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P300-based BCI to drive an assistive device: Usability Evaluation with Stakeholders

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Abstract

This work aims at evaluating the usability of an assistive device for people with amyotrophic lateral sclerosis, designed to permit a wide range of input modalities to support communication and interaction with the environment. Nine stakeholders (assistive technology experts, medical doctors and BCI researchers) were involved in the study, which included four experimental conditions, each considering a different input modality: touchscreen, buttons (scan mode), headtracker, and a P300-based brain computer interface. The latter exhibited a lower effectiveness and efficiency with respect to the other input devices. However no differences were found among the four conditions in terms of ease of access, ease of use, ease of understanding, usefulness and satisfaction.

1 Introduction

The “user-centered design” (UCD; ISO 9241-210) implies that end-users play an active role in the device design and development following an iterative process. The UCD approach has been recently introduced in the Brain Computer Interface (BCI) field of research (Zickler et al. 2011; Kubler et al. 2013). The Brindisys project (www.brindisys.it) recently deployed a prototype assistive device (AD) providing functionalities which are seamlessly accessible through several conventional/alternative input channels, among which a P300-based BCI, to enhance/allow basic communication and environmental interaction of people with Amyotrophic Lateral Sclerosis (ALS). The multimodal access to this AD prototype provides end-users with an adaptable system coping with the different stages of the disease. This study aims at evaluating the usability of the proposed prototype AD by involving three different categories of stakeholders, namely medical doctors working with patients with ALS, psychologists experienced in the assistive technology (AT) field and BCI researchers with previous experience with ALS. In fact, stakeholders have a broad knowledge about the different stages of the disease and about the conventional ATs currently adopted by end-users, making their opinion extremely valuable for the evaluation of a new AT.

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2 Methods

2.1 Description of the Assistive Device Prototype

The AD prototype can be operated through several input modalities: touchscreen, hardware buttons, headtracker and a P300-based BCI. To ensure portability and affordability, the prototype was developed on a 10'' tablet and the software written in Java and C++ running on the Windows operating system (Caruso et al. 2013). The selection of available functionalities has been performed in agreement with the results of a preliminary user survey (Schettini et al. 2014). In the domain of interpersonal communication, a Graphical User Interface (GUI) running on the tablet, provided three main functions: *(i)* an alarm sound to draw the attention of a caregiver; *(ii)* a simple text editor, for both face-to-face and remote (SMS) communication; and *(iii)* an interface to select predefined sentences for quick communication. In the domain of environmental control, functionalities available on the GUI included on/off switching of lights and appliances, TV and music players remote control. These functionalities required the deployment of a "domotic kit", i.e. dedicated hardware packed in briefcase, which includes: a WiFi router (communication with the tablet), three controllable mains sockets (appliances), an infrared controller (TV remote), and an UMTS router (internet monitoring).

As for the BCI input, stimulation timing and data acquisition were managed by the BCI2000 framework. A custom software program managed the communication between BCI2000 and the GUI, and generated the visual stimuli (green grids), necessary to generate evoked potentials, on top of the aforementioned input-independent GUI.

2.2 Participants and Experimental Protocol

Nine stakeholders (mean age = 37.8±5.6) were involved in the study. Three of them were medical doctors working with patients with ALS, three were psychologists with experience in AT for people with ALS and three were BCI researchers (an engineer, a neuropsychologist and a neurophysiology technician) with experience in experimentation with persons with ALS.

The experimental protocol consisted of a single session in which the stakeholders evaluated the AD prototype in four conditions: *(i)* touch screen, *(ii)* two buttons (one used to scan the icons, the other one to select the icon of interest), *(iii)* a head tracker with "dwell" selection and *(iv)* the P300-based BCI. At the beginning of the session, each participant watched a video-tutorial describing the AD prototype functionalities and how to use the different input devices. Participants were then given 10 minutes to familiarize with the prototype at their will, using a touchpad. The four conditions were presented in a randomized order. Participants were required to complete a communication task and an environmental control task twice (2 runs for task, 4 runs for condition). A minimum of 12 and 10 selections were required to complete the first and the second task, respectively. The experimenter did not provide participants with indications about the sequence of individual selections (menu navigation) to complete the tasks. At the end of each condition, stakeholders were requested to fill a questionnaire about ease of access, ease of use, ease of understanding, usefulness, satisfaction and perceived efficiency. Each variable was scored from 1 to 5, by means of a likert scale. Participants were requested to evaluate the system taking into account the broadest needs of potential users with ALS. Before performing the BCI condition, each participant carried out 6 calibration runs (no feedback was provided), selecting four items from grids of three different sizes (2 by 2, 4 by 4, and 6 by 6). Parameters of the linear classifier were extracted applying a stepwise linear discriminant analysis on the ensemble of the calibration runs. The number of stimuli repetitions to use during the online tasks was defined by means of a 6-fold cross-validation on the calibration runs, and set as the minimum number of repetitions needed to achieve the highest accuracy.

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2.3 Usability assessment

According to the UCD methodology we assessed the overall usability of the AD prototype for each condition within three domains: (*i)* effectiveness, assessed as the number of correct selections performed (including selections needed to correct errors) divided by the total number of selections performed to complete the task; *(ii)* efficiency assessed as the average time for correct selection, i.e. the total time (in seconds) to complete the task divided by the number of correct selections; *(iii)* and satisfaction, assessed by means of a questionnaire. For effectiveness and efficiency, a comparison between the first and the second run has been performed for each task and subject, in order to evaluate the learnability of the AD prototype as well as the overall simplicity in getting acquainted with it. A non-parametric one way Friedman ANOVA for repeated measures was performed for each variable. A Wilcoxon test was performed as post-hoc analysis for the variables with a significant F test.

3 Results

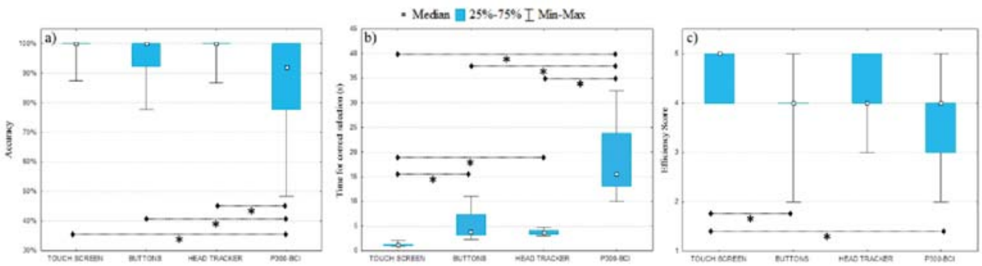

Figure.1 a) Accuracy achieved during the tasks in all conditions; b) Time for correct selection in all conditions; c) Efficiency perceived by stakeholders

With regard to effectiveness, (Figure 1.a.), the ANOVA showed significant differences among the four conditions (χ^2=25.59; p<.01). The P300-BCI exhibited significant lower accuracy (p<.05) with respect to other conditions. Figure 1.b shows the values of time for correct selection. The ANOVA pointed out significant differences among the four conditions (χ^2=49.02; p<.01). P300-based BCI exhibited higher (p<.05) time for correct selection with respect to the other conditions, the touch screen being the fastest condition (p<.05), as assessed by the post-hoc test.

These differences influenced the efficiency perceived by participants and assessed by means of the questionnaire. Indeed, Friedman ANOVA showed a significant difference among the four conditions in the efficiency variable (χ^2=7.9; p<.05). As a result of the post-hoc test, efficiency of the touch screen condition resulted higher than the two buttons condition (p<.05) and the BCI condition (p<.05). No significant differences were found by analyzing the other 5 variables (ease of access, ease of use, ease of understanding, usefulness and satisfaction).

With regard to the comparison between the first and the second run, the ANOVAs point out significant differences neither in terms of accuracy increment (χ^2=1.74; p=.62) nor in terms of time for correct selection (χ^2=2.20; p=.53) among the four conditions (Table 1).

The analysis of feedbacks about the overall usability of the system highlighted some usability issues regarding both the structure of the GUI (e.g. the pause function resulted confusing), and some weak points with specific input devices (e.g. the alarm call menu was not well designed for the buttons input). Problems identified in usability were not directly related to the inclusion of the BCI as control input.

Table 1. Comparison between the first and the second run. White and gray cells denote an increment and a decrement of the value from the first to the second run respectively.

	Accuracy				Time for Correct selection (s)			
	Touch Screen	Buttons	Head tracker	P300-BCI	Touch Screen	Buttons	Head tracker	P300-BCI
Mean	0,05%	2,51%	0,37%	3,19%	0,29	1,05	0,18	1,55
Median	0,00%	0,00%	0,00%	2,05%	0,26	1,14	0,11	0,22
I Quartile	0,00%	9,38%	0,00%	3,33%	0,18	0,05	0,01	2,41
III Quartile	0,00%	0,00%	0,00%	5,53%	0,33	2,43	0,39	1,99
Min Value	0,00%	12,06%	6,67%	28,48%	0,12	1,98	0,23	10,69
Max Value	0,42%	10,00%	3,33%	12,50%	0,73	3,40	0,64	4,19

4 Discussion

Despite not conclusive, these results confirm the feasibility of a single AD accessible from a broad range of input modalities, including a BCI. In fact, no differences in terms of simplicity in getting acquainted with the prototype were pointed out by stakeholders. The P300-BCI exhibited lower efficiency and effectiveness with respect to the other access conditions, but this did not affect the ease of access, ease of use, ease of understanding, usefulness and satisfaction perceived by participants with BCI. Indeed no differences were found between the four input conditions. This confirms that the overall system has been perceived by stakeholders as a single multimodal AD system.

Acknowledgments

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