Computer-Brain Interface Device Experimental Research
Study of Ergonomy and Usability in Business Environment

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Keywords: BCI, EEG, Interface, Brain Waves, Commercial Devices, Epoc Headset, Business Application.

Abstract: This paper presents results of experimental research from 2011, performed on a group of volunteers and which aim was to properly explore the maturity of BCI devices to be integrated in business environment, e.g. office work. The testing scenarios and focus was aimed to verify if the current capabilities of the selected devices were sufficient in their ergonomic features and spectrum of functions to properly complement and in some case substitute the traditional ways of utilising keyboard and mouse by the users. The research focused also on ability to learn to use BCI device. The study led to identification of several ergonomic and hygienic areas which act as a hindrance for wide utilisation of these devices as a feasible way to provide an users input for the computer over a prolonged period of time.

1 INTRODUCTION

1.1 Aim of the Paper

The utilisation of electroencefalograhical (EEG) signals as a mean of communication between human and computer represents one of the greatest tasks within the borders of theory of signals research (Bazztarica, 2002). The crucial part of systems of communication known as BCI (Brain-Computer Interface) is the interpretation of EEG signals.

The electrical nature of human brain is known for more than one century and the first successful recording of human brain electric activity was performed by a German psychiatrist and neurologist, Hans Berger in 1924 (Berger, 1940). Berger utilised a galvanometer and electrodes created from a platinum wire, implanted under the test subject's skin.

Technology accessible to a broader spectrum of population is still in it's infancy, first economically affordable device together with dedicated software for the end users became available in 2009 (Dillow, 2010); (Hanlon, 2008).

These days with a 3 years long development and creation of several companies pioneering this marker, we have a spectrum of cheap devices that are affordable almost for everyone.

This paper summarises results of a brief study performed on a group of students during 2011 at University of Economics, Prague. The aim of this study was to assess the feasibility of this innovative way of interfacing with computer to substitute the traditional ways of interacting with computer. The research also focused on ability of the students to fulfil given tasks and we focused on the learning ability of the students.

1.2 BCI

We consider as a BCI technology such one that possesses an interface through which human EEG signal can be captured and transmitted to further processing (Berger, 2008). Alternative labels are NI – Neural Interface and BMI – Brain Machine Interface. (Hatsopoulos, 2009)

We distinguish two types of this technology. Invasive version requires to be physically implanted into the brain to allow capturing the EEG signal. Non-Invasive types attempt to capture the set of signal by using external devices that do not need to be implanted into the subject's body. The current trend is to develop more advanced non-invasive types of devices that will reach the quality and precision of their invasive counterparts (Graimann, 2010).

The current trend in the area of commercial BCI technologies is to penetrate into the already established segments and provide and alternative method of controlling the computer for the purpose

Brixí R., Kalina J. and Němec P..
Computer-Brain Interface Device Experimental Research - Study of Ergonomy and Usability in Business Environment.
DOI: 10.5220/0003990200860090
In *Proceedings of the 14th International Conference on Enterprise Information Systems* (ICEIS-2012), pages 86-90
ISBN: 978-989-8565-12-9

of entertainment or to substitute classical ways of input by assigning certain functions to defined brain activity patterns (Beschizza, 2006).

The utility of alternative means of machine control and possibly in the future on higher interconnection or merging between the machines and their users, and the diminishing of the clear borders between then may lead to potential ethical problems as well and redefinition of the relationship between humans and machines (Kotchetkov, 2010). Other implied ethical issues into business environment also are necessary to take in account (Sigmund, 2010). BCI technologies are innovative approaches facing problems described in Mildeová and Brixí (2011).

2 STUDY

2.1 Study Design

The study was conducted on a group of 10 separate volunteers in the age of 20-26 years by using commercial end-user EPOC headset BCI device from EMOTIV. Each participant went through 12 separated testing sessions invoking selected set of functions through contraction of facial muscles, simulating mouse movement by inbuilt gyroscope and providing user input solely through cognitive functions of the brain.

All participants went through 12 session, each long 10 minutes and focused on invoking predefined functions in the testing program interface that were bind to combinations of facial expressions.

Table 1: Overall cognitive training time per participant.

Test subject	Overall cognitive training duration in minutes
1M	480
2F	840
3M	850
4M	610
5M	800
6F	840
7M	840
8F	840
9M	840
10F	860

Table 2: Overall time summary of the study.

Participants	10
Sessions	12
Avg. total time per person	935 min.
Avg. session time per person	78 min.
Total time of sessions	9350 min.

Mouse movement simulation took altogether time of avg. 35 min. spread across testing sessions during the study.

2.2 Facial Expression Recognition

The training scenario practiced in this section consisted of mapping facial expression recognizable by the neuroheadset to 4 alphanumerical characters to write a 3x word “Hello” by their invoking, without making a mistake. Each tested subject was allowed 25 attempts. Table 3 summarizes the amount of successful attempts.

Table 3: Writing through facial expression letter invoking.

Participant	No. of successful attempts.	Attempts total.
1M	15	25
2F	7	25
3M	17	25
4M	4	25
5M	0	25
6F	10	25
7M	0	25
8F	7	25
9M	2	25
10F	0	25
Total	62(25,5 %)	250

Additionally two tests were performed on the set of participants, during which the participants had to invoke randomly one of the four previously bound letters through their facial expressions. A simple program was built to randomly generate the required letters and the users had to react with appropriate facial expression to write the required letter. The first contained a series of 25 attempts and users were allowed see virtual representation of their faces on the screen. The anticipated success rate was decided upon 70 %.

Test no. 2 was a variation on the first one and users were not allowed to see the virtual representation of their faces on the screen. The anticipated success rate was lowered to 60%.

2.3 Cognitive Activity Recognition

The series of tests focused on usability of computer functions keybinded to a recognized patterns of brain activity is of utmost importance from the point of view of this study, as it is the testing of proper BCI part of the Emotiv Epoc device.

Participants were asked to focus on a virtual cube model and to imagine specific movement patterns (rotation and movement in a specific direction). The patterns captured by during this calibration were assigned to defined movement types of the virtual model.

The aim of this series of tests was to assess the reliability of this way of exchange of information with the computer.

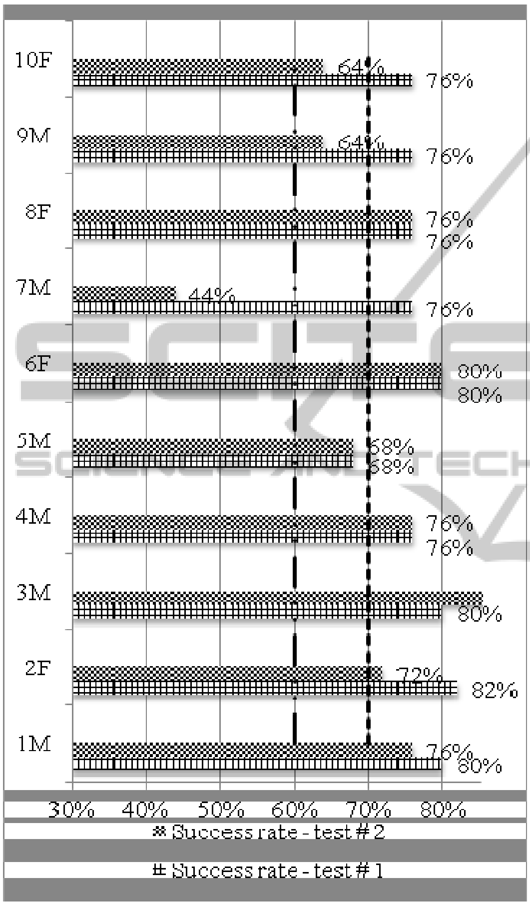

Figure 1: Random facial expression function invoking test results.

First test consisted of asking the participants to attempt to invoke a demanded movement of the 3D model cube through the previously bound brain patters as set of random 25 instructions were generated for the users to attempt to follow. Required success rate was decided on 67%.

Test no. 2 required users to again invoke 25 times, in randomly generated order, one the previously trained brain activity patterns and through binding with selected keyboard button combinations call functions assigned to these buttons in MS Project Professional 2010, an office application for planning of projects. Decided success rate was decided on 60%.

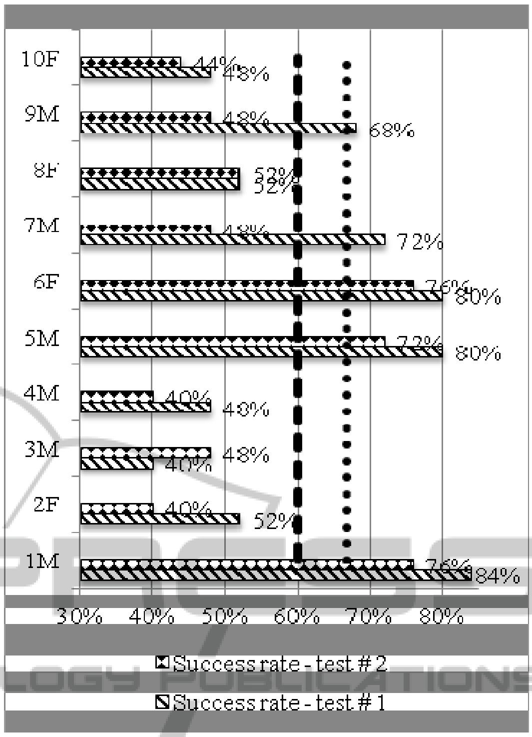

Figure 2: Random brain activity pattern invoking test results.

3 RESULT DISCUSSION

3.1 Functional Attributes

The obtained data from observation suggest that the main issue that may hinder utilization of these devices for a serious work is precision and reliability.

The mouse movement simulation through the inbuilt gyroscope proved to be the only type of activity the where the users scored success all of the times. Also the both series of facial expressions control tests proved successful in case 90% of the users against decided threshold. However this high success rate is only for a set of discrete attempts from test 1 and 2. When faced with a more complex task (writing “Hello” through invoking keys bound to certain facial expressions) only 25,5 % attempts led to a flawless execution.

Test series focused on true BCI aspects of the device were even less positive. Invoking movements of the model 3D cube, over desired threshold, was successful only for 50% of the tested subjects. The most important part of this study, working with an existing office application, e.g. invoking 3 functions (calling the menu, escaping the application, opening settings, etc.) by binding them to brain activity patterns proved to be above the agreed threshold only in case of 30% of the users.

These low rates basically inhibit the utilization of these devices for office work, acting in the current state more as a hindrance, than as a tool to improve working with the computer in office conditions.

Each tested subject spent in avg. 935 minutes training with various aspects of the device. We do consider this time to be an unbearable obstacle in real business environment, especially accompanied with the low reliability the test data have uncovered. Even though 935 minutes is a relatively long time for learning, it is matter of further testing how much can one improve when working with BCI device very much longer (for example as long as one learns to write by hand).

3.2 Non-functional Attributes

3.2.1 Subjective Repulsion from Wet Sensors

Tested users reported a continuous repulsive feeling accompanied with application of wetted sensors on their skin. The ends of sensors made from foam or dross need to be drenched properly in conductive salt fusion to increase the quality of received EEG signals by the sensors.

From practicality point of view this has been issue for people with longer hair, especially female participants. The ideal user for employing the non-invasive class of EEG sensors is ideally free of hair cover completely.

3.2.2 Hygiene Issues

Prolonged contact with foam or dross drenched in the conductive fusion on the skin can lead to skin irritation over time. Especially individuals with more sensitive types of skin are susceptible to this effect.

From hygienic point of view, it is recommended to have a spare set of sensor endings to avoid possible transmission of skin diseases, lice and dandruffs.

Keeping the ends of sensors in humidor to preserve the wetness needed to properly transmit the signals creates an ideal environment for growing of funguses and mould.

3.2.3 Drying of Sensors

The necessity of keeping the ends of the sensors drenched in the conductive fusion brings a problem for scenarios that take a prolonged period of time, e.g. a simulation of a typical 8 hours office work day. The drying during the scenario leads to a reduction of the quality of perceived signal and deteriorates the capability of the BCI device perform it's function as a computer interface. Additional reapplications of the fusion, lead to a necessity to stop working and take of the headset, re-apply the fusion and arrange the sensors once again on the designed spots of the head. This re-application is a source additional time-loss.

The usage of conductive salt fusion leads in time to creation of salt sediments on the surface of the sensors and the foam ends. Newly available dry sensors should solve most of the problems, but the testing of proper functionality of these dry sensors is a matter of other future research.

3.2.4 Pain, Frustration and Loss of Concentration

Tested users have reported a growing pressure due the frame of the sensor device on their heads, leading to feeling of physical pain.

Table 4: Avg. times of continuous wearing of the neuroheadset without perceived pain.

Test Subject	Avg. time without interruption (minutes)
1M	60
2F	38,21
3M	60
4M	53, 08
5M	30
6F	60
7M	60
8F	60
9M	42,5
10F	43,75

Our prior aim was to test if the users can wear the neuroheadset at least 60 minutes continuously. Table 4 summarizes the time during which were the users able to suffer the device on their heads. After this time the perceived pain and loss accompanied loss of concentration grows rapidly, making further work unfeasible. The 60% success rate indicates that the device is in a significant number of cases problematic for long term wearing ergonomically.

3.2.5 Preparation Time

Preparing and proper positioning the device on user's head requires certain amount of time as well-mostly to drench the sensor ends in the conductive fusion and set the ends on designed points on the head. Table 5 provides the average preparation time per tested subject over all 12 sessions.

Table 5: Avg. preparation time per users.

Subject	Avg. preparation time (minutes)
1M	3:13
2F	4:05
3M	2:16
4M	1:15
5M	2:29
6F	3:57
7M	1:43
8F	2:47
9M	2:39
10F	4:02

It is noticeable that the avg. time to set the device properly on the head was noticeably longer with females, mostly due to complications accompanied by longer hair. All tested users had to set-up the device on their heads by themselves.

The whole sample of volunteers was tested on exactly one device. This traffic generated enough strain on the BCI device's cover to lead to chipping off several parts used to fixate the device properly on the skull.

4 CONCLUSIONS

The study has identified several areas ranging for hygiene, ergonomic aspects, and conformability to concentration issues that from our point of view represent an obstacle for serious utilisation of these devices in day to day life of end users. However there is significant success in achieving successfully not all but at least some tasks by users. This fact opens possibilities for future improvements of ergonomic issues and preciseness based on number of sensors of BCI device together with more time for learning to use such a device. If development is focused especially on presented issues we believe, that success in the tests should get noticeable better.

Regardless of the critique backed by the study's results, and remaining lack of proper robustness and spectrum of capabilities of the device used during the study, we are enthusiastic about the developments in this area and it's future implications for the computer industry, user experience and the implications for development of business software applications.

In the perspective of the upcoming decades BCI devices may contribute to fundamental changes in several areas:

- Layout changes of the distribution of control elements in graphical user interfaces or web pages that will be better handled by users accessing then by using BCI device as their primary way of interacting with the computer.
- Gaming industry is currently the most promising are, where BCI devices can be used even with relatively limited spectrum of different inputs they can record. The potential of BCI lays in enhanced immersion of the virtual experience.
- Training and therapeutic utilisation of the device for practicing concentration and self-control.

ACKNOWLEDGEMENTS

Authors would like to thank the faculty of Informatics and Statistics, University of Economics in Prague, to allow this branch of research to be followed within the borders of the programme of applied information science and institutional research funding on Department of System Analysis.

Authors also thank all participating volunteers for cooperation and time dedication which was provided without any financial compensation.

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