Hybrid-P300 BCI: Usability Testing by Severely Motor-restricted End-Users

E.M. Holz¹, A. Riccio², J. Reichert¹, F. Leotta², P. Aricò², F. Cincotti², D. Mattia², A. Kübler¹

¹Institute of Psychology, University of Würzburg, Germany ²IRCCS Fondazione Santa Lucia, Rome, Italy

Correspondence: Elisa Mira Holz, Institute of Psychology, University of Würzburg, , Marcusstraße 9-11, 97070 Würzburg. E-mail: elisa.holz@uni-wuerzburg.de

Abstract. In this study the usability of a hybrid-P300 BCI communication application was evaluated by four severely motor restricted possible BCI end-users. The P300 BCI was combined with EMG for error correction (see also abstract Riccio et al.). The prototype was evaluated in terms of effectiveness (accuracy), efficiency (time needed to complete task) and end-user’s satisfaction. In two copy-spelling tasks accuracy was high (M=92.5% and M=98.75%), but lower in the free-spelling sentence (M=85.02%) and email task (M=75.34%). The hybrid letter correction could be used by all end-users and improved efficiency. Overall, end-users were moderately to highly satisfied with the BCI, but least satisfied with the adjustment (M=3.25 of 5), effectiveness (M=3.25 of 5) and aesthetic design (M=3 of 5) of the BCI, as assessed with the Extended Quest 2.0. One end-user could imagine using the BCI in daily life.

Keywords: Hybrid-BCI, P300, EMG, evaluation, usability, motor-restricted end-users

1. Introduction

The hybrid approach in BCI research aims to increase efficiency and effectiveness, enabling the end-user to use not only EEG activity, but also EMG activity as input channel for the BCI. The present study investigated the feasibility of a hybrid P300 BCI system, which is the second prototype of the P300-Qualilife communication prototype, evaluated by end-users in the study of Zickler and colleagues (2011). The new hybrid prototype includes a new P300-stimulation, with bigger central dots or grid stimulation, a pause mode and the undo-option based on electromyographic (EMG) activity, enabling to delete wrong selected letters in the matrix. Based on the findings of Zickler et al. (2011), showing that low speed, low effectiveness and complex adjustment were the main obstacles for BCI use, the current hybrid prototype includes (1) individual adaptation of flashing sequences, (2) EMG-undo letter correction, (3) easy-to-use active EEG-cap. The P300 hybrid BCI including EMG is the first to be evaluated by patients.

2. Material and Methods

2.1. Subjects

Four patients (age: A:47, B:41, C:26, D:52, 3 male) participated in this study. End-user A was diagnosed with brainstem stroke, end-user B with muscular dystrophy (Duchenne), end-user C with spinal muscular dystrophy (SMA), end-user D with ALS (spinal form). Patients were severely motor restricted, with only residual muscular control, therefore they were considered as potential end-users for the hybrid-P300-BCI.

2.2. Hybrid-P300-BCI application

EMG was recorded from two active electrodes, which were placed individually, depending on the end-user’s residual movements (A, C, D: hand; B: face). 8-channel-EEG was recorded from scalp positions Fz, Cz, P3, Pz, P4, Po7, Po8, Oz with a 16-channel amplifier (g.tec, Austria).

2.2. BCI Protocol

BCI protocol consisted of three sessions on three separate days: In the first session (S1) a screening was performed, in which the best stimulus modality (least number of sequences needed) and number of sequences (necessary to reach 100% offline) were identified (results of S1 not shown in this paper). In the second session (S2) end-users completed a copy-task, in which the EMG was used for error correction and compared to BCI. End-users had to copy-spell two 8-letter words and delete the last character with either the BCI (CP-BCI), or the EMG (CP-EMG), and respell the letter again. In session three (S3) end-users had to write a sentence in the free-spelling mode with 10 characters using the EMG-correction for wrong selections and choose the pause mode (Sentence; 14 selections). Next, this text had to be sent by email, after terminating the pause mode (Email; 11 selections).
2.3. Evaluation

According to ISO 9241-210:2010 the BCI device was evaluated in terms of its effectiveness, efficiency and satisfaction. Effectiveness was defined as the percentage of correct responses achieved with BCI (accuracy). Hybrid-accuracy included error correction. Efficiency was defined as the time needed to complete tasks. End-users’ satisfaction regarding different aspects of the BCI (Dimensions, Weight, Adjustment, Safety, Comfort, Ease of use, Effectiveness, Professional services, and reliability, speed, learnability and aesthetic design) was assessed with the Extended Quest 2.0 [Demers et al., 2000, Zickler et al., 2011]. End-users rated their satisfaction with the EMG vs. BCI correction with a visual analogue scale (from 0 to 10; VAS Satisfaction).

3. Results

3.1. Effectiveness and Efficiency

See table 1 for accuracy (% correct) and time needed to complete the tasks, number of sequences and stimulus type for each end-user:

<table>
<thead>
<tr>
<th>End-User</th>
<th>Stimulus</th>
<th>Sequences</th>
<th>CS –EMG</th>
<th>CS-BCI</th>
<th>Sentence</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>grid red</td>
<td>5</td>
<td>100 (223.63)</td>
<td>100 (244.90)</td>
<td>100 (302.95)</td>
<td>100 (142.25)</td>
</tr>
<tr>
<td>B</td>
<td>dot red</td>
<td>6.7</td>
<td>90 (257.39)</td>
<td>100 (282.38)</td>
<td>81.82 (533.92)</td>
<td>85.71 (230.86)</td>
</tr>
<tr>
<td>C</td>
<td>grid red</td>
<td>9</td>
<td>100 (358.64)</td>
<td>100 (394.92)</td>
<td>78.26 (687.91)</td>
<td>67.74 (739.19)</td>
</tr>
<tr>
<td>D</td>
<td>dot green</td>
<td>10</td>
<td>80 (392.40)</td>
<td>95 (432.38)</td>
<td>80 (831.58)</td>
<td>47.89* (1781.55)</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td>92.5</td>
<td>98.75</td>
<td>85.02</td>
<td>75.34</td>
</tr>
</tbody>
</table>

3.3. Satisfaction (Extended Quest 2.0 and VAS Satisfaction)

Overall, end-users A and D were highly satisfied with the BCI ($M=4.13$ to $4.5$), B and C were moderately satisfied ($M=3.25$ to 3.75). End-users were least satisfied with the adjustment ($M=3.25$ of 5), effectiveness ($M=3.25$ of 5), and aesthetic design ($M=3$ of 5). They were moderately satisfied with speed ($M=3.5$ of 5). End-users were quite satisfied with ease of use ($M=4$ of 5). End-users were highly satisfied with both letter correction methods (BCI: $M=8.25$, EMG: $M=8.50$, VAS Satisfaction).

4. Discussion

The results show that end-users achieved high effectiveness, comparable to the results of Zickler and colleagues (2011), even with lower sequences, and thus in less time (in 3 of 4 end-users). End-users reported that they had problems selecting items in the sentence and email task, because the symbols (dot/grid) were too close to each other. This resulted in lower performance in this task. The copy-spelling tasks revealed that the hybrid approach is more efficient meaning that less time is needed to correct erroneous selections, especially for end-users with high number of sequences. However, from the end-users perspective, main reasons for dissatisfaction remain, i.e. complicated adjustment, low speed and low effectiveness. Only ease of use has been rated better than that of the first prototype [Zickler et al., 2011]. Despite these obstacles, one end-user could imagine using the BCI communication device in her daily life (end-user D).

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References
