Overlaid P300 stimulation-based BCI: a solution to "limit" workload in communication application?

A.Riccio[1], L. Bianchi[2,1], F. Aloise[1], C. Zickler[3], E-J. Hoogerwerf[4] , D._Mattia[1], F. Cincotti[1]

[1]NEILab, Fondazione Santa Lucia, Rome, Italy; [2]Dip. di Neuroscienze, Univ. Tor Vergata, Rome, Italy; [3]University of Tübingen, Germany; [4]Ausilioteca (AT Team) of AIAS Bologna onlus, c/o AT Area of Corte Roncati, Bologna, Italy.

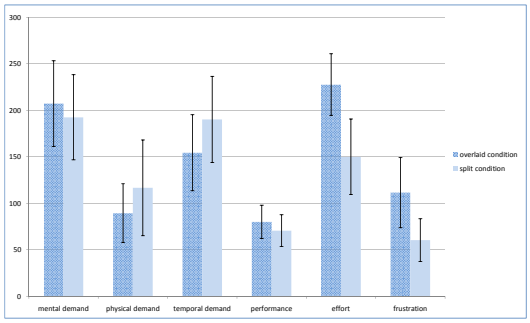
BACKGROUND AND OBJECTIVE

Advancing in BCI technology towards practical applications in technology based assistive solutions for people with disabilities requires coping with problems of accessibility and usability, in order to increase user acceptance and satisfaction.
Here, we propose an initial approach in the assessment of BCI technology development in terms of usability that is focused on the evaluation of user's mental workload in operating a mainstream software controlled via a P300-based BCI.
BCI-controlled software applications are usually either embedded in the BCI system (e.g. a simple speller) or they are specifically developed with BCI control in mind. A third option is that mainstream software (e.g. a web browser or a commercial assistive software) with no or little customization is operated by a BCI. Applications like Mozilla Firefox were previously controlled by a P300 based BCI [1], using separate screens (or windows) for the control interface (i.e. the P300 stimulation) and the application itself. In this study compare the usability in term of performance, workload and satisfaction of two systems: a) a prototype with separate screens/windows to display the control interface (i.e. P300 stimulator) and the application (Fig 1) b) a prototype in which the BCI stimulation overlays the application (Fig 2).This latter condition should require the user not to switch attention as in the case of two separate screens/windows, and thus would reduce her/his workload in mastering the BCI application.

METHODS

User interface. The prototype is based on a brain transducer based on P300, implemented in the BCI2000 platform [2], and on the QualiWorld accessibility software (QualiLife A, Paradiso, Switzerland).
•In the "**overlaid**" condition the stimulation by dots (125 ms SD, 125 ms ISI) randomly occurs directly on the QualiWorld graphical user interface (GUI); no dedicated BCI window is visible to the user (Fig. 2).
•Under the "**split**" condition, the QualiWorld computer is connected to 2 screens: on the first, it is displayed the QualiWorld GUI where the user can choose the desired control or control group (a letter is associated to each single control); on the second screen, a speller matrix is showed to the user for the stimulation (Fig 1)

Experimental procedure. Eight healthy volunteers were challenged with 3 tasks (internet browsing, word processing, configuration of the software), each requiring 10-17 selections with both overlaid and split interface.
The EEG was recorded with Ag/AgCl electrodes in a 16-channel cap (Electro-Cap International) (Fp1, Fp2, F3, Fz, F4, T7, T8, C3, Cz, C4, Cp3, Cp4, P3, Pz, P 4, and Oz) based on the International 10–20 system [2]. All 16 channels were referenced to the right earlobe, and grounded to the right mastoid. Impedances were kept below 5 k. The EEG was amplified with a g-tec USB amplifier, bandpass filtered between 0.1 and 60 Hz, and sampled at 256 Hz.
All aspects of data collection and experimental procedure were controlled by the BCI2000 system [3].



Histograms show mean ± ED for each NASA TLX domains (n=8 subjects)

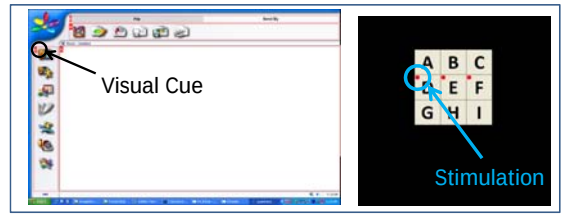


Fig.1 split condition

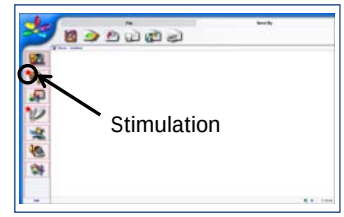


Fig 2 overlaid condition

The **usability** is defined by three measures: effectiveness (the accuracy and the completeness with which intended goals are achieved), efficiency (the measure of the amount of human, economic and temporal resources that are expended in attaining the required level of product effectiveness), satisfaction (the immediate and the long term comfort and acceptability of the overall system .
Effectiveness of both the systems was measured in terms of measuring accuracy/error rate. The global time to successfully complete each task was considered. The ratio between the total time and the minimum number of selections needed to achieve each single task was considered as the parameter to compare the level of performance under the 2 interface modalities.
Efficiency was measured by subject's evaluation. Rating of mental workload was performed by means of the multidimensional **NASA TLX** questionnaire [4] that assesses the workload by considering six different factors: Mental, Physical and Temporal Demands, Frustration, Effort and Performance. These factors have a direct bearing on the usability of a software interface. If fewer mental resources are used, then the efficiency, and also the effectiveness and satisfaction associated with the interface can be increased. The questionnaire was self-administered to the users at the end of each performed task to capture the potential differences in workload level relative to the 2 conditions.
User satisfaction was measured by presenting to the subjects a Visual Analogue Scale (VAS) for satisfaction either at the end of the "overlaid" condition both at the end of the split condition. The subjects were asked to rate their overall satisfaction with the BCI-device drawing a vertical bar on a line where number 0 indicated that they were not satisfied at all with the device while number 10 meant that they were absolutely satisfied.
Finally the participant's overall preference between the two conditions was recorded with a VAS. The VAS showed the complete preference for the overlaid condition at the left extremity (0 points) and the complete preference for the split condition at the right extremity (10 points). The mid-point was the 'no-preference' point (5 points).

Results:
Student's T test was used to test for a significant difference between the means of subjects performances in the two conditions and it was not statistically significant (p=0.71); the differences between the workload measured by NASA-TLX in the two conditions shown to be non-significant as well (p=0.21); no significant differences between the satisfaction scores for the two conditions (p=0.56) were found and the mean expressed preference score was 5,15 where 5 was no preference.

Rating Scale Definition

Title	Endpoints	Description
Mental Demand	Very low/very high	How much mental and perceptual activity was required (e.g. thinking, deciding, remembering, looking, searching)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Very low/very high	How much physical activity was required (e.g. pushing, pulling, turning, controlling, activating)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Very low/very high	How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Perfect/Failure	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Very low/very high	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration Level	Very low/very high	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

Conclusion

Unlike we hypothesized, no differences were observed in efficiency, user satisfaction and workload measures between the two prototypes. These preliminary results suggest that the benefit/cost ratio (usability) associated with the use of the overlaid interface is affected by several variables. In this end, from a methodological perspective, the human factor methodologies such as workload assessment using the NASA TLX, user satisfaction measurement, and time accuracy measurement are important in approaching the evaluation of BCI-based prototypes . Usability studies can provide a well-suited approach for investigating human influences on the use of a BCI system. These analyses should be conducted on BCI systems to adequately support the end-users and to increase their acceptance of the system.

References

[1] Mugler E., Benschc M., Halder S., Rosenstiel W., Bogdan M., Birbaumer N., Kübler A. (2008). *Control of an Internet Browser Using the P300 Event- Related Potential*, International Journal of Bioelectromagnetism, 10(1):56-63
[2] Sharbrough, F., E.G. Chatrian, P.R. Lesser, et al. 1991. American Electroencephalographic Society guidelines for standard electrode position nomenclature.
J. Clin. Neurophysiol. 8: 200–202.
[3] Schalk G., McFarland D.J., Hinterberger T., Birbaumer N., Wolpaw J.R. (2004). *BCI2000: a general-purpose brain–computer interface (BCI) system.* IEEE Trans Biomed Eng, 51(6):1034–43.
[4] NASA Human Performance Research Group (1987). Task Load Index (NASA-TLX). NASA Ames Research Centre: NASA Human Performance Research Group. http://humansystems.arc.nasa.gov/groups/TLX/

This work is supported by the European ICT Programme Project FP7-224631 (TOBI). This paper only reflects the authors' views and funding agencies are not liable for any use that may be made of the information contained herein