the physical design of previous multi-touch tables our design required that we either replaced the projector and camera, or that we shortened the optical path of both the projector and camera. Initially this led us to examine touch screen approaches that do not use cameras and projectors such as resistive and capacitive touch screens. Most resistive touch screens are single touch devices. Capacitive touch screens allow for a limited number of simultaneous touches but are not considered true multi-touch displays [12].

Techniques that create true multi-touch displays rely on optical techniques such as frustrated total internal reflection (FTIR), diffused illumination (DI), and diffused surface illumination (DSI). These optical techniques consist of two main components, infrared emitters and infrared detectors, usually found in the form of infrared light emitting diodes (LEDs) and infrared cameras. When users touch the display surface, infrared light is produced and can be tracked by the infrared detector allowing for n amount of touches, where n is not bounded, so that the system can track as many fingers/objects as can fit on the screen.

Optical based systems that use infrared cameras must include enough space in their design to satisfy the length requirements needed for the optical path of the camera. This causes them to have a large physical form factor [7], [8]. An exception to this is Fiberboard, which uses traditional camera based techniques accompanied with an array of optical fibers to create a device much smaller than other camera based displays. The developers of this system used a bundle of optical array fibers to channel infrared light created from the user(s) touching the top of the surface to the camera. The camera is now free to be placed anywhere, thus reducing the depth of the desk and creating a thin form factor [12].

Thinsight and FlatIr, like Fiberboard, are also a set of new emerging technologies focusing on the advancement of thin displays that can be used for table top systems. Using a grid of infrared emitters and detectors Thinsight is a true multi-touch display capable of detecting multiple touches while being thin enough to fit behind a LCD screen [7].

Similar to Thinsight, FlatIr also uses a grid of infrared sensors positioned behind an LCD screen. With infrared light placed in front of the screen and the sensing grid positioned behind the screen, the user's touch triggers the same optical effect found in FTIR that can be detected and tracked [8].

3 Design Considerations

Our design choices were guided by four essential factors:

- ergonomics
- degree of mobility
- collaboration /scalability
- design simplicity

In the following sections, we will discuss the each of these factors and the role that they played in the creation of DeskTop.

3.1 Ergonomics

In section 1, we identified two problems currently found in multi-touch tables: users working from an unnatural posture, and systems with a very low degree of mobility. This identification led us to review the design of office furniture for the workplace where people are often required to sit at their workstations for long periods of time. Closely following the design guidelines described in *Ergonomics and Design A Reference Guide Book*, we looked at the following three design specifications when creating our prototype: height for thighs, depth for knees, and depth at foot level [5]. The first specification, height for thighs, should be at least 26.8" high (see Table 1). Depth for knees should be no less than 17". Depth at foot level should be no less than 23.5". Table 1 summarizes these specifications.

Table 1. BIFMA guidelines for desks and worksurfaces [2][5]. Measurements can be nvisualized using Figure 4.

		Letter	Specifications	
			Measurement	BIFMA Guideline
Seated Work	Height for Thighs	A	Thigh clearance + Shoe allowance + Popliteal height	At least 26.8"
	Depth for Knees	B	Buttock-knee length – Abdominal extension depth	No less than 17"
	Width for Thighs	Not Shown	Hip breadth sitting + Movement allowance + Clothing allowance	No less than 19.8"
	Height at Foot Level	C	Lateral malleolus height + Show allowance	4.2"
	Depth at Foot Level	D	Buttock-popliteal length + Foot length – Abdominal extension depth	No less than 23.5"

Fig. 4. Sitting at Desk

3.2 Mobility

With current multi-touch tables there is a design trade-off between mobility and user comfort. Rear projected systems like the Microsoft Surface come in one single unit allowing for the placement of casters on the bottom of the system for ease of mobility. However, the single unit design contributes to user fatigue and poor posture because the user is leaning over a large box [8]. Systems where the camera and projector are mounted above the display surface allow the user to sit at the table as they would at a regular desk since no components are housed below the surface. However, this design is not very compact and when the system is moved, the projector and camera must also move as a unit or be recalibrated. Our prototype aims to create a self-contained unit that allows a user to sit comfortably and that has a compact and mobile design.

3.3 Collaboration and Scalability

By scalability we mean the design should support the transition between personal and group work so that users can work individually and then come together to collaborate [9], [18]. By collaboration we mean that multiple users can interact with the surface at the same time. Collaboration requires multi-touch capability plus a large touch surface [9]. With collaboration tasks ranging from multiple users browsing and sharing photos to playing musical instruments together, it was important that our design considers the size of the touch surface so that we can have a large number of touches on the screen at the same time. However, increasing the touch surface will also increase the depth of the system, because a longer optical path is required for the projector and camera.

3.4 Simplicity of Design

We wanted to create a design that is straight-forward and can be reproduced by others. Technologies such as FlatIR and ThinSight show a lot of promise in that they support true multi-touch capabilities, as well as being thin and mobile, but they are based on complex custom electronic sensor arrays for which very little technical information is easily accessible. While the construction of Fiberboard is straightforward, specialized software is required to make the system work. Although camera and projector systems have the problem of long optical paths that often result in bulky form factors, this approach does allow for simple designs from inexpensive commercial components [8]. In the end we concluded that although several technologies were viable, an optical approach was the least complex design that allowed us to meet our other goals.

4 Design of DeskTop

The critical step in creating DeskTop was to develop a method that significantly reduced the overall optical path needed for both image generation and touch detection on the display surface. Doing this would allow us to create a thin display cabinet incorporated into a desk design that meets appropriate ergonomic specifications. Our first step was to choose the appropriate technology for touch detection.

As mentioned earlier there are various types of technology for detecting touches, our design decisions were based on ergonomics, degree of mobility, collaboration/ scalability, and design simplicity. Based on these factors we decided to go with a traditional optical based system allowing us to incorporate techniques such as FTIR, DI and DSI. These techniques are well researched and commonly used within the multi-touch community allowing us to concentrate on the physical design of the system [8], [6], [17].

When choosing which optical technique we planned on implementing, we weighed the advantages and disadvantages of each technique. In DI systems the infrared emitters are placed above or below the screen. If the infrared emitters are placed below the screen we reduce the leg room (*height for thighs*) needed for a comfortable sitting position at the desk. If the infrared emitters are placed above the screen we increase the size and reduce the mobility of the system.

In FTIR and DSI the infrared emitters are placed around the edges of the touch surface resulting in a compact design for illuminating the surface of the table. Of these two choices both options allow us to completely remove the projector from the design, eliminating the optical path required to project an image. We chose to use DSI because it also allowed us the option of recognizing fiducial markers. We replaced the projector with a 23 (diagonal) inch LCD flat screen. Placed above the LCD is an acrylic sheet (ACRYLITE® Endlighten) that serves as our touch surface. The acrylic sheet evenly distributes the infrared light produced from strips of infrared light emitting diodes that have been stationed around the perimeter of the touch surface. When a user touches the surface the infrared light is scattered, creating a “blob” that can be tracked by a camera from below [17].

Building on previous work done by Microsoft and others we were also able to significantly reduce the length of the optical path required for the camera by distributing the viewing of the touch surface among multiple cameras instead of using a single camera [1]. Using four cameras, we split our touch surface into four 10 x 5.5 inch quadrants. Each camera is positioned eight inches away from the back edge of each quadrant, four inches away from the top of the surface and centered with respect to the back edge of the quadrant with the camera lens pointing at a 105° angle with respect to the bottom surface (Figure 5 camera position). This positioning allows each camera to see one full quadrant. Then, using a custom image stitching algorithm, we were able to take the four images grabbed by the cameras and stitch them together to form one large image of the desk that could be passed to our image processing module for finger detection and tracking.

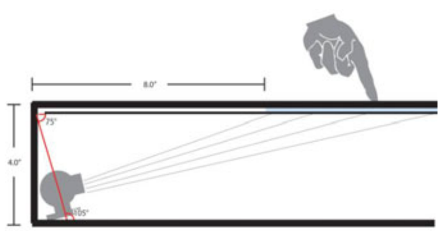

Fig. 5. Camera position

Before detecting and tracking the fingers we must first correct the barrel distortion created from the wide angle lenses attached to the cameras. This can be done using the un-distort methods in the image processing library Open Computer Vision [15], [11]. Once we have fixed the barrel distortion we then pass the image to different image filters, where we adjust the image properties to make the blobs more visible for detection and tracking [15].

Our final prototype of DeskTop, shown in Figure 6, is a multi-touch desk that permits a user to sit in a comfortable position, and supports easy mobility. It also facilitates collaboration and scalability between multiple users by allowing adjacent desks to communicate with each other so that they function as a single large desk.

Fig. 6. Final Design

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References

1. Anderson, N.: What Lurks Below Microsoft's Surface? A Brief Q&A with Microsoft, http://arstechnica.com/gadgets/news/2007/05/what-lurks-below-microsofts-surface-a-qa-with-microsoft.ars
2. BIFMA International, Ergonomics Guidelines for VDT (Video Display Terminal) Furniture Used in Office Workspaces. Document G1-2002 (2002)
3. Center for Disease Control: National Health and Nutrition Examination Survey, http://www.cdc.gov/nchs/nhanes/nhanes2009-2010/questexam09_10.htm
4. Dietz, P., Leigh, D.: DiamondTouch: a multi-user touch technology. In: Proceedings of the 14th Annual ACM Symposium on User Interface Software and Technology, November 11-14, pp. 219–226. ACM Press, New York (2001)
5. Ergonomics and Design A Reference Guide Book, http://www.allsteeloffice.com//NR/rdonlyres/3B6AC489-FC78-4B78-895A-0A5D8A9E888A/0/ErgoHandbook.pdf
6. Han, J.: Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection. In: Proceedings from UIST 2005: User Interface Software and Technology, pp. 115–118 (2005)
7. Hodges, S., Shahram, I., Butler, A., Rrustemi, A., Buxton, B.: ThinSight: Versatile Multi-Touch Sensing for Thin Form-Factor Displays. In: Proceedings of the 20th Annual Symposium on User Interface Software and Technology, Newport, Rhode Island, USA, October 7-10, pp. 259–268. ACM Press, New York (2007)

8. Hofer, R., Naeff, D., Kunz, A.: FLATIR: FTIR Multi-Touch Detection on a Discrete Distributed Sensor Array. In: Proceedings of the 3rd International Conference on Tangible and Embedded Interaction, Cambridge, United Kingdom, February 16-18 (2009)
9. Hunter, S.: MemTable – Contextual Memory in Group Workspaces Media Arts and Sciences Master's Thesis, Massachusetts Institute of Technology (2009)
10. Inkpen, K., Hancock, M., Mandryk, R., Scott, S.: Collaboration Around a Tabletop Display: Supporting Interpersonal Interactions. SFU Technical Report (2001)
11. Intel: Open source computer vision library: Reference manual, `http://www.intel.com/technology/computing/opencv/`
12. Jackson, D., Bartindale, T., Olivier, P.: FiberBoard: compact multi-touch display using channeled light. In: Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces, pp. 25–28. ACM, New York (2009)
13. Kroemer, K., Grandjean, E.: Fitting the Task to the Human: a Textbook of Occupational Ergonomics, 5th edn. Taylor & Francis, London (1997); Krueger, M., Gionfriddo, T., Hinrichsen, K.: VIDEOPLACE:–An Artificial Reality. In: Proceedings of the SIGCHI conference on Human factors in computing systems, CHI 1985, pp. 35-40. ACM, New York (1985)
14. Muller, L.: Multi-touch displays: design, applications and performance evaluation, MSc thesis, University of Amsterdam, Amsterdam, Netherlands (2008)
15. Murph, D.: Touchy Remix is the Multitouch Table You Could Actually Use (2010), `http://www.engadget.com/2010/02/10/touchy-remix-is-the-multitouch-table-you-could-actually-use/` (last accessed October 12, 2010)
16. NUI Group Authors: Multitouch Technologies. 1st edn. NUI Group (2009)
17. Scott, S., Grant, K., Mandryk, R.: System Guidelines for Co-located, Collaborative Work on a Tabletop Display. In: Proceedings of European Conference Computer-Supported Cooperative Work, Helsinki, Finland, pp. 159–178 (September 2003)
18. Wellner, P.: Interacting with paper on the DigitalDesk. Communications of the ACM 36(7), 87–96 (1993)

Changing Color over Time

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Abstract. The revolution in lighting we are experiencing goes beyond the basic capabilities of the light sources used and has enabled new ways of improving the overall experience of both lighting and displays. However, specifics of LEDs, the technical driving force behind the revolution, also introduce new challenges. One of those challenges is the temporal control of full-color light systems. In this work we explore the properties of human color vision relevant to the generation of pleasant dynamic light effects. We show that the spatial models of color are unsuitable for predicting temporal phenomena and give steps towards building a new, temporal model.

Keywords: dynamic light, color vision, smoothness perception, flicker perception, chromatic flicker, peripheral vision, preferred color path.

1 Introduction

Advances in lighting, especially in Solid State Lighting, enable new uses of light. Having improved spatial and temporal resolution, more saturated primaries and lower power consumption, LED based lighting systems can be used to design more complex and attractive lighting atmospheres.

Parallel to these developments is the evolution of displays and media presentation. Since the introduction of television, much has been done to improve the experience of watching television. Improvements in image quality and sound quality have contributed to a better overall experience. Nowadays, new dimensions such as depth are added to the displays to further enhance the viewing experience. The new capabilities of solid state lighting systems also enable the addition of new experience enhancing functionality to the display world.

The Philips Ambilight TV [1] is one of the examples of such new functionality. Not only does the additional light enable more pleasant viewing conditions, resulting in less eye fatigue [2], but the extended viewing extent provides a more immersive viewing experience. Seuntiens in [3] showed that the overall viewing experience on a display system with 3D and Ambilight capabilities depended on the quality of all the ingredients. Even though it was shown that the overall experience mostly depends on the image quality, the overall image quality of modern displays is already high and only minor improvements are to be expected. This makes the addition and the improvement of new functionality more important to the overall viewing experience. The relative importance of different functions also depends on the desired part of

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experience that needs to be improved. For example, the additional value of 3D is strongest in the presence (immersion) ratings.

The extension of the view produced by the Ambilight TV provides an interesting use case in the study of the desirable properties of produced light distributions. Even though the light distribution is based on the color distribution of the video, a pleasant rendering of the former is dependent on a new set of requirements. The produced light effect has a much lower spatial frequency compared to the one of the display, which in turn makes temporal variations in the light effects more visible. These variations are masked in the source content by the higher spatial distribution. The lower spatial frequency also makes the differences between adjacent light effects more noticeable, requiring better color matching.

The new challenges given by the new capabilities extend further when the light distribution covers a larger area, in the end covering the whole room. This natural progression makes results of research inspired by either improving viewing experience or atmosphere creation interchangeable.

In this work we give an overview of a selection of studies on the temporal control of light effects.

2 Perceived Smoothness

One of the largest differentiators of SSL lighting systems are their dynamic capabilities. However, the produced dynamic lighting atmospheres need certain properties to be attractive to the users.

Perceived smoothness is one of those desirable properties. Aside from a limited set of applications, such as for disco lights and concerts, or being used as attention attractors, abrupt changes in environment lighting are hardly perceived as pleasant. Given the smoothness requirement and the limitations of the hardware, it is interesting to look at the maximum speed with which a certain light progression can be rendered on a device without producing visible discontinuities. To understand the possible source of problems connected to smoothness perception, we discuss the design of most solid state lighting systems and applications first.

Modern lighting applications use discrete control of the light sources, with a limited number of intensity levels. Contrary to the analog systems which have a continuous change in color, in digital systems the smallest distance between two colors, both in color and time, is limited by the resolution of the system. Similar to spatial color perception, an inappropriate minimum distance between colors can introduce perceived discontinuities.

Existing dynamic lighting systems use the device color space (usually RGB) of the lights to control the temporal changes. To produce smooth light transitions, low pass filters are applied on the individual color channels. Under some conditions, for example light effects computed from another medium (such as a video signal for the Philips Ambilight TV), this leads to seemingly unsolvable problems. If the parameters of the low pass filter are tuned such that the transitions from low intensity to high intensity of the lights appear smooth, the transitions between chromatic colors are perceived as too slow. In the case of content dependent dynamic lighting, this introduces a mismatch between the color of the lighting and the representative color of the video frames during the transition. A video transition from a red sunset to a blue underwater scene is followed by a light transition being purple for a noticeable time. This behavior is deemed undesirable by most users.

The above mentioned problem is present in all dynamic lighting systems that control the temporal changes in a device color space. The core of the problem is that using a device color space, the properties of the human visual system, which determine the perceived qualities, are not taken into account. Previous work on the temporal properties of the human visual system shows differences in the way intensity and chromaticity changes are perceived. Namely, the human visual system processes intensity changes faster than chromaticity changes [6, 7]. Moreover, the changes in chromaticity are smoothed by the human visual system more than the changes in intensity [8, 9]. Using a device color space to control the temporal changes does not allow the use of such results.

To compute the required distances between colors that produce spatial patterns which appear smooth, the notions of visibility threshold and just noticeable difference [10] were introduced. The continuation of the work on spatial just noticeable differences led to development of, among others, the CIE Luv, CIE Lab, and CIECAM97s color spaces [11], which show a relatively good uniformity in the predicted differences, thus also the predicted smoothness of spatial patterns.

Unfortunately, no such spaces exist for temporal patterns. The fact that the perception of the temporal transitions depends on the frequency at which the changes are made, further complicates the representation and smoothness prediction in the temporal case. To gain better understanding of the way the human visual system processes temporal patterns in the context of dynamic lighting applications, we designed and carried out a set of experiments. The stimuli in the first experiment [12] were linear transitions around a base color point (red, green, magenta, blue, white for the lightness transitions) in different directions (lightness, chroma, hue) in a spatially near uniform color space (CIE LCh), and at different frequencies of change (5, 10, 20, 30, 50 Hz) . Figure 1 depicts the base points and the chromatic change directions for the stimuli used in the first experiment in the CIE XYZ color space. To provide an easier task for the participants, the basic linear transition was repeated in alternating directions. The first and the last step in the transition were smoothed to diminish the effect of the edges of this compound transition.

Results demonstrated that the existing spatial difference based color spaces are not suitable in predicting the smoothness of temporal color transitions. Figure 2 shows a comparison of the step sizes of transitions that are just unsmooth, in different directions in a nearly spatially uniform color space, for different frequencies and around different base color points. If the spatial difference based color space could be used for the prediction of the smoothness of light effects, all the threshold step sizes for one frequency would have the same value. Contrary to that, it can be seen that the chroma change threshold for a color transitions around green and at a frequency with the highest sensitivity, 10Hz, is two orders of magnitude larger than the corresponding lightness change around the same color point and at the same frequency. Furthermore, the lightness threshold around 10Hz is below the spatial just noticeable difference, while the one for a hue transitions around red for example is ten times the spatial just noticeable difference.

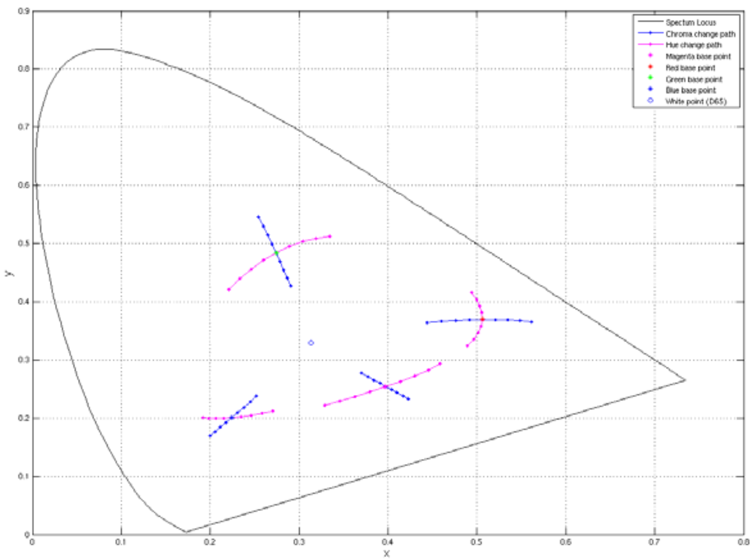

Fig. 1. The stimuli used in the first experiment, given in the CIE XYZ color space

Even though the results show that the spatial vision based model is unsuitable for the prediction of temporal visibility, the results demonstrate it can be used in a solution for the problem in the introduction. It is clear from the results that if the smoothing is done not in a device dependent space, but using a color space in which the intensity and chromaticity axes are orthogonal, the application of different amount of smoothing on those axes can produce a suitable temporal transition.

3 Flicker Perception

Based on the above, it is clear that a new model of temporal vision is needed. Measuring the perceived smoothness, however, becomes hard at higher frequencies due to fact that the duration of the transition becomes very small and the judgment of the smoothness of the linear transition is easily confused with the effect of beginning and the end of the transition. To overcome this, in [12] the smoothness perception thresholds were compared to flicker visibility thresholds. To compare, for every linear color transition with a certain step size, another temporal variation between two levels (flicker) with a difference equal to the step size was created. All the effects found for both types of temporal variations were the same and the thresholds were related by a function dependent on the frequency, where a linear transition of around 10Hz corresponded to flicker of around 20Hz. Furthermore, once the frequency dependent function was applied, the results of the smoothness experiment could be predicted by the results of the flicker experiment. Flicker visibility, being an easier question for the participants, can thus be used to predict the thresholds for both phenomena.

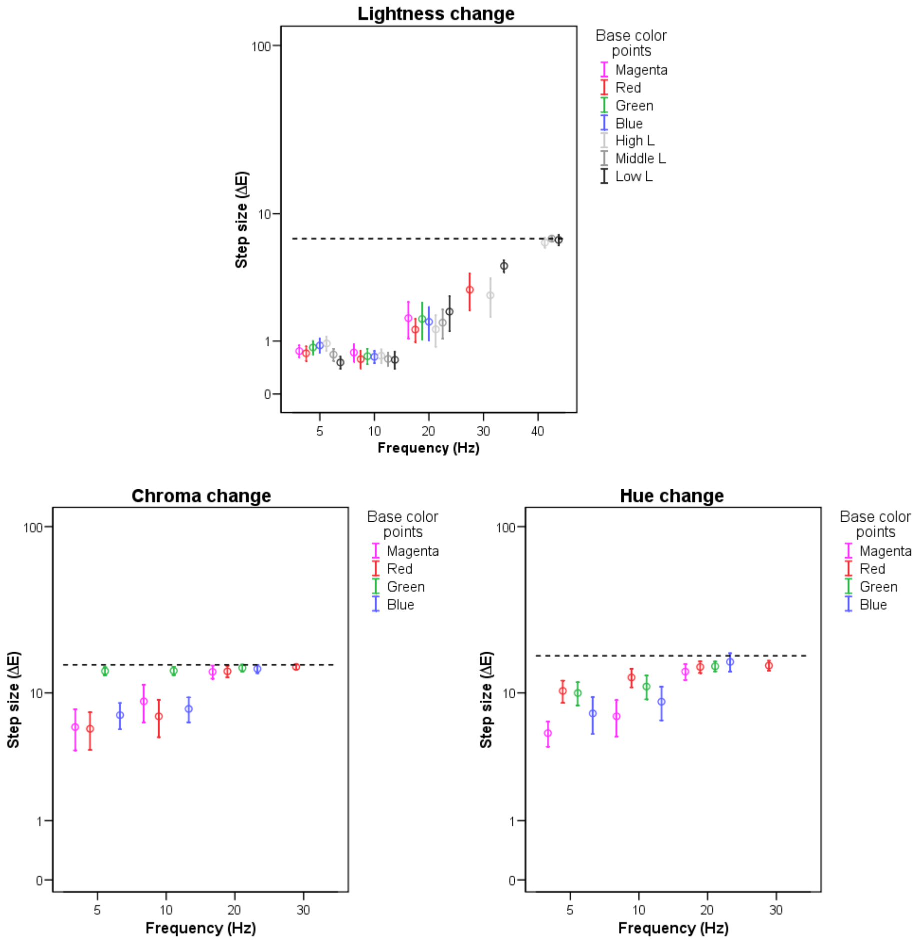

Fig. 2. Step sizes of just unsmooth temporal color transitions in different directions in a nearly spatially uniform color space

Frequency as an additional parameter makes modeling of temporal transition sensitivities harder than the simple spatial difference case. Fortunately, in [13] it was shown that there is an exponential relation between the speed of a transition given in ΔEab/sec and the frequency of change of the transition. Furthermore, even thought there is a large difference between the thresholds for lightness and chromaticity variation, they are different only in their absolute level, but the change over frequency (the slope in the graph) matches. Figure 3 depicts the speed of just unsmooth transitions (solid lines) and the amount of change of just visible flicker (dashed lines) for different directions and for different frequencies. The relation between the two types of temporal variations studied is also evident on Figure 3.

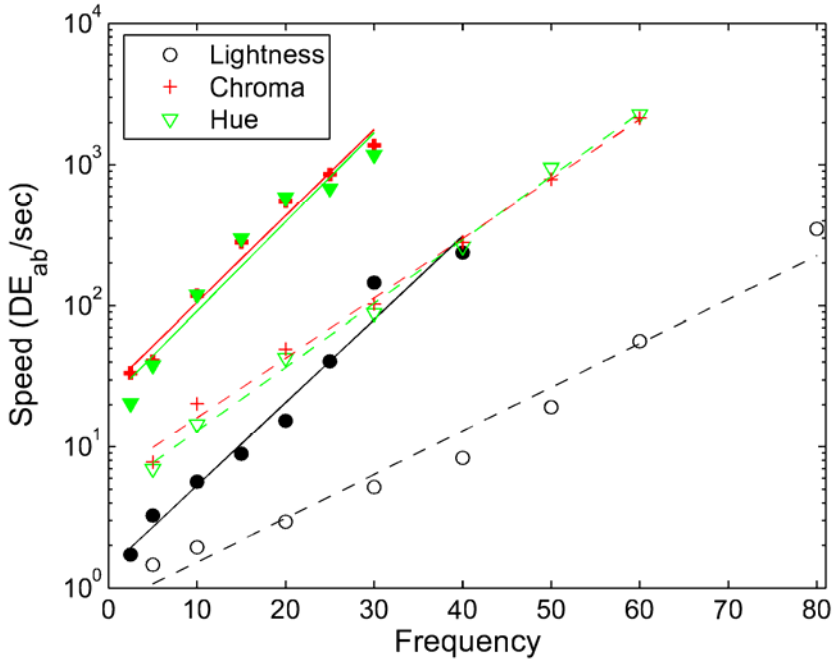

Fig. 3. Logarithm of speed of just unsmooth transitions (solid lines) and amount of change of just visible flicker (dashed lines)

4 Peripheral Vision

Light supports daily activities and as such is seldom the main focus of attention, resulting in the fact that light effects produced are often being perceived in the periphery of the visual field. This is also true in the example application in this work, the Philips Ambilight TV, where the light emitted supports the viewing experience. As the perception of both chromaticity and intensity and the density of the two basic types of light detectors, rods and cones, change at different angles in the visual field, the sensitivity to temporal changes should also be influenced by the eccentricity of the temporally changing stimulus.

In [14], a series of experiments are presented, designed to study flicker visibility in the peripheral vision. Similar to the experiments in central vision, the effect of the base point, the direction of change and the frequency of flicker were studied. Furthermore, an effect of an additional task in the central visual field was found. Results of the experiments show, as expected, a large deviation of the sensitivity in the peripheral vision, especially for chroma and hue changes, which are practically undetectable at any amplitude above 20Hz.

5 Path of Change

The series of experiments described so far explored the speed of temporal transitions and the visibility of flicker. Another question that arises in the creation and control of temporal color transitions is the one of the path between two colors. The question of what is a preferred way to make a transition from one color to another and the difference between transitions required to perceive them as different was studied in [15]. The influence of the starting and ending color, the type of transition, the speed and the presence of images with matching colors was studied. Possible transitions were: linear in RGB; linear in CIE Lab; transitions with a middle point higher and lower in luminance compared to the linear transition in CIE Lab; and transitions with the middle point more or less saturated than the middle point of the linear transition in CIE Lab. To select appropriate paths, first discrimination thresholds for different transitions were found. The discrimination thresholds ranged between 2.5 and 10.5 ΔEab, dependent on the color pair, direction and duration of the transition. Based on these results, transitions with a well noticeable difference were selected as stimuli in the preference part of the experiment. Results showed that the most preferred transitions were the linear transition in CIE Lab, a linear transition in RGB, and a transition that has a middle point having a lower lightness then the end points. This preference was not influenced by the presence of matching images. The preference for the linear RGB path suggests that appealing temporal color transitions can be created without complicated calculations.

6 Conclusions

This overview presented a selection of works studying the properties of the human visual system relevant to the creation and control of temporal color transitions. The results presented demonstrate the lack of general suitability of existing spatial vision based color models to temporal effects. Furthermore, the effect of a number of parameters on the perception of the resulting temporal transitions is shown and first limited modeling efforts are presented. Most notably, it is demonstrated that the frequency dependence of both smoothness and flicker sensitivity can be modeled by a simple exponential law. Lastly, the effect of the eccentricity of the stimulus is discussed.

The results of these studies can be used as a base in the design of both the direct controls of future light sources as well as the controls of complex light atmospheres.

References

[1] Salters, B.A., Krijn, M.P.C.M.: Color reproduction for LED-based lighting systems. In: Proceedings of the SPIE, vol. 6338 (2006)

[2] Bullough, J.D., Akashi, Y., Fay, C.R., Figueiro, M.G.: Impact of surrounding illumination on visual fatigue and eyestrain while viewing television. Journal of Applied Sciences 6(8), 1664–1670 (2006)

[3] Seuntiens, P., Vogels, I., van Keersop, A.: Visual Experience of 3D-TV with pixilated Ambilight. In: Proc. Presence 2007, 10th Ann. Int. Workshop on Presence, Barcelona, Spain, pp. 339–344 (2007)

[4] Seuntiens, P., Vogels, I., Kraaijenbrink, E.B.: Visibility of Hue, Saturation, and Luminance deviations in LEDs. In: Proc. of SPIE 2007: Conf. Electronic Imaging, San Jose, CA (2007)
[5] Seuntiens, P., Vogels, I.: How to create appealing spatial color gradients. In: Proceedings of the 11th Congress of the Int. Colour Ass., AIC Sydney, Australia (2009)
[6] Coren, S., Ward, L.M.: Sensation & Perception, 3rd edn., Harcourt Brace Jovanovich, Orlando, Florida (1989)
[7] Bowen, R.W.: Latencies for chromatic and achromatic visual mechanisms. Vision Research 21(10), 1457–1466 (1981)
[8] Stork, D.G., Falk, D.S.: Temporal impulse responses from flicker sensitivities. Journal of the Optical Society of America A 4(6), 1130 (1987)
[9] Swanson, W.H., Ueno, T., Smith, V.C., Pokorny, J.: Temporal modulation sensitivity and pulse detection thresholds for chromatic and luminance perturbations. Journal of the Optical Society of America A 4(10), 1992–2005 (1987)
[10] MacAdam, D.L.: Visual sensitivities to color differences in daylight. Journal of the Optical Society of America (32), 247–274 (1942)
[11] Fairchild, M.D.: Color Appearance Models, 2nd edn. Addison-Wesley, Reading (2005)
[12] Sekulovski, D., Vogels, I.M., van Beurden, M., Clout, R.: Smoothness and flicker perception of temporal color transitions. In: Proc. of the 15th Color Imaging Conference, pp. 112–117 (2007)
[13] Sekulovski, D., Vogels, I.M., van Beurden, M., Clout, R.: Effect of Frequency on the Sensitivity to Temporal Color Transitions. In: CIE Light and Lighting Conference, Budapest (2009)
[14] Perz, M., Sekulovski, D., Murdoch, M.: Chromatic Flicker Perception in Human Peripheral Vision Under Mental Load. In: Proc. of the 18th IS&T CIC Conference, San Antonio, Texas, USA, pp. 33–37 (2010)
[15] Vogels, I., Sekulovski, D., Rijs, B.: Discrimination and preference of temporal color transitions. In: Proc. of the 15th IS&T CIC Conference, Albuquerque, USA, pp. 118–121 (2007)

SmartHeliosity: Emotional Ergonomics through Coloured Light

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Abstract. In this paper we present research activities on the interaction between light and human emotion. We describe the SmartHeliosity prototype which evaluates human emotions to provide appropriate coloured light in order to enhance emotional wellbeing within the working environment. We present technical specifications, colour concepts to provoke certain emotions and user feedback to the prototype system.

Keywords: Adaptive light, coloured light, emotion, face detection.

1 Introduction

Colour and light are an integral part of human life. Colour is a very important factor for human emotional development and growth. Light is important for the sleep-wake cycle, health and well-being [1], [2], [3], [4]. Dynamic light can be activating [5] and give a sense of nature, progression and growth. SmartHeliosity aims at inducing positive emotions by providing an adaptive mood light. Our system evaluates human emotions and controls a colour changing light based on this information, with the aim to enhance the emotional well-being within the working environment (figure 1).

Designing ergonomic workplaces involves elements of working systems and environmental factors. An often neglected but important factor is human emotion. Psychological balance is an important factor, well-known for its influence on physical health. Colour therapy or sometimes called chromotherapy is an established alternative medicine method. Even our choice of decoration and clothing is strongly influenced by colour. Some physiological and psychological effects of colours on humans are described in chapter 1.1. [6].

1.1 Colour and Emotion

Red, being a long wavelength, is a powerful colour. Even though the highest sensitivity of the human eye is in the green region, red-colored objects have the property of appearing to be closer than they really are, and therefore red grabs our

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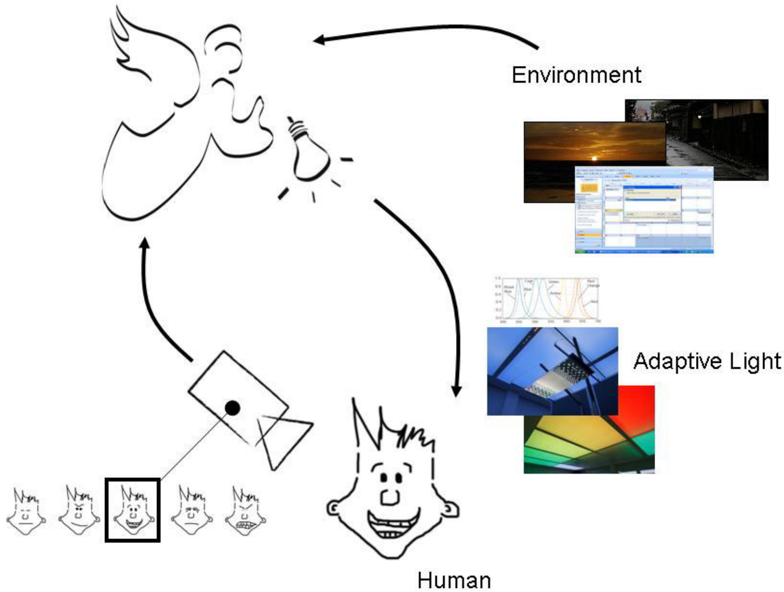

Fig. 1. SmartHeliosity closed loop: A lighting system that adapts to the user and its environment

attention first (hence it is used in traffic lights the world all over). Red can raise the pulse rate, giving the impression that time is passing faster. Red is stimulating, lively and friendly but at the same time, it can be perceived as demanding and aggressive.

Blue, being a short wavelength, is the colour of the mind and is essentially soothing. It affects us mentally rather than physically. Strong blue will stimulate clear thoughts and soft blue will calm the mind and aid concentration. Consequently it is serene and mentally calming. It is the colour of clear communication. Blue objects do not appear to be as close to us as red ones. However, blue can be perceived as cold, unemotional and unfriendly.

Yellow is an emotional colour and has a strong psychological effect. Yellow can lift our spirits and our self-esteem and it is the colour of confidence and optimism. Too much of it or the wrong tone in relation to the other tones in a colour scheme can rise fear and anxiety.

Green is restful for the eye. Being in the centre of the spectrum, it is the colour of balance. When the world around us contains plenty of green, it indicates the presence of water, so we are reassured by green on a primitive level. Negatively, it can indicate stagnation and, incorrectly used it can be perceived as being too bland.

Violet is very introversive and encourages meditation. It has associations with royalty and usually communicates the finest possible quality. Excessive use of violet can cause too much introspection and the wrong tone of it communicates something cheap and nasty.

Orange is stimulating and very warm. It is also a ‘fun’ colour. Too much orange suggests frivolity and a lack of serious intellectual values.

Pink also affects us physically and soothes. “Baker Miller Pink” in prison cells is used to calm prisoners. Pink represents feminism. Too much pink is physically draining.

Light and colour can be used for creating or inducing certain emotions or moods for specific situations. Axel Venn [7] shows that certain colour combinations imply certain feelings. In a survey with more than 60 participants, 1625 colours of the RAL design system have been connected to more than 360 feelings and adjectives. Some examples are

- Cosy: Warm red-orange-yellow shades with light toned beige-brown
- Spring: More than eighty percent of the colour range is yellow-green
- Tasteful: About 50 percent of the colours contain blue and black
- Painful: Reddish-black, turquoise, rose and lemon-yellow

1.2 Measurement of Emotion

Measurement of emotions is possible with multi-sensory systems using physiological parameters (heart frequency, skin resistance, etc.) as well as patterns of behaviour and facial expressions. SmartHeliosity connects dynamic light with multi-sensory systems with the goal to ensure emotional ergonomics of the user. With our prototype, emotions are detected through facial expression via a web cam and the software SHORE™ from Fraunhofer IIS. Using the SDK we modified the software to give us an emotional value of the user on a predefined scale. SHORE™ is a highly optimized software library for face and object detection and fine analysis (figure 2). SHORE stands for Sophisticated Highspeed Object Recognition Engine. The software recognises the emotional value of the user like happy, sad, excited, etc. [8]

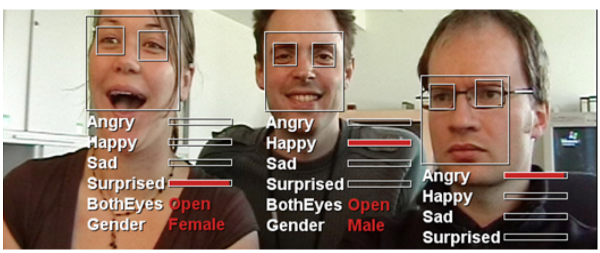

Fig. 2. Fraunhofer IIS face detection software SHORE™

The information about the emotion is passed to the colour database which provides light algorithms to tune to the emotions of the user. Eventually this will create an ambient light in an emotionally ergonomic work environment. So far no physical interface is involved as we trigger the light by the facial expression only. We believe it is important that there are no additional interfaces as this may have effects on the user's emotional state. Facial features are interpreted by the following characteristics [9]:

- Anger: Lowered, inward slanting eyebrows squeezed together in a wrinkle. Eyelids are tight and straight as a result of the lowered brow. Mouth is either closed as tight straight lips, or the lips are puckered. Forward thrust of the jaw or lift of the chin.
- Annoyance: Inward slanting eyebrows squeezed together in a wrinkle or crease. Mouth twisted into a side placement creating a crease in the cheek. Puckered lips are optional.
- Depression: The upward slanted eyebrows; there is no prominent frown involved. Also, the lowering of the eyes looking downward give the helpless, dejected mood that is associated with depression.
- Excitement: The excited facial expression is a positive face expression that is often characterized through an open mouthed smile. The eyes are usually open to their fullest and the eye brows are up high to show an active energy level.
- Fear: The fear facial expression is characterized by upward slanted eyebrows with wide open eyes. The mouth is typically open as a wide gape
- Happiness: The happy facial expression is characterized through the use of a smile. The facial characteristics are different from that of a grin, because typically just the upper teeth are exposed. The lower lids of the eyes are raised to form crescent shapes.

1.3 SmartHeliosity Scenario

As SmartHeliosity is intended to be used in offices we would like to describe a typical scenario, how the luminaire system could support a worker at his office workplace: Mr. John Doe enters his office in early morning and is still a little sleepy. SmartHeliosity detects the tiredness in his eye movements and reacts with a blue-enriched spectrum, in order to suppress melatonin. As Mr. John Doe is annoyed because of an email, SmartHeliosity detects its annoyance by face recognition and reacts with a relaxing light program. An activating lighting program helps him during the preparation for his meeting at 10:30 and brings him into the right form for discussion.

1.4 Related Projects

The "ALADIN" project (Ambient lighting assistance for an ageing population) received funding from the ICT strand of the European Union's Sixth Framework Programme. It addressed the impact of lighting on the wellbeing and health of older people. The system used information from biosensors to determine what users are doing and then changed the lighting accordingly. The researchers' goal was to improve the wellbeing of elderly people suffering from age-related illnesses and people with reduced mobility. [10]

2 SmartHeliosity Specifications

2.1 SmartHeliosity Concept

The technical realization of the SmartHeliosity concept is based on the integration of various already available sources of information about the working environment and the user as well as an adaptive LED-luminaire. The luminaire is flexible and can be adapted to the environment and to the preferences of the user in size and form like a modular sculpture. It is made of LEDs embedded in silicone. Each module is like a "Lego" which can be joined together in any numbers to create different patterns in three dimensions. This gives flexibility to the user to have its own light sculpture.

As already mentioned, the detected emotions are linked to a colour database. Our software provides light algorithms to tune to the emotions of the user. These algorithms continuously calculate appropriate colour combinations to suite emotion of the user. Basically we try to provide a light condition to bring the user's emotional level to the desired and appropriate condition. Whenever some negative emotions are induced, such as angriness, annoyance or sadness, it tries to normalize it to well being conditions like relaxed and calm conditions. Whenever positive emotions are detected it tries to maintain them at a certain level and not to go into hyper emotional conditions. Figure 4 shows some emotions and the corresponding colour combinations [6].

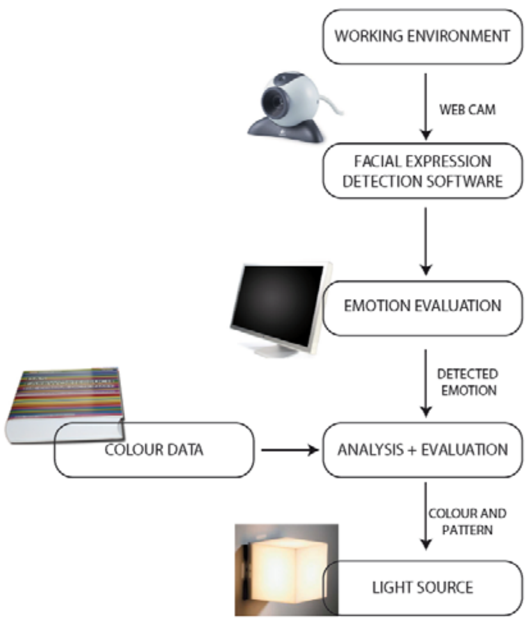

Fig. 3. SmartHeliosity technical concept

Fig. 4. Mood and corresponding colour combinations

2.2 Heliosity Light Fixture Design

SmartHeliosity is flexible in two respects: the material itself is flexible and can be bent in various shapes, and several single tiles can be connected to each other to build a modular light sculpture in various forms and sizes. It can be adapted to the environment and to the preferences of the user. One module is shown in figure 5. Figure 7 shows four separate modules that can be connected to each other. Several modules can be joined together in any numbers to create different patterns in 3 dimensional spaces.

LED stripes are embedded in silicone. The aluminium wire mesh allows for bending and forming the structure to the desired shape. The silicone protects the LEDs and holds the structure together. The flexible LED stripes are endowed with RGB 120° viewing angle PLCC2 SMD LEDs. They are driven with 12V and have a luminous flux of 800 lm. The LEDs are controlled by a 12 channel 16 bit DMX dimmer [11]. The transformation from the computer signal to the DMX values is realized by an Ethernet / DMX512 Control Box [12].

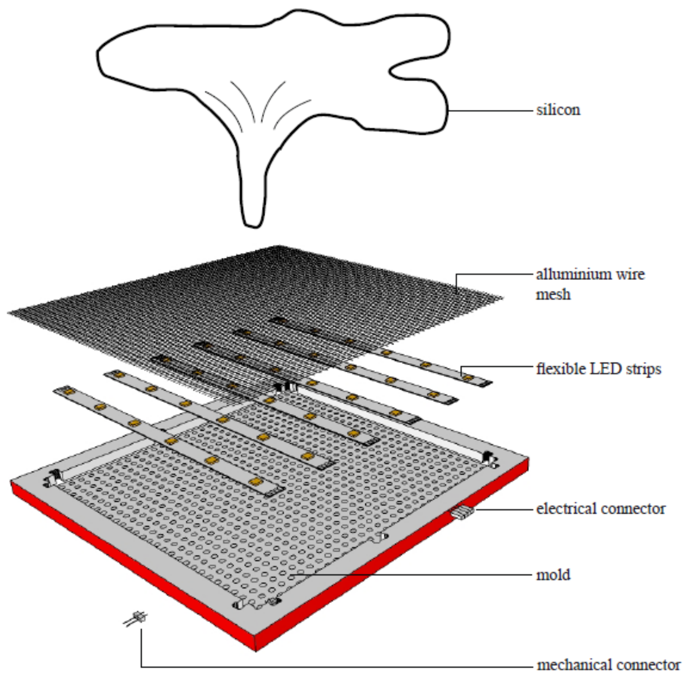

Fig. 5. SmartHeliosity mechanical design

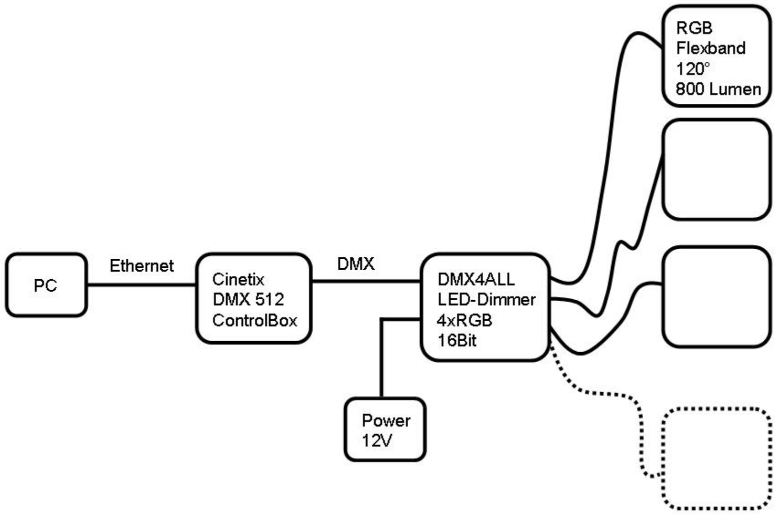

Fig. 6. SmartHeliosity electronic design

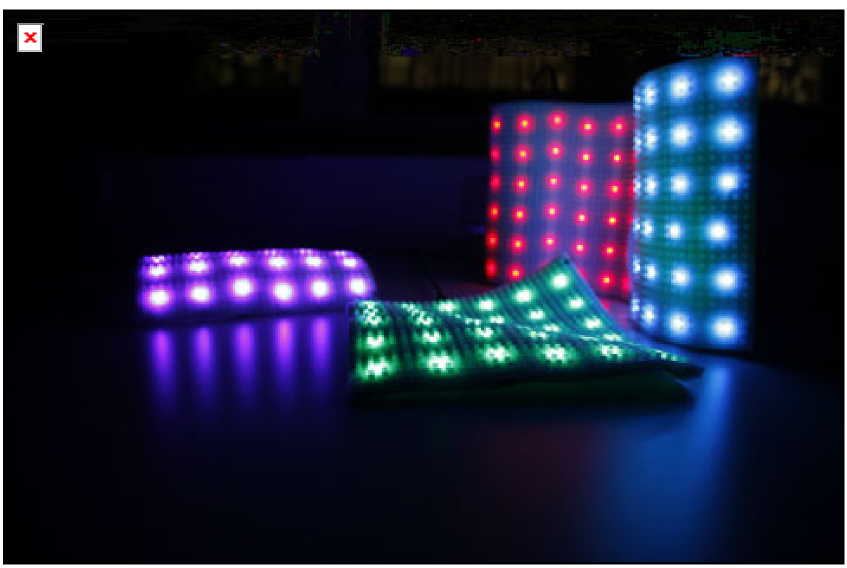

Fig. 7. SmartHeliosity final prototype of the light modules

3 User Feedback

Our user test was conducted with seven male and two female participants. Their age was between 25 and 44 years. The test was divided into two parts, where in first part users were asked to play a game (four in a row) against the computer for 15 minutes. While playing the game, users were not informed about the SmartHeliosity concept and that their emotion was evaluated. After the game, users were asked about the influence of the ambient lighting and the change of the colours during the game. In the second part of the test, users were informed about the SmartHeliosity concept and how everything works. Users were then allowed to use the system for a few minutes and subsequently asked to rate different aspects of the concept, such as response to emotions, detection of emotions, appropriateness of colours, etc.

In general, seven participants would like to use the system at their workplace while two participants denied to use it at their workplace.

Five participants answered with "yes", to the question "do you like the changing of ambient light?". Two participants found the change of light distracting while two other participants did not recognize any change of light at all. After the test, four participants reported to be relaxed, and two to be excited. Only one participant was bored at the end, while two other participants were happy and more awake. To the question "How well did the light respond to your emotions?", seven participants said "good" and two said "ok". Possible answers were "very bad", "bad", "ok", "good" and "very good". The answers to the question "How well did the system recognize your emotion "happy", "angry", and "surprised?" are presented in the following figures.

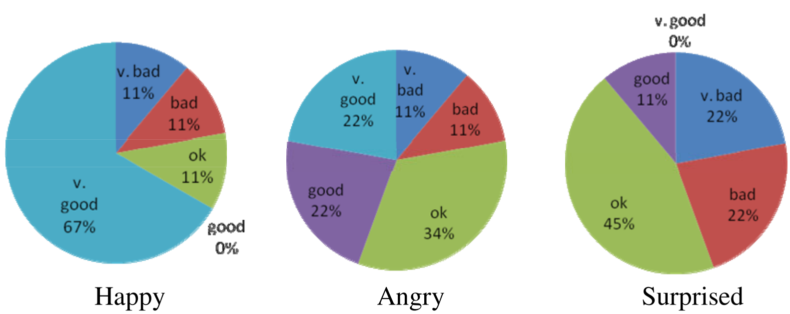

Fig. 8. User responses to the question "How well did the system recognize your emotion "happy", "angry", and "surprised?"

4 Future Work

Based on the user feedback we will improve the adaptive lighting design. In particular we have to improve the recognisability of the emotion "angry" and "surprised". We also discovered, that the system can not differentiate between an angry and concentrated face, so we will work on this issue. Furthermore we will integrate more input parameters such as body temperature, perspiration, and pulse rate. We will also consider voice modulation and gestures. Together with environmental parameters such as the outlook calendar, emails, weather and natural light conditions we will refine the adaptive lighting system to respond to the user's emotion with more appropriate coloured light.

References

1. Lieverse, R., Nielen, M.M., Veltman, D.J., et al.: Bright light in elderly subjects with nonseasonal major depressive disorder: a double blind randomised clinical trial using early morning bright blue light comparing dim red light treatment. Trials 9, 48 (2008)
2. Terman, M., Terman, J.S.: Light therapy. In: Kryger, M.H., Roth, T., Dement, W.C. (eds.) Principles and Practice of Sleep Medicine, Philadelphia, 4 edn., pp. 1424–1442. Elsevier, Amsterdam (2005)
3. Wirz-Justice, A., Fournier, C.: Light, Health and Wellbeing: Implications from Chronobiology for Architectural Design. World Health Design, 44–49 (January 2010)
4. Brainard, G.C., Hanifin, J.P., Greeson, J.M., et al.: Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. J. Neurosci. 21, 6405–6412 (2001)
5. Stefani, O., Bues, M., Pross, A., Hille, K., Spath, D.: Lichtdynamik am Wissensarbeitsplatz der Zukunft. 56. Kongress der Gesellschaft für Arbeitswissenschaft (2010) ISBN 978-3-936804-08-9
6. Boyle, C.: Colour Harmony for the Web. A Guide for Creating Great Colour Schemes On-Line, ISBN-10:3-283-00427-7
7. Venn, A., Venn-Rosky, J.: The Colour Dictionary - The Colourfulness of the Words, Callway (2010) ISBN 978-3-7667-1825-9
8. Kueblbeck, C., Ernst, A.: Face detection and tracking in video sequences using the modified census transformation. Journal on Image and Vision Computing 24(6), 564–572 (2006) ISSN 0262-8856
9. `http://www.faceturn.com/index.php`
10. `http://cordis.europa.eu/ictresults/index.cfm?section=news&tpl=article&id=90417`
11. DMX-LED-Dimmer 4xRGB HR; Product No.: 90-3412, `http://www.dmx4all.de`
12. Ethernet / DMX512 Control Box, `http://www.cinetix.de/interface/english/etdmxbox.htm`

All in Hand Keyboard Designing and Researching Based on Ergonomics

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Abstract. Traditional keyboard can easily cause discomforts, keeping hands and arms under constant strains, especially when people have to work on computers for a long time. For that reason, some companies have introduced types of ergonomic keyboards. However the problem of straightening the wrists and arms has not been solved. Combining the ancient oriental's Buddhism Mudras and Chinese finger calculation method, we proposed a new keyboard operating mode. This kind of keyboard could be worn on fingers, and every finger prominence represents a letter input button. The information could be input by touching the special keyboard material which could transfer perceive and record press signals in position magnitude and direction. In addition, the design of number keyboard and mouse integration was also analyzed and discussed in this paper.

Keywords: keyboard design, ergonomics, input device, finger calculation method.

1 Introduction

With the widely application of IT technology, people spend long hours in front of computers, as well as on using the keyboard and mouse.

The normal 104 keyboard needs a particular position, which can not be optionally changed. When people use the keyboard, the hands, wrists, arms are all under physical stress. Working at the computer for long periods, hand, wrist, and arm symptoms can range from occasional soreness or stiffness to the debilitating carpal tunnel syndrome. If things go on like this, it is harmful for your health and may cause a series of wrist or knuckle disease such as peritendinitis [1].

Alan Hedge, professor of the human factors laboratory at Cornell University, warns that the risk of repetitive stress injuries-more broadly known as musculoskeletal disorders (MSDs)-increases if the computer is used for just 1 hour a day. For people who spend 4 hours or more in front of the computer each day-and that's almost every office worker in America-the risk of injury is nine times greater According to the U.S. Bureau of Labor and Statistics, MSDs account for 26.2 percent of all workplace injuries-that's 1.8 million workers [2].

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Therefore, it is necessary to design a new kind of keyboard usage mode to free people's twisted, strained, downward hands and arms, which also should guarantee the input validity and convenience.

2 The Analysis and Comparison of Ergonomic Keyboards

The designers and manufacturers have apparently noticed the problem, and developed a wide variety of ergonomic keyboards.

An ergonomic keyboard is a computer keyboard designed with ergonomic considerations to minimize muscle strain and a host of related problems. Though there are many kinds of ergonomic keyboards on the market in different shapes, sizes and colors, there are two types are much more popular, one is the "Wave" or "Curved" key layout ,like Microsoft Natural Elite™ (Fig.1), the other is the split keyboard, like the Goldtouch Keyboard (Fig.2).

Fig. 1. Microsoft's wireless ergonomic keyboard gives those weary fingers a rest, while Logitech builds a better mouse using laser beams. It's got all sorts of handy buttons that streamline common operations like launching favorite applications and documents [3].

Fig. 2. The Goldtouch keyboard features a literal split-key design, and the two halves of the keyboard actually separate but stay connected by a pivot ball at the top center. This allows the user to position each section in the best possible location, for maximum ergonomic comfort and relief [4].

Just as most ergonomic keyboards in the market, Microsoft keyboard tried to realize straightening the wrists and arms through changing the keys arrangement, but that means more materials, a higher price and more working space. Moreover, it is not very artistic, you can not imagine an office lady use it with a pair of swinging elbow.

The split keyboard separates and pivots from one central location at the top and it allows you to lock each half into an infinite number of positions. Besides being unconventional (okay, just plain weird-looking), the split-keyboard design was intimidating even for expert touch-typists, but especially for hunt-and-peckers.

Besides Microsoft, Goldtouch, other companies also gave a good try on ergonomic keyboard, however the problem of straightening the wrists and arms has not be solved. Taking Curved mound ergonomic keyboard for example as shown in Fig.3.

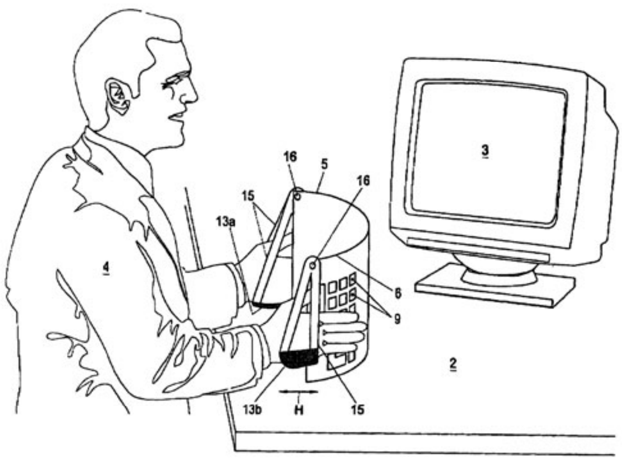

Fig. 3. Curved mound ergonomic keyboard is designed by Te Maarssen, Johannes Wilhelmus Paulus and Shankar, Vineet

The user can keep his forearms in a very favorable position, with the hands extending likewise in a substantially vertical direction. The operation sides can substantially face away from each other. As a result, the user can place his arms and hands in a very natural position during use of the keyboard, with palms of the user's hands more or less facing each other [5].

However the Curved mound ergonomic keyboard is increased in size like an accordion, and it may obstruct the view of the users. Moreover, it is very difficult for beginners to learn to use, because you cannot see all the keys. Thus, those kinds of questions keep this design staying in the lab.

The disadvantages of some ergonomic keyboards are clear. For most computer user who is familiar with the traditional key board, it may take them a little practice to get used to, and many people don't want to go to the trouble of adjusting. In fact, some keyboards may take more space on the computer table. Some ergonomic keyboards are so expensive that people don’t want to pay for that.

3 Inspiration form the East

One the trend of the modern world is ,When plagued by the computer and modern science and technology, people like to ask for the old oriental culture, such as yoga. In Indian, there is term of classical dance called "Hasta Mudra" (hasta is Sanskrit for hand). In the Buddhist tradition , gestures of hands were given a completely different meaning, called Mudras, here are some examples as follow.

Fig. 4. The Gesture of Teaching (Dharmacakra Mudra) with both hands in front of the breast, tips of the index finger and the thumps touching. And the Gesture of Debate explaining the Buddha's teachings (Vitaka Mudra) with the hands raised and the tips of the forefingers and the thumbs touch each other [6].

Do you know how ancient Chinese calculated? There is a Chinese idiom, counting on one's fingers. That means people can communicate with the sky by counting their fingers. In fact, it is just a simple timing method. In old China, people choose 10 Chinese characters to represent the sky, and another 12 characters to represent the land, combining them together, get 60 specific combination words. Thus, each year, each month, each day, each time can be named after these 60 combination words. Chinese believed that different time may represent the good and bad fortune, only those talented persons can understand how to calculate the time and tell the fortune. How did the old Chinese calculate? All secrets are on the fingers.

Fig. 5. Based on Chinese finger calculation method, these twelve positions on fingers of hand are corresponding to the twelve characters of land

The gestures are mainly acting by touch between them and the other four fingers belly in turns with the palm up. We found that these gestures just consistent with the requirements of our demands for healthy input mode without twisting forearm muscles. In a way the combination of hands and fingers is a completely natural calculator and an ergonomic keyboard, it's so natural that you can not even feel that, and it will never cause any injuries. The hands are the true ergonomic keyboard. Therefore we proposed a design called 'all in hand keyboard'.

4 All in Hand Keyboard Design

Perhaps one day in the future, text can be inputted bare-handed in stead of by keyboard. However, it depends on the development of technology. Fortunately, we have found a new material to realize our concept about 'all in hand keyboard'. There's a new keyboard for tiny devices that makes lots of sense - the ElekTex Smart Fabric keyboard is designed for Smart phones, PDAs and handheld devices, is lightweight, portable and wireless [7]. It is made of ElekTex Fabric, using blue tooth technology which enables wireless connection to make your using process more relax and enjoyable. So it can be worn on hand.

This keyboard designed by us looks like a pair of gloves. Whenever working on the computers, you wear the gloves, then move the thumbs, you can input.

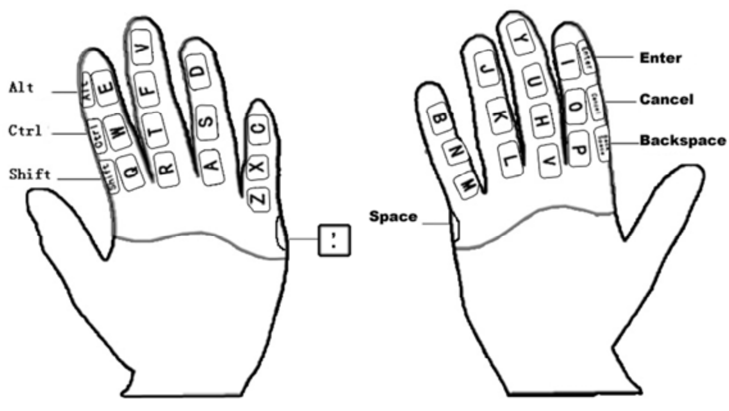

Fig. 6. All in hand keyboard is consisted of keys (based on the typical keyboard layout), and signaling device (using Bluetooth wireless technology). Keys, signaling device, and computer are connected. All the keys are located on the fingers.

In fact, all the keys are pressure sensor which is installed in one pair of glove. And this pair of glove is made of conducting layer and protective layer, each hand. A pair of glove makes a set of standard keyboard.

The keys on the glove of left hand. On the forefinger are Q|,W, E and shift, ctrl, alt keys; On the middle finger are R, T ,F keys; On the ring finger are A, S, D keys; On the little finger are Z, X, C keys; and on the root of the little finger is the punctuation key. Thumb is for operation.

The keys on the glove of right hand. On the forefinger are I, O, P and Enter, Cancel keys; On the middle finger are Y, U, H, V keys; On the ring finger are J, K, L keys; On the little finger are B, N, M keys; and on the root of the little finger is the space key. Thumb is for operation as well.

Comparing with the QWERTY keyboard, the three rows of letter keys are rearranged to four rows, and the positions of keys have not changed much so as to help uses to get used to the new input way.

In addition, we put the enter key and the cancel key on the forefinger of right hand, half for easy to use, and half to work in conjunction with the mouse, which is offered in the following sections.

5 Design of Number Keyboard and Mouse

All in hand keyboard should be used on kinds of electronic devices. Here are two examples.

5.1 Number Keyboard

The number keyboard is widely applied in the electrical appliances remote control, the handset, the computer as well as in many instruments and meters.

Fig. 7. This number keyboard can be worn on a hand, and takes person's finger joint as keyboard's key position, switching twelve basic key positions, and the functional key position, can realize all the function of input

On the forefinger are 1, 2, 3 keys; On the middle finger are 4, 5, 6 keys; On the ring finger are 7, 8, 9 keys; On the little finger are *, 0, # keys. Thumb is for operation as well. This set of keys, arranged like a common number keyboard, will make uses know it very well.

5.2 Mouse

Nowadays computer operations rely increasingly on mouse. It is a good idea to combine mouse with all in hand keyboard, and mouse also can be used separately.

Fig. 8. This design takes the first joint of forefinger as the touchpad of a laptop computer. Clicking on the left side is OK, and clicking on the right side is cancel.

ElekTex Smart Fabric can locate the position of a point of pressure, such as a finger press, thanks to its unique X-Y positioning capabilities. If there was enough accuracy, we can control the pointer on the area of one square centimeter on the forefinger.

Because of the material characterization, the system works even if the fabrics folded, draped or stretched. A single switch can also be used to provide 'switch matrix' functionality.

6 Conclusion

The human development history might be regarded as a tool's history, the writing tools also recorded the progress of civilization

Perhaps we may imagine the earliest writing tools is man's finger, then coming up with the branch, the bamboo knife, the writing brush, the quill pen, the fountain pen, the pencil, and so on. All these are similar with ours fingers. In modern society, people get used to type the information in the computer though the keyboard instead of writing them down on a piece of paper. However the new "writing" tools bring discomforts and injuries as well. Thus we try to seek for a kind of more friendly keyboard, the answer is already in our hands.

Inspired by the Oriental Civilization, we found the combination of hands and fingers is a completely natural calculator and an ergonomic keyboard. Along with the development of blue tooth technology, wireless connection with computers is becoming very easy, and the electronic fabric technology is making the hard electronic equipment much softer. All these could make the design of All-in-hand gloves keyboard become true.

All-in-hand is hoping to break through the hedge among keyboard, mouse, handset and faraway control, making everything possible by touching fingers.

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References

1. Franchi, M., Quaranta, M., De Pasquale, V., Macciocca, M., Orsini, E., Triré, A., Ottani, V., Ruggeri, A.: Tendon crimps and peritendinous tissues responding to tensional forces. EJH - European Journal of Histochemistry 51, 9–14 (2007)
2. Allbritton, C.: Ergonomics with flair. Popular Mechanics 180(1), 28–29 (2003)
3. Lewis, P.: Gadgets-Microsoft's wireless ergonomic keyboard and Logitech's laser-beam mouse. Fortune International 150(5), 26–27 (2004)
4. Ergonomic Keyboard: Computer Keyboards Designed to Prevent Repetitive Strain Injury, http://www.ergonomickeyboards.org/
5. Te Maarssen, J.W.P., Shankar, V.: Keyboard, United States Patent 6822854 (2004)
6. Buddhist Art and Architecture, http://www.buddhanet.net/
7. Chang, J.: G-tech smart- fabric wireless keyboard. Sales and Marketing Management 159(2), 38 (2007)

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