Personalised Tiling Paradigm for Motor Impaired Users

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Abstract

This paper presents an investigation that was carried out to design and develop a paradigm for motor impaired users to navigate a computer screen. And also test whether the improvements obtained using tiling with Cyberlink™ can be transferred to other devices. Many motor impaired users have difficulty with mouse movements and holding the cursor at a precise position on a computer screen to highlight an icon or launch an application. This paper discusses an investigation carried out in designing and testing an accessibility program for users with motor impairment. The researcher drew motivation for this study from the previous research designing interfaces for the brain injured and using the Cyberlink™ as the assistive device. The rationale for the design is presented, along with details of its implementation.

1.0 Introduction

Motor impairment can be defined as "a loss or limitation of function in muscle control or movement or a limitation in mobility. This may include hands that are too large or small for a keyboard, shakiness, arthritis, paralysis, and limb loss, among other difficulties [28]." Motor impairment could cause irrational movements of the cursor when some of this group of users try to use a pointing device. The cursor can move around the computer screen without much control from the user, which brings frustration to the user [29]. This necessitated in the need for controlling cursor, so that the user can use it with full control. The researcher drew enthusiasm for this study from the previous research designing interfaces for the brain injured carried out at the University of Sunderland [9 - 16]. As medical technology not only extends our natural life span but also leads to increased survival from illness and accidents, the number of people with disabilities is constantly increasing. At the 56th Session of the UN Commission on Human Rights in Geneva (April 2000) Bengt Lindqvist stated: "It will take a long time to change this pattern of behaviour, which is deeply rooted in prejudice, fear, shame and lack of understanding of what it really means to live with a disability". At the 52nd meeting of the Third Committee, on 29 November 2001, the representative of Mexico introduced a draft resolution on an international convention on the rights of persons with disabilities, which the Committee recommended for adoption by the General Assembly. General Assembly resolution 56/168, entitled "Comprehensive and integral international convention to promote and protect the rights and dignity of persons with disabilities", was adopted on 19 December 2001 [27]. Assistive technology may be helpful in allowing the motor impaired people some form of control for a personal computer, allowing them to study, work, communicate or recreate but more work needs to be done to seamlessly integrate assistive technology to computer interfaces.

Various research methodologies were considered before the choosing the appropriate one for this investigation [35, 37, 40, 7, 5, 17]. One method of conducting scientific research in a new area of study with a new tool is to use the tool with a group of participants and to collect data from the performance of tasks with the tool [19, 30]. The data then display trends that allow other questions to be formed. These questions can be used to form a hypothesis that may be tested in further experiments. This method is known as naturalistic inquiry [3]. Research was carried out using Naturalistic Inquires, Formative research methods and Empirical Summative research methods. The approach used for this research was one of developing a prototype interface using non-disabled people as test subjects, then evaluating the interface with brain-injured participants. This allowed better feedback for faster interface development.

The experiment involved reaching targets on a screen in a controlled manner using joystick and tracker ball using the developed artefact. Cyberlink™ was used as the controlling device with data obtained from previous research [9 - 16]. Formative and summative evaluation was carried out with able-bodied participants to obtain optimum data for time spent on each tile, dimensions of tile and gap between tiles. Results obtained were recorded and analysed. The results obtained with the able-participants were used as the default settings for the evaluation with disabled participant.

2.0 Assistive Technology for motor impaired

There are various assistive technologies for motor impairment here are some examples:

- Trackball – Upturned mouse, rolling the mouse ball with fingers [22]
- Joystick – A stick looking device that can be moved around in all directions to simulate a mouse [25]
- Eye-tracking – a system that follows the movements of the eyes [26]
- HeadMouse™ - using wireless optical sensor that transforms head movement into cursor movement on the screen [24].
- Tonguepoint™ - a system mounted on mouth piece [39].
- Sip/Puff Switch - a two position switch by a simple sip or puff [24]
- Software such as Sticky Keys that make difficult keystrokes more accessible [28, 20]
- Voice recognition systems [28, 20]
- Text entry systems to help enter messages with fewer keystrokes [28, 20]
- Cyberlink™ - a brain body actuated control technology that combines eye-movement, facial muscle and brain wave bio-potentials detected at the users forehead [21, 31].

Assistive technologies are used as determined by individual needs. Motor impairment assessments can help the choice of assistive devices [23, 44]. All the devices above have their advantages and disadvantages [32, 41]. A user with cerebral palsy will not have good motor abilities to operate the 'Tonguepoint™'. A user with spinal vertebrate fusion may not be able to turn his or head and the HeadMouse™ will be of no use.

3.0 Experimental Methods

The experiment involved reaching targets on a screen in a controlled manner using joystick and tracker ball, as pointing devices. Cyberlink™ was used as the controlling device with data obtained from previous research [14]. Formative and summative evaluation was carried out with able-bodied participants to obtain optimum data for time spent on each tile, size of tile and gap between tiles. Results obtained were recorded and analysed. The results obtained with the able-participants were used as the default settings for the evaluation with disabled participant.

3.1 Methodology

Wide ranges of research methods are used in Human-Computer Interaction [17]. Research was carried using Naturalistic Inquires [3], Formative research methods and Empirical Summative research methods [4]. The main task here was to produce an artefact that delivered improved performance in specific settings, an artefact that can produce individual profiles and use sophisticated input control algorithm [14]. An evolutionary iterative development methodology was used to get the best possible version [1, 8].

3.2 Experiment

There are wide differences in capability, both between individuals and at different times for the same individual, for many groups of impairments [14]. This indicates that some form of adaptation to individual needs may improve accessibility of each individual user [42]. The rationale for the artefact developed here for motor impaired, uses the "Personalised Tiling Paradigm" used successfully for the brain-injured participants [14] in previous research. The artefact developed for the motor impaired is described in this section.

Adaptation can take three forms [42].

- *Adapted* user interface – adapted to end user at design time [9 – 12]
- *Adaptable* user interface – the end user can make changes (this study)
- *Adaptive* user interface – the dynamic behaviour can change at run time [13, 14]

This investigation was conducted in two phases. Phase one was the development phase. The main task in this phase was to produce an artefact that delivered improved performance in specific settings, an artefact that can produce individual profiles. An evolutionary iterative development methodology was used to get the best possible version. Iteration was driven by Phenomenological formative evaluation [34, 38] then mainstream empirical methods were used for experimental summative evaluation [33, 36, 2, 18]. The iterative approach used was that of developing a prototype [1] interface using non-disabled people as test subjects using qualitative and quantitative evaluation. This allowed better feedback at the development stage and faster development. The interface developed here was to work with any assistive device used by motor impaired computer users. Able-bodied participants were used to test various versions of the interface program to derive the final interface. Phase two of this investigation was the evaluation phase with the disabled participant to complete the final testing process [6].

The programming language used this time was Visual C++. The interface program controlled the movement of the cursor on the computer screen and stopped any irrational uncontrolled steering of the mouse on the computer screen. In order to support 'Personalised Tiling Paradigm', the computer screen was divided into tiles (Fig. 1), which support discrete jumps from one tile to the next predicted tile on the user's route and configuring a time delay on each tile (Figs 2 & 3). The width and height tiles, gap between tiles and time delay on each tile were configured to suit each individual user (Figs 2 & 3). Each user was able to have an individual profile to suit their disability and assistive device. The interface program worked in the background so the user did not see anything different on the computer screen but the movements of the cursor was controlled for any irrational movements using the individual personalised tiling paradigm.

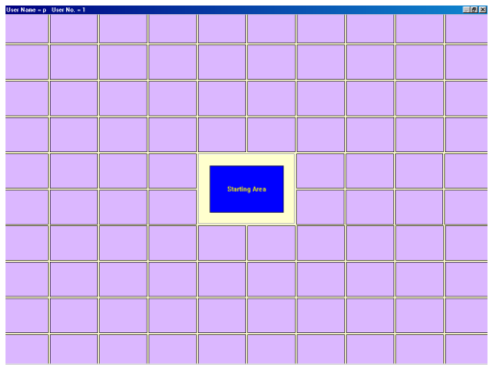


Figure 1: computer screen split into tiles transparently
(This diagram shows the process that takes place transparently to user)

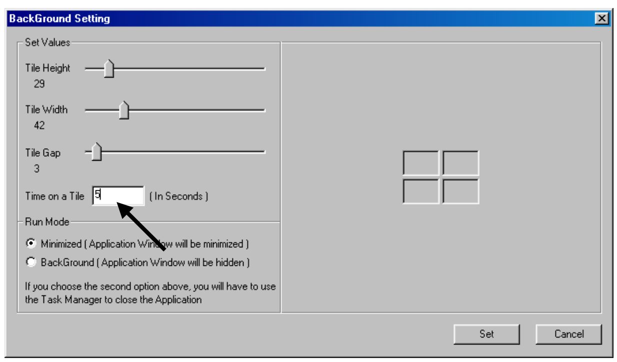


Figure 2: Configuration of time delay on each tile

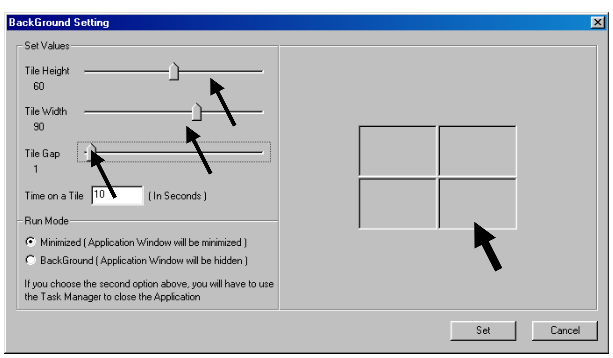


Figure 3: Configuration of Tile Height, Tile width and Tile Gap

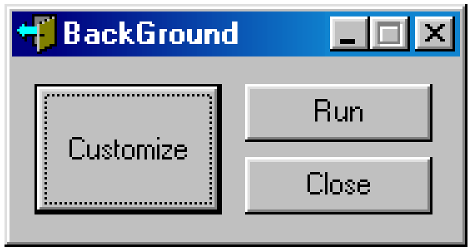


Figure 4: Opening window

The interface program operates using the following algorithm.

- The user launches the program which opens as shown in Fig. 4
- The user chooses 'customize', which open the window as shown in Figs. 2 and 3
- Customize window is utilised to set individual tile dimensions, gap between tiles and delay in each tile as shown in Figs. 2 and 3
- Then a radio button is chosen to either keep the program window in the task bar or completely hide it from the screen as shown in Figs. 2 and 3
- Pressing the 'Run' button will run this program in the background controlling the cursor navigation on computer screen
- Pressing the close button (Fig. 4) will quit the program and return to uncontrolled cursor navigation

3.3 Results

Phase one of the experiments was conducted with ten able bodied participants (four females aged 11 to 40 and six males aged 14 to 52) and phase two was conducted with two motor impaired cerebral palsy participants (male 48 yrs old and female 56 yrs old). The results obtained in phase one was used as optimum settings for evaluation of the interface in phase two.

3.31 Phase One

The aim of this phase was to find the optimum dimensions for the tiles, delay in each tile and gap between tiles. Two pointing devices (Cyberlink™ was used as the controlling reference);

- Tracker Ball
- Joystick

were used with different dimensions for tiles (5 x 5, 15 x 10, 20 x 15, 30 x 20, 35 x 22.5 mm^2), delay (1, 3, 5, 10 sec) in each tile and gap between tiles (04, 1.2, 2, 4, 8 mm) [41, 40, 43]. The participants also had to complete a formative evaluation by trying to reach the targets in an allocated time interval using one pointing device at a time and indicate their preferences on the five variations of the interface. The following date was recorded to give summative feedback from each participant.

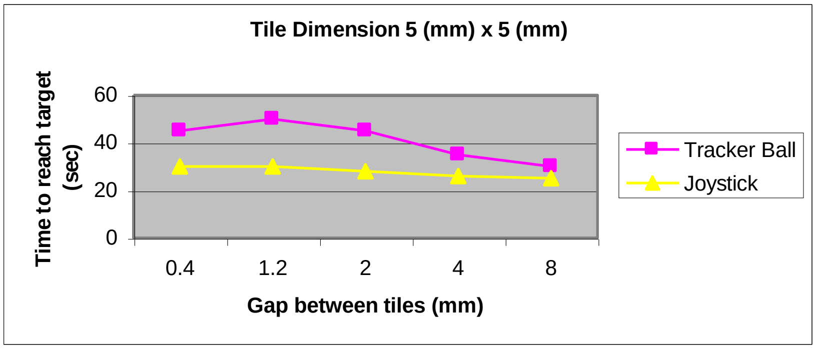
- Time taken to reach the targets
- Dimensions of tiles, delay in each tile and gap between tiles
- Any reconfiguration to the original settings

The results obtained showed that as the delay increased the time to reach the target also increased (table 1). This was consistent with the previous results obtained using Cyberlink™ [14]. Hence the optimum time on each tile was accepted as one second.

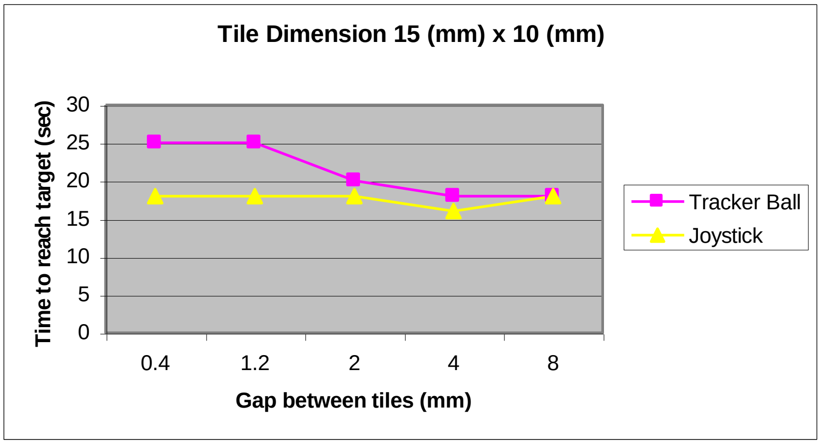
Table 1: time to reach target versus delay (tile 15 x 10 mm², gap between tiles 1mm)

Delay in each tile	Time taken to reach target
1 sec	20 sec
3 sec	35 sec
5 sec	45sec

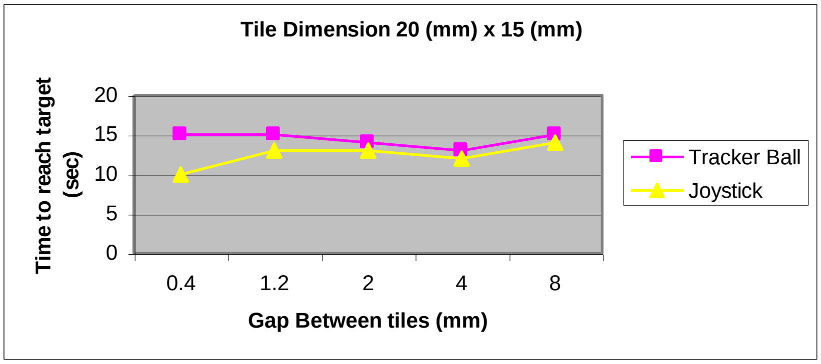
The next part of the experiment was to find the optimum dimensions for the tiles and the optimum gap between the tiles. Tracker ball and the joystick were used with various tiles and various gaps between tiles. Graphs 1 to 5, show the average time to reach target versus gap between tiles for each of the different tile settings.



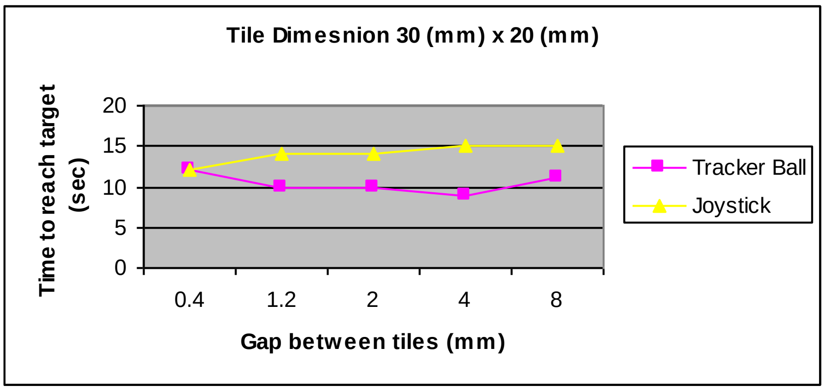
Graph 1: Data for tile 5 x 5 mm²



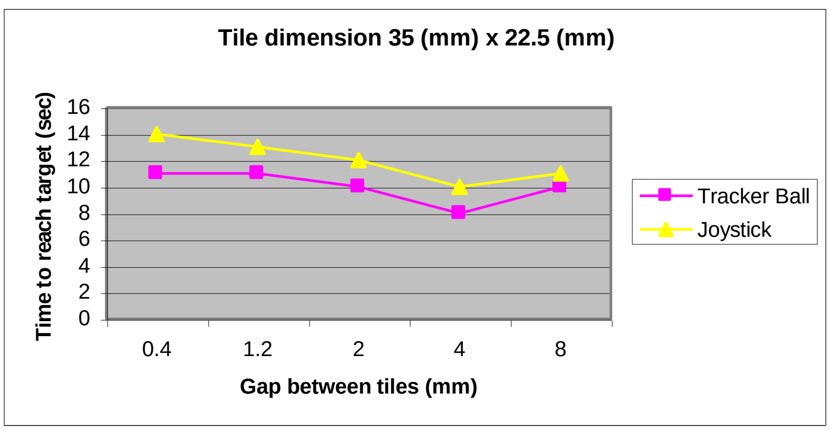
Graph 2: Data for tile 15 x 10 mm²



Graph 3: Data for tile 20 x 15 mm²



Graph 4: Data for tile 30 x 20 mm²



Graph 5: Data for tile 35 x 22.5 mm²

The graphs 1 to 5, show that the optimum tile dimensions is the largest tile (35 x 22.5 mm²) and the optimum gap between tiles is 4 mm. Hence the optimum data for motor impaired user, using summative evaluation was 35 x 22.5 mm² tile, with 4 mm gap between tiles and 1 second delay in each tile. The formative evaluation using the able bodied participants also yield the same results for the easiest interface.

Table 1: optimum results obtained from pervious research for Cyberlink™

Tile width	Tile Height	Gap between tiles	Delay in each tile
36 mm	12.5 mm	4mm	1 sec

The data from previous research for Cyberlink™ is shown above in table 1. The result obtained in this study is consistent with the previous research conducted by the researcher with Cyberlink™ for non-verbal paraplegic participants. The only difference is the smaller tile for the Cyberlink™ interface to control the cursor, to stop picking up noise due to unwanted bio-potentials.

3.32 Phase Two

Phase two of this study was conducted by visiting participants at their homes and letting the motor impaired participants use the navigation program at their environment, using their individual pointing device. It should be noted that the investigator obtained all permissions and informed consents from participants before research began. Two one-hour visits per participant were conducted and data recorded. Data collected from each participant shows the improvement made by the personalised tiling paradigm (Table 2). Optimum setting obtained in phase one was used as the starting configuration for all participants with the provision of changes if and when need. The times taken to reach a target on screen was recorded using with and without the navigation program and the progress was noted.

Table 2: Results obtained in Phase Two

Part. No	Pointing Device used	Average time to reach a target with navigation program (secs)	Average time to reach a target without navigation program (secs)
1	Tracker Ball	35	60
2	Joy Stick	32	45

4.0 Conclusions and discussions

This investigation shows how Personalised Tiling Paradigm can be used to enhance navigation of a computer screen by controlling the movement of pointing devices and help the users navigate with their individual personalised profile according to their disability and their assistive device. The researcher would also like to suggest further investigation should be done to investigate whether using an input algorithm to accelerate the cursor towards a target or addition of artificial intelligence would further increase the performance of this interface program. Another area to explore will be a scanning mechanism for switch users to scan the tiles until a target is reached. Any study in partnership with computer scientist and medical professionals will open wide avenues of research in rehabilitation for motor impaired computer users. The study also shows the consistency of between optimum results of this research and the previous work by the researcher. The experiment shows that the improvement using tiling with Cyberlink™ can be transferred to other devices such as tracker ball and joystick. More evaluation is being carried out for phase two of this investigation to achieve a statistically significant result.

5.0 Acknowledgements

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References

1. Abowd, G., Bowen, J., Dix, A., Harrison, M., Took, R., (1989), User Interface Languages: a survey of existing methods, Oxford University Computing Laboratory, Programming Research Group, October 1989, UK.
2. Ascot, J., Zhai, S., (2003), Refining Fitts' law models for bivariate pointing, Human Factors in Computing Systems: CHI 2003 Conference Proceedings, April 2003, Florida, 193 - 200.
3. Burns, G., Grove, S. (1997), The Practice of Nursing Research, Conduct, Critique, and Utilization, W.B. Saunders Company, Philadelphia, Pennsylvania, pages 70-80
4. Card, S., Moran, T., Newell, A., (1983) "The Psychology of Human-Computer Interaction" Lawrence Erlbaum Associates Publishing, Hillsdale, New Jersey
5. Chatrian, G., Bergamasco, B., Bricolo, B., Frost, J., Prior, P., "IFCN recommended standards for electrophysiological monitoring in comatose and other unresponsive states. Report on IFCN committee", (1996) Electroencephalography and Clinical Neurophysiology, vol. 99, pages 103-122
6. Chen, C., Ke, H., Wu, F., (2003), Disability Participation to Design an Assistive Product for Cerebral Palsy Patient, June 2003, HCI International 2003, Crete.
7. Dix, A, J., Finlay, E. J., Abowd, G. D and Beale, R., Human-Computer Interaction, pages 105-139 Prentice Hall, 2nd Edition, 1998
8. Dix, A., Finlay, J., Abowd, G., Beale, R., (1998) Human-Computer Interaction, 2nd Edition, Prentice Hall, UK, 205 – 212
9. Doherty E.P, Cockton G., Bloor C. & Benigno, D., "Mixing Oil and Water: Transcending Method Boundaries in Assistive Technology for Traumatic Brain Injury," in *Conf. on Universal Usability*, eds. J. Sholtz and J. Thomas, ACM, pp 110-117, 2000.
10. Doherty E.P, Cockton G., Bloor C. & Benigno, D., "Improving the Performance of the Cyberlink Mental Interface with the Yes/No Program," in *Proc. CHI 2001 Conference*, Eds.
11. Doherty E.P, Cockton G., Bloor C., Rizzo J. and Blondina, B., "Yes/No or Maybe – Further Evaluation of an Interface for Brain-Injured Individuals," in Interacting with Computers, 14(4), 341-358, 2002.
12. Doherty, E, Bloor, C., Cockton, G., Engel, W., Rizzo, J., Berg, C., (1999a) Cyberlink – An Interface for Quadriplegic and Non – Verbal People, Pages 237-249, Conference Proceedings, CT99 3rd International Cognitive Technology, Aug 11-14,1999 in San Francisco, Proceedings Available at http://www.cogtech.org/CT99, Published by M.I.N.D. Lab, Michigan State University
13. Gnanayutham, P., Bloor, C and Cockton, G., AI to enhance a brain computer interface – June 2003, HCI International 2003, Crete.
14. Gnanayutham, P., Bloor, C., Cockton, G., Discrete Acceleration and Personalised Tiling as Brain-Body Interface Paradigms for Neurorehabiliation - April 2005, CHI 2005
15. Gnanayutham, P., Bloor, C., Cockton, G., Robotics for the brain injured: An interface for the brain injured person to operate a robotic arm – October 2001, *ICCIT'2001*, New York.
16. Gnanayutham, P., Bloor, C., Cockton, G., Soft-Keyboard for the disabled - July 2004, ICCHP2004, Paris.

17. Greenberg, S., Thimbleby, H., (1992), "The Weak Science of Human-Computer Interaction." *Proceedings of the CHI '92 Research Symposium on Human Computer Interaction*, Monterey, California
18. Hawthorn, D., (2000), Possible implications of aging for interface designers, Interacting with Computers, Elsevier Publication, 12 (2000), 507 – 528
19. Hickey, A.M., O'Boyle, C.A. and McGee, H.M (1992), Head injury: looking beyond the patient. *Irish Medical Journal* 84, p.109-110
20. http://shapevle.cant.ac.uk/slemotorimpairment.htm, retrieved 16th February 2005
21. http://www.brainfingers.com/, retrieved 14th February 2005
22. http://www.logitech.co.uk/, retrieved 14th February 2005
23. http://www.onbalance.com/neurocom/protocols/motorImpairment/index.aspx, retrieved 16th February 2005
24. http://www.orin.com/index.htm, retrieved 14th February 2005
25. http://www.semerc.com/, retrieved 14th February 2005
26. http://www.smi.de/, retrieved 14th February 2005
27. http://www.un.org/esa/index.html, retrieved 14th February 2005
28. http://www.usabilityfirst.com/glossary/term_262.txl, retrieved 16th February 2005
29. http://www.useit.com, retrieved 14th February 2005
30. Ilmonen, T., Kontkanen, J., (2003), Goal-Oriented vs. Open-Ended Applications, June 2003, HCI International 2003, Crete.
31. Junker A., United States Patent, 5,692,517, (1997).
32. Kalcher J., Flotzinger D., Gölly S., Neuper G., and Pfurtscheler G. (1994) Brain-Computer Interface (BCI) II, Proc. 4th Int. Conf. ICCHP 94, Vienna, Austria 171-176
33. Kleinig, G., Witt, H., (2000), The Qualitative Heuristic Approach: A Methodology for Discovery in Psychology and Social Sciences, Rediscovering the Method of Introspection as an Example, Forum: Qualitative Social Research, Volume 1, Issue 1, January 2000
34. Nielsen, J., (1995), Technology Transfer of Heuristic Evaluation and Usability Inspection, Keynote at Interact'95, June 1995.
35. Norman, D. A., The Psychology of Everyday Things, 1988, Basic Books, New York
36. Omery, A., (1987) Qualitative research designs in the critical setting: review and application, Heart & Lung, 16(4), 432 – 436
37. Preece, J., Rogers, Y., Benyon, D., Holland, S and Carey, T., Human-Computer Interaction, 1999, pages 45-51, Addison Wesley, United Kingdom
38. Preece, J., Rogers, Y., Sharp, H., (2002) Interaction Design, Wiley, USA
39. Salem, C., Zhai, S., An Isometric tongue pointing device, *Proc. Of CHI* 97 (1997) pp 22-27
40. Shneiderman, B., Designing the User Interface, pages 14-27, 54-61, Addison Wesley, 3rd Edition, 1998
41. Soede, M., (2003), Issues in Human Computer Interaction seen from an Assistive Technology perspective, June 2003, HCI International 2003, Crete.
42. Stephanidis, C., "Adaptive Techniques for Universal Access", 2001, User Modeling and User-Adapted Interaction II: 159-179, 2001, Kluwer Academic Publishers, Nederland
43. Ware, C., (2000), Information Visualization, Morgan Kaufman Publishers, USA, 203 – 213
44. Wu, T. Meng, L., Wang, H., Wu, W., Li, T., (2002), Computer Access Assessment for Persons with Physical Disabilities: A Guide to Assistive Technology Interventions, July 2002, ICCHP 2002, Austria