Artificial Intelligence to Enhance a Brain Computer Interface

Paul Gnanayutham
De Montfort University MK
Hammerwood Gate, Kents Hill
Milton Keynes, MK7 6HP
United Kingdom
pg@dmu.ac.uk

Chris Bloor and Gilbert Cockton,
University of Sunderland
St Peter's Way
Sunderland, SR6 0DD
United Kingdom
firstname.lastname@sunderland.ac.uk

Abstract

This paper discusses an investigation carried out in designing and testing neurorehabiliatory communication interfaces for nonverbal quadriplegic and other clinically brain damaged persons. For many years this group of people could not communicate with the outside world and this was accepted as norm. This important study collected the information from neurologically disabled persons by conducting simple communication tasks and created interfaces for communicating with the outside world for the very first time. The study was conducted in two phases the first phase being an exploratory study and second phase being the new improved version taking into account the results from the first phase. It was proved from the first phase of the study that every disabled person is an individual and cannot be grouped in any way when designing interfaces. It was also discovered that the users found the brain body interface impossible to use without artificial intelligence support to steer the cursor on a computer screen.

1 Introduction

This paper deals with this category of disability and provides means to communicate reliably for the very first time (the best existing work is not reliable [4]). Over the last four decades advances have been made in the design and construction of aids and appliances for disabled people. Having considered various assistive devices this research chose the Cyberlink™ as the best device for the brain injured quadriplegic nonverbal participants. The design process involved using the Cyberlink™ with appropriate programming interfaces. Various interfaces were designed to cater for different brain injured groups. These interfaces were tested with participants. This was the first phase of this project, which proved beyond any doubt, that every disabled person regardless of having a particular type of disability was still an individual with his or her own characteristics. Hence each one needed an individual profile not a group profile based on some generic clinical syndrome or diagnosis. This characteristic was included in the second phase of the design. This necessitated giving the disabled user a target test, where targets appeared at random, at different parts of the screen, and the user has to move the mouse cursor on to the target at a within particular time specified by the program. Areas for placing the targets and the number of targets could thus be chosen to cater for each individual user, giving his/her individual profile.

2 Brain Body Interface

Assistive technology may be helpful in allowing these people some form of control of a personal computer allowing them to communicate or recreate. Assistive technologies fall into various categories. One of the categories is Brain Body Interface, which may be the only technology suitable for brain injury [5]. There are many brain body interfaces; e.g.

- HeadMouse™ - using wireless optical sensor that transforms head movement into cursor movement on the screen [15].
- Tonguepoint™ - a system mounted on mouth piece [13].
- Cyberlink™ - a brain body actuated control technology that combines eye-movement, facial muscle and brain wave bio-potentials detected at the users forehead [8].

All the devices above have their advantages and disadvantages. 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. Only the cyberlink™ seems to be applicable to the brain injured because it uses a combination of signals [6]. The research only concentrated on communications for the brain injured, hence dealt with the electric signals emanating from brain waves, muscle contraction, eye movement or some combination thereof. Having considered various assistive devices this researcher chose the Cyberlink™ as the best device for brain injured nonverbal quadriplegic participants [3, 9, 10, 14].

3 Experimental Methods

This section deals with the methodologies used and the two phases of the investigation. Phase one was carried out in the following institutes Mother Teresa's Missionaries of Charities New Delhi, Vimhans New Delhi, Choithram Hospital And Research Centre Indore**.** Phase two of this investigation was carried out at the following institutes Holy Cross Hospital Surrey, Castel Froma Lemington Spa and at various private homes.

3.1 Methodology

The ethics boards at each institution approved these inquiries for the investigation of the Cyberlink as an assistive technology. It should be noted that the investigators obtained all permissions and informed consents from the institutions, participants, and/or their guardians before research began. A wide range of research methods is used in Human-Computer Interaction (HCI, [7]). For brain-body interfaces, methods range from experiments with unimpaired individuals on aviation tasks [12] to a blend of experiments and field studies [4]. The study reported here uses naturalistic inquiry [2] within field studies. Very little was known about the participants at the beginning of the research. The information available about the participants varied greatly, inconsistent, and unreliable. The cognitive level of the participants and their ability to perform tasks varied greatly from week to week. Contextual Inquiry and Design is a user-centred technique employed by industry to learn about the role people play in their organisational settings [1].

3.2 Participants

The participants had a diverse background of physical abilities ranging from no disability to severe motor impairment. All have formal assessments from large hospitals that diagnosed mental retardation or brain injury. The objective mental ability of some participants is unknown due to brain injury and can only be obtained from estimates of the attending personnel and from parents. The responsible physicians or their guardians were asked to provide approximate ratings Participants for the phase one of the study fell into these groups:

- Group 1 – Brain injured because of Cerebro vascular accident (Stroke)
- Group 2 – cerebral palsy with mental retardation with/without sensory deprivation
- Group 3 – highly spastic cerebral palsy with mental retardation
- Group 4 – persons with no physical or mental impairments that affect Cyberlink™ use
- Group 5 - (miscellaneous) – A case of severe Parkinson disease was included in the study

It was decided upon examination of resources, that thirty participants would be the maximum amount of participants that could be accommodated in the phase one of this study study. The results obtained from phase one was used as the foundations for the second stage of this investigation. The ten participants for phase one could be assigned to one of three groups:

- Group 1 – Brain injured because of Cerebro vascular accident (Stroke)
- Group 2 – Traumatic brain injury and brain stem fracture
- Group 3 – Miscellaneous

However each participant is an individual with little similarity to the other. Each participant was able to get an individual interface according to the target test results.

3.3 Phase One

The first program in this phase was to see whether the participant could move the cursor in all directions within a tunnel based program similar to that reported in [4]. It was found that most participants were able to do part of this controlled experiment but because there were various potentials being picked in their forehead by the Cyberlink™ the users were finding it almost impossible to control the cursor on a computer screen. This showed that there was a necessity to control the cursor. This finding brought in the second set of interfaces written in Visual basic. The idea here was to control the cursor and keep it in the maze. The participants were able to use this but it took a lot of effort, causing frustrations and fatigue. This suggested a need for Artificial Intelligence in this interface. This enabled the users to communicate using this simple interface and answers their questions for the very first time after the brain injury (Figure 1). The VB program analysed the direction of the cursor and moved the cursor along to help the user. The 'Yes/No Program' allowed motor impairment persons to answer leading questions put forward by the medical professionals, attending personnel or relatives. The interface has three-turn maze to reach the target and the cursor has been kept in a pipeline, which did not allow the cursor to move beyond the pipe. The doctors liked the maze because the brain injured person could be asked to navigate prespecified paths that demonstrated some form of control and intelligence [4]. Times taken to reach the target were recorded. The participant was asked to navigate the cursor to select the yes or no in relevance to the asked leading questions, which were randomly selected. Ten questions were randomly selected and asked randomly to different participants. A more sophisticated was also created for some of the participants to use simple phrases to communicate. This interface is shown in Figure 2.

Figure 1

Figure 2

3.4 Phase Two

This phase of the program was to solve problems encountered in the first phase. The programming language used this time was Visual C++. The first problem encountered was the unintentional movements of the cursor when brain body interface is used. The cursor moved around the computer screen without much control from the user, picking up EOG, EMG and EEG signals,

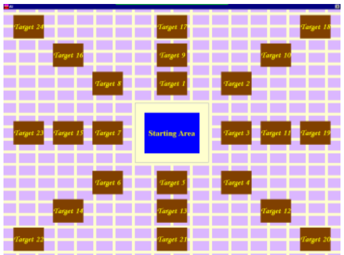

Figure 3

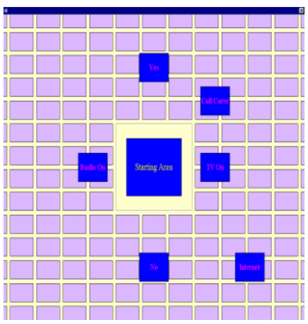

Figure 4

which brought frustration to the user. This necessitated in the need for controlling cursor, so that the user can take full control. This was done by splitting the computer screen into tiles and configuring the time spent on each tile, size of tile, gap between tiles, time to reach a target, etc., to suit each individual user. With this new interface the users were able to take full charge of the brain body interface Cyberlink and the control of the cursor. It takes a lot of effort for a disabled person using Cyberlink™ to move the cursor from a particular area of a computer screen to another using brain wave voltage, which are very small. This meant artificial intelligence had to be added to the Interface design. Single targets appeared randomly in different parts of the screen, the user had to reach each target in a given time interval. A user can have two to six targets at the final desktop depending on the severity of their disability. The targets are shown in (Figure 3). The final individual interface can look like Figure 4. Artificial Intelligence played a big part in the final design. Fuzzy logic sets were used to enhance this interface. And the final the design was tested with volunteer brain injured participants. The results obtained showed that some of the participants were able to communicate for the first time after their injury. The program itself was easier to use after adding artificial intelligence and running the target-testing program to create individual profiles for each user. As explained earlier the screen is split in to tiles with a gap between the tiles. The carer can choose the dimensions of the tiles, targets, time delay on each tile etc. This gives the opportunity to individually configure each interface. The only movement to be done by the users will be to jump from tile to tile. The users of this phase of the investigation were severely disabled, there was hardly any EOG and EMG, the researcher had to depend very much on EEG, which is the thought process. The program calculated the direction each time the user moves the cursor from tile to tile, if there is a target in that direction, the target blinks to indicate to the user the intended target and takes the cursor to the nearest edge of the tile in the direction of the target, this is repeated until the user reaches the target or moves the cursor to a tile touching the target, this minimises the effort needed by the user. If there are no targets in that direction, the fuzzy logic algorithm waits for further cursor movement by the user. The program chooses the target by calculating the minimum angle from the direction of the cursor, in case there is more than one target in the same direction. Figure.4 shows a typical interface, the targets can be programmed to say simple phrases such as YES/NO, launch applications or send signals to the parallel port. So a brain injured user can communicate, launch the Internet or send a signal to the parallel port and switch the light on.

3.0 Conclusions and discussions

This investigation shows how Artificial Intelligence can be used to enhance a Brain Computer Interface. By adding fuzzy logic the interfaces became communication devices for the severally brain injured giving them the first opportunity to communicate. More artificial intelligence can be added by using Knowledge base and also neural nets to discover any patterns than can be utilised to enhance the communications, thus creating neuro-fuzzy systems. The researcher would also like to suggest that the medical community could also investigate the use of the Cyberlink™ with persons of locked in syndrome as a tool to assess their consciousness level. Any study in partnership with computer scientist and medical professionals will open wide avenues of research in rehabilitation medicine.

4.0 Acknowledgements

Dr. Annapurna Sen, Dr. Ivan Jordanov, Ms. Penny Roper (Headway), Mr. Wishwa Weerasinghe and to the following institutes Mother Teresa's Missionaries of Charities New Delhi, Vimhans New Delhi, Choithram Hospital and Research Centre Indore**,** Holy Cross Hospital Surrey and Castel Froma, Lamington Spa.

References

1. Beyer, H., Holtzblatt K. (1998), Contextual Inquiry and Design, Morgan Kaufman Publishers,USA
2. Burns, G., Grove, S. (1997), The Practice of Nursing Research, Conduct, Critique, and Utilization, W.B. Saunders Company, Philadelphia, Pennsylvania, pages 70-80
3. Chatrian, G., Bergamasco, B., Bricolo, B., Frost, J., Prior, P. (1996), IFCN recommended standards for electrophysiological monitoring in camatose and other unresponsive states. *Report on IFCN committee, Electroencephalography and Clinical Neurophysiology*, vol. Pages 103-122
4. 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. J.A. Jacko, A. Sears, M. Beaudouin-Lafon & R.J.K Jacob, ACM 69-76, 2001.
5. 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.
6. 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.
7. 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
8. Guerrero, J., Leadbetter, S., Thurman, D., Whiteneck, G., Sniezek, J. (2000), A Method for estimating the prevalence of disability from traumatic brain injury
9. Junker A., United States Patent, 5,692,517, (1997)
10. Keirn, A., Aunon, J. (1990), Man-Machine Communication Through Brainwave Processing *IEEE Engineering in Medicine and Biology Magazine*, pages 55 – 57
11. Knapp, B., Lusted, H., Paatmore, D. (1995), Using the ElectroOcularogram As a Means of Computer Control, *Resna 95 Proceedings*, June 9-14th 1995, pages 699-701
12. Metz, S., Hoffman, B. (1997), Mind Operated Devices, *Cognitive Technology*, Vol. 2 Issue 1,Spring1997, Indiana State University, Terra Haute Indiana, pages 69-74
13. Nauck, D., Klawonn, F., Kruse, R. (1997), Foundations of Neuro-Fuzzy Systems, p. 103-117, John Wiley & Sons.
14. Origin Instruments. HeadMouse: Head-Controlled Pointing for Computer Access, 1998, from http//www.orin.com/access/headmouse/index.tm
15. Robinson, D. (1999) The technical, neurological and psychological significance of 'alpha', 'delta' and 'theta' waves confounded in EEG evoked potentials: a study of peak latencies, *Clinical Neurophysiology* (110) p1427-1434, Elsevier Science Ireland Ltd.,
16. Wenden, F.J., Crawford, S., Wade, D.T *et al* (1998), Assault, post-traumatic amnesia and other variables related to outcome following head injury. *Clinical Rehabilitation.* 12, p.53-63.