Can severe Acquired Brain Injury users control a communication application operated through a P300-based brain computer interface?

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Abstract

In this study a P300 based prototype for communication and control was evaluated by three Acquired Brain Injury (ABI) users. The prototype was developed by merging an already existing assistive technology commercial solution (Qualiworld) with a BCI system and it allows the user to access to text entry and internet applications. The three ABI users were challenged with four complex tasks and the results revealed good performance levels in standard communication and internet tasks (mean=73.79%, SD=9.4). Two end-users completed the four tasks and reached a performance of respectively 69% and 76% on average. One of the end-users did not finish one of the tasks (internet task) and the mean of accuracy for the three completed tasks was 73%.

1 Introduction

Different neurological disease may lead to severe motor disabilities.

Brain Computer Interface (BCI) represents a promising technology to provide severely motor-disabled people with an alternative channel for sending commands to the external world that does not rely on muscular activity [1]. A list of potential BCI users can include individuals with severe disability because of disorders such as Amyotrophic Lateral Sclerosis (ALS), cerebral palsy, brainstem stroke, spinal cord injuries, muscular dystrophies or chronic peripheral neuropathies. Acquired Brain Injuries (ABIs), which include both Traumatic Brain Injuries (TBI) and strokes, are among the major causes of disability worldwide and affected users could benefit by the BCI.

Despite of this, the few BCI studies conducted over potential users with a P300-based BCI for communication and control, during the last years, were mostly conducted on ALS users ([2], [3], [4], [5], [6]). Only in two recent studies two ABI users were included in the sample for testing a visual P300-based BCI: Piccione at al. [7] included one stroke patient in the testing group of a visual P300 based BCI, while Hoffman [8] included in the testing sample one TBI user. In previous studies a system in which the BCI stimulation overlays a commercial software application was described and tested by healthy volunteers ([9], [10]) and by four potential users with degenerative diseases [11]. Both the healthy and patients groups achieved high level (> 70%) of performance. As Stroke and TBI can result in severely motor disabilities and in a locked-in state and as the development of the medical techniques are improving ABI patients estimated life, they could be potential BCI users. In the present study the same system was evaluated in terms of effectiveness (accuracy) by three ABI patients whose cognitive abilities were previously evaluated.
<table>
<thead>
<tr>
<th>Syndrome Aetiology</th>
<th>Age</th>
<th>Months since event</th>
<th>Speech deficit</th>
<th>Movement impaired</th>
<th>Cognitive Deficit</th>
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<tr>
<td>Hemorrhagic stroke</td>
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<td>129</td>
<td>Disartric</td>
<td>Tetraparetic</td>
<td>Vigilance</td>
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<td>Ischemic stroke</td>
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<td>24</td>
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<td>Hemorrhagic stroke</td>
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</table>

Table 1: Clinical features of participants

2 Methods

2.1 Prototype

The QualiWorld (QW) platform[12] allows the access to many applications (text editor, web browser etc.), while replacing standard mouse and keyboard by a variety of computer access solutions (Auto-Scan mode, mouse alternatives, gesture recognition). The prototype exploits the BCI2000 P300 signal processing pipeline [13] as brain transducer to access to the QW application. The stimulation is overlaid to the graphical interface of the QualiWorld application suite: the stimuli are directly superimposed on the buttons available on the interface and the stimulation is obtained by means of using flashing dots (color can be selected by the user; 125 ms SD, 125 ms ISI) ([10],[11]).

2.2 Participants and Procedure

Three acquired brain injury end-users were enrolled in the testing of the prototype. They were post-comatose users who had suffered a hemorrhagic stroke (user A and user C) and an ischemic stroke (user B). A neuropsychological screening was performed: the users were screened for verbal and visuo-spatial working memory and for the intensity (alertness and sustained attention) and selectivity aspects of the attention (selective and divided attention). In the table 1 the patients’ clinical profile is reported. None of the users had working memory problems. They presented vigilance (user A and user B) alert (user B) and divided attention (user B and user C) deficits. They were challenged with four complex tasks performed in 4 daily sessions: ”word processing in copy mode”, ”word processing in free mode”, ”email sending”, ”internet browsing”. In order to cope with the variability of the number of the stimuli available on the screen, the calibration comprised the selection of a total of 20 pre-set letters from four different matrices with different sizes (5 letters per matrix) and was performed during the first session. The ”word processing in copy mode” task consisted of writing three pre-established words. The ”word processing in free mode” task consisted of the following steps: i) selection of the ”word-function” on the graphical user interface (GUI); ii) a selection to open the text-matrix and finally iii) writing an individually chose sentence requiring 20 selections. As for the the email sending task, the users were asked to write a five letters word and send it as an email. This task required the following: the users had to select the e-mail sending application (i.e. select the “send by” icon and the “email” icon), then, a predefined address within an address book had to be selected (i.e “to” icon, “address book” icon, “predefined address”) and finally, he had to confirm the address and to send the email (“add” icon, “ok” icon and “send” icon). The internet task consisted of selecting the internet browser application, choosing two specific links of the webpage and performing some browser operations. In particular they were asked to zoom-in the web page previously selected (choosing the predisposed icon), to scroll it down, then to select one more link, zoom-out the page and scroll it down. The total number of selections (without errors) was 21 for the copy spelling, 22 for the free spelling, 17 in the email and 15 in the internet task. The errors had to be corrected in the last three tasks.
Table 2: Accuracy: (%) number of correct selections/number of total selections of the 3 users challenged in the 4 tasks. N. sel: total number of selection needed to accomplish the tasks.

<table>
<thead>
<tr>
<th></th>
<th>Copy Mode</th>
<th>Free Mode</th>
<th>Email</th>
<th>Internet</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Accuracy</td>
<td>n. sel</td>
<td>Accuracy</td>
<td>n. sel</td>
</tr>
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<td>Subject A</td>
<td>85.71%</td>
<td>21</td>
<td>80%</td>
<td>36</td>
</tr>
<tr>
<td>Subject B</td>
<td>76%</td>
<td>21</td>
<td>70.5%</td>
<td>51</td>
</tr>
<tr>
<td>Subject C</td>
<td>80.57%</td>
<td>21</td>
<td>73.5%</td>
<td>44</td>
</tr>
<tr>
<td>Average</td>
<td>± 4.8</td>
<td>± 5.6</td>
<td>± 11.1</td>
<td>± 16.5</td>
</tr>
</tbody>
</table>

2.3 Data acquisition

The EEG data were acquired with an 8-channels cap (Electro-Cap International) with electrodes placed according to the International 10–20 system (Fz, Cz, Pz, Oz, P3, P4, PO7, PO8). All 8 channels were referenced to the right earlobe, and grounded to the right mastoid. Impedances were kept below 10 k-ohm. The EEG signals were recorded with a g-tec USB amplifier, bandpass filtered between 0.1 and 30 Hz, and sampled at 256 Hz. All aspects of data collection and experimental procedure were controlled by the BCI2000 system [13]. Data acquired during calibration in the first session were loaded into an off-line analysis software based on Matlab environment, for feature extraction. The Stepwise Linear Discriminant Analysis (SWLDA) was used for signal classification [11].

2.4 Data analysis

The group of users was too small for inferential statistical analysis, therefore individual data will be reported descriptively. The accuracy was calculated for each task as Correct Response Rate (CRR, number of correct selections/number of total selections).

3 Results

Despite their attention deficit all the three ABI end-users were able to accomplish the four tasks except the end-user A who did not terminate the "internet browsing" task.

The average of the overall performance was 73.79% with a standard deviation of 9.4. The accuracy and the number of selections needed for each task are reported in the table 2. The performance of the user A was high in the "copy mode spelling" task and "free mode spelling" task and had a drastic decline in the more complex "email sending" and "internet browsing" tasks, probably because of the vigilance deficit of the user. Even the performance of the user B was lower in the in the email and internet tasks than in the two spelling tasks and her general performance was lower in comparison to the other users. The user B had more attention deficit than the others, in particular alertness, vigilance and divided attention deficit. The user C, who had only a slight divided attention deficit, did not result compromise in any other cognitive domain and did not suffer decline in performance due to increasing of attention load.

4 Discussion

For the first time a P300-BCI was integrated with an assistive technology commercial software and was tested with several tasks by severely disabled end-users whose attention and memory capabilities were previously screened. These preliminary findings revealed good performance levels (>70%) on average and showed that attention deficits should not prevent in proposing the use of visual P300-based BCI as one input channel to operate AT device. Although with caution due to the small sample size, we can preliminary drawn the conclusion that specific attention deficit
might affect BCI performance in specific applications. This should be taken into account when designing BCI systems for daily life use.

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References