Towards a *Hybrid* Control of a P300-based BCI for Communication in Severely Disabled End-users

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Abstract. A hybrid (electromyographic, EMG) control devoted to the correction of spelling errors was introduced in a previously implemented P300-based BCI system designed to control an assistive technology software (Riccio et al., 20111; Zickler et al., 2011). The *hybrid* version of such system would provide severly disabled end-users with a way to exploit not otherwise functionally reliable residual muscular activity. Six healthy subjects and one severly motor impaired end-user participated to the system testing. Preliminary findings are in favour of the superiority in *efficiency* of the *hybrid* control with respect to the *no-hybrid* (only BCI-based) as indicated by the observed improvement of the performance (expressed as time for selction and number of errors) that was associated with a decrease of the system usage frustration perceived by the users.

Keywords: Brain computer interface, Hybrid, Electromyography, Event related potential, Communication

1. Introduction

1.1 The Hybrid BCI

A hybrid Brain Computer Interface (BCI) is a BCI combined with at least one other system or device enabling people to send information (Müller-Putz et al., 2011). In a previous study, we reported on a developed system in which a P300-based BCI was combined with a QualiWorld Assistive Technology (QW) software for communication and environmental control (Riccio et al., 2011). Such BCI-based system was successfully tested with severely disabled potential end-users (Zickler et al., 2011) and according to their feedbacks on system's usability, we endowed the system with a *hybrid* control that subserved the function of deleting uncorrected selections by means of electromyographic (EMG) signal generated by the end-user's residual muscular activity.

2. Material and Methods

2.1. Participant

Six healthy volunteers (3 males, 3 females; mean age 30) and one severely disabled end-user (female, 48 year old) participated to the study. The end-user, had tetraplegia with severe dysarthria due a brainstem ischemic stroke and she could communicate her primary needs only with the support of the caregivers.

2.1. Hybrid system

To fully adhere to a user-centered design, the *hybrid* system is adaptable to several degrees of residual motor activity and the customization of the EMG control channel is obtained during a screening session wherein the end-users' target muscle is identified on the basis of their residual functional voluntary movements. For the same reason the visual stimuli eliciting P300 are adaptable to user's needs in terms of shape, colors, dimension and position (Holtz et al., 2013). The visual stimulation is overlaid on top of the QW window through a proxy and the system is based on the TOBI common implementation platform both for the biosignal acquisition (signal server) and for the exchange of messages (Breitwieser et al., 2012).

2.3. Protocol and Data Acquisition

A calibration session was performed in order to define the EMG control features, such as the onset and offset of signal amplitude thresholds and the optimal time window for the EMG signal onset and offset to occur in order to operate the delete command. The same session was also devoted to identify the best stimulation modality (least number of sequences needed to achieve the 100% offline accuracy) within four stimuli changing for shapes (dot vs. grid) and colors (red vs. green) (Holtz et al., 2013). In a different session, participants were asked to spell online three predefined words (21 characters) using the system under two conditions: *(i) No-hybrid task*: uncorrected letter selections were deleted by means of the BCI control operating a backspace command integrated in the QW virtual keyboard; *(ii) Hybrid task*: the errors were canceled by exploiting the EMG control signal; in case of failure, the user had to delete the wrong letter as in the previous condition. For between

conditions comparative purposes, the number of sequences of stimulation was set at the minimum number of sequences needed by a given user to reach 80% of accuracy in order to artificially introduce spelling errors in a controlled manner. EEG and EMG signals were acquired using 8 EEG (Fz, Cz, Pz, Oz, P3, P4, Po7, Po8) and 2 EMG active electrodes, respectively. All EEG channels were referenced to the right earlobe and grounded to the left mastoid, amplified using a g.tec USB amplifier (Graz, Austria) and recorded by the BCI2000 software.

2.4. Data Analysis

The *efficiency* of the *hybrid* BCI-system was evaluated in terms of performance estimated as *i)* time for selection (*TIME*; ratio between the total time to successfully complete the task and the minimum number of selections needed to execute it); percent of errors (*ERRORS*; ratio between the number of BCI errors and the total number of BCI selections) and users *FRUSTRATION* (as a workload factor by means of the NASA-tlx). The comparison between the two modalities was performed by means of a non-parametric Wilcoxon test.

3. Results

As shown in Figure 1, the *efficiency* of the *hybrid* BCI-system was higher as compared to that of the *no-hybrid* system version, as indicated by the significantly lower scores relative to *TIME* and *ERRORS* obtained in the *hybrid task* ($p < 0.05$) with respect to those observed in the *no-hybrid task*. Further, the level of *FRUSTRATION* perceived by the healthy users resulted significantly lower for the *hybrid* condition ($p<0.05$). The end-user achieved *TIME* and *ERRORS* mean values lower in the *hybrid task* (*TIME*=19.13 sec; *ERRORS*=19.3%) as compared to the *no hybrid task (TIME*=34.8 sec; *ERRORS*=33.9%). The perceived *FRUSTRATION* was also lower while using the *hybrid* modality function (3.3) with respect to the *no-hybrid* (4.6).

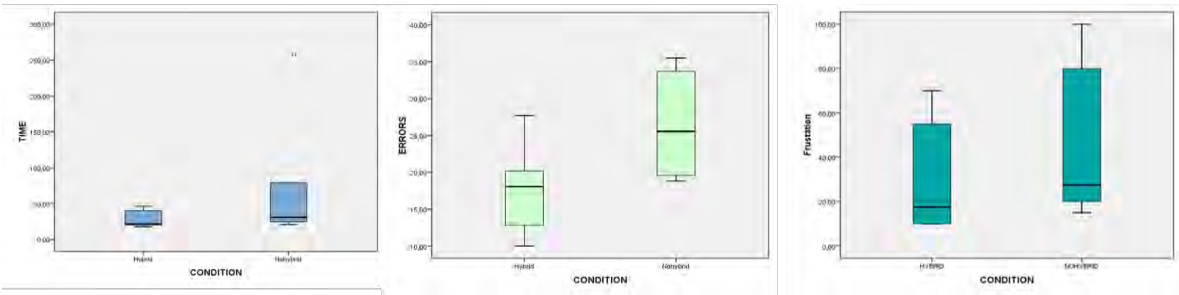

Figure 1. *Plots showing statistic comparison between the "hybrid task"and the "no-hybrid task" on the time of selection (TIME), percentage of errors (ERRORS) and perceived frustation (FRUSTRATION).*

4. Discussion

These preliminary findings support the initial assumption that the integration of the EMG channel into the system would yield to an improvement of the system *efficiency,* as indicated by the significant decrease of the *time for selection* and of the *percentage of errors* in an on line spelling task performed under the *hybrid* and *no-hybrid* task modality. One can speculate that the observed decrease of the *percentage of errors* under the *hybrid* task might be ascribed to a reduced psychological demand of the BCI-based spelling letters due to the possibility of correcting errors by exploiting the EMG channels. The lower level of perceived *frustration* associated with the *hybrid* task could be a consequence of the performance enhancement. The similarity in the system usage performance showed by the end-user corroborates the added value of the hybrid control concept. In severely disabled end-users, the residual muscular activity could be indeed, easily fatigable or not reliable and consequently not functionally useful to operate a control of a standard assistive device.

Acknowledgements

The work is supported by the EU FP7-224631 "TOBI" (Tools for Brain-Computer Interaction) project.

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