The Brindisys Project: Brain Computer Interfaces as Assistive Technology for People with ALS

F. Schettini[1,2], A. Riccio[1,7], L. Simione [1,7], G. Liberati[1,6], M. Caruso[2], B. Calabrese[3], N. Ielpo[3], A. Palumbo[3], V. Frasca[5], M. Mecella[2], F. Amato[3], A. Pizzimenti[4], M. Inghilleri[5], D. Mattia[1], F. Cincotti[1,2]

[1]Fondazione Santa Lucia, Rome, Italy; [2]DIAG, Sapienza University of Rome , Italy; [3]Department of Experimental and Clinical Medicine, "Magna Graecia" University of Catanzaro Italy; [4]Crossing Dialogues Association, Rome, Italy; [5]Department of Neurology and Psychiatry, "Sapienza" University of Rome, Italy; [6]Institute of Medical Psychology and Behavioral Neurobiology", Eberhard-Karls-University, Tübingen; [7]Department of Psychology, "Sapienza", University of Rome, Italy

Correspondence: F.Schettini, Fondazione Santa Lucia, IRCCS, Via Ardeatina, 306 I-00179 Rome, Italy. E-mail: f.schettini@hsantalucia.it

Abstract. The Brindisys project aims at designing and developing a general assistive technology to support communication and autonomy in people with Amyotrophic Lateral Sclerosis (ALS) from the onset of the disease to the locked-in phase. The prototype consists of a specific interface allowing for communication and environmental control that can be managed both with conventional/assistive input devices and with a P300-based Brain Computer Interface (BCI). This work describes the system functionalities and reports a preliminary assessment with end users.

Keywords: ALS, P300 Potential, Brain Computer Interface (BCI), Assistive technology

1. Introduction

Persons with Amyotrophic Lateral Sclerosis (ALS) experience a progressive loss of muscle strength that eventually prevents any movement. In this course, independence and communication ability are increasingly impaired. In each phase of the disease, this condition can be temporarily compensated by adopting an assistive device, tailored to the current functional deficit. When muscular contraction is eventually impossible, BCIs could be a solution by detecting the voluntary modulation of brainwaves, and convert them into messages and commands to interact with the environment [Cincotti et al., 2008; Millán et al., 2010].

The Brindisys project (Brain-computer interface devices to support individual autonomy in locked-in individuals) aims at developing a new assistive system designed to preserve communication and interaction with the external world in people with ALS during all the stages of the disease. In fact, the proposed device is designed to be operated with several input devices, coping with user's motor abilities.

2. Material and Methods

2.1. The Brindisys System

The Brindisys system consists of two main components: a tablet PC that allows several applications for communication and environmental control, and an application that can overlay BCI stimuli on the user interface. The novelty of the proposed prototype is in making seamlessly accessible its functionalities both with conventional/assistive input devices relying on the current user's residual motor abilities (touch screen, mouse, keyboard, joystick, buttons, and head tracker) and with a P300-based BCI. It was indeed designed in order to follow the user from the onset of the disease to the complete loss of motor abilities. This way, the user can start using the system and familiarize with it before the BCI becomes the only way to communicate with the external world.

All calibration and configuration procedures of the BCI have been simplified, so that the system can be operated by people with limited technical competence. Moreover, new classification algorithms have been developed in order to increase system reliability and usability [Aloise et al., 2011].

2.2. The role of end users and system functionalities

The Brindisys project focused on users through the planning, design and development of the system (user-centered design). To identify users' requirements, 7 end users, 13 caregivers and 20 stakeholders were interviewed

about both communication and environment control needs of people with ALS, all of them recruited from the ALS Center (Sapienza, University of Rome). Two focus groups about the potentialities of a BCI were carried out. This first phase allowed defining the system functionalities. As far as the communication is concerned, the system provides three main applications: (i) an alarm bell to draw the attention of the caregiver; (ii) a text writing function for both face to face and remote (e-mail, SMS) communication; and (iii) fixed sentences or keywords for quick communication. For the environmental control, simple functions have been required by users such as TV control, movement of armchair/bed, lights control and doors opening [Caruso et al., 2013]. These functions have been implemented using the KNX standard to control devices available in an apartment designed for people with limited mobility, where preliminary assessment took place. Users were successfully involved in the prototype assessment.

2.3. Evaluation

Usability of the Brindisys system was evaluated in terms of effectiveness (reliability), efficiency (workload, NASA-tlx), and satisfaction (Visual Analogue Scale VAS for overall satisfaction and System Usability Scale SUS for perceived satisfaction and usability). Three end users with ALS (2 male, 1 female; age 56, 59, 75 years; ALSfrs 9, 37, 38) were involved in the evaluation protocol, which included two sessions: during the first one, the subjects operated the prototype using the input device coping with their motor abilities (buttons and automatic scanning, touchscreen and keyboard and mouse respectively), while during the second session they operated the prototype by means of BCI. The required tasks were the same for both sessions, and each session consisted of (i) a communication task: spelling of predefined sentences and (ii) an environmental control task: performing of some actions on the environment mimicking real-life situations. During the experimentation, users' feedbacks and suggestions were collected in order to improve system features for the final release of the prototype.

3. Results

The three end users successfully completed the experimental protocol. All subjects were able to complete the proposed tasks controlling the Brindisys prototype with the P300-based BCI and reaching on average a 95% classification accuracy (ranging from 89% to 100%). The end users showed high satisfaction (VAS, 0-10) with both the BCI-device (ranging between 8.3 and 10, average 9.4) and conventional/assistive input devices (ranging between 9 and 10, average 9.6). The usability perceived by the end users and measured by means of the SUS (0-100) was on average 73.75 for the BCI and 59.1 for the conventional/assistive input devices. Furthermore the BCI exhibited a comparable efficiency in terms of required workload (29.2) compared to muscular input devices (31.5).

4. Discussion

This work provides an overview of the first prototype of the Brindisys system and reports the preliminary results about assessment with end users. The achieved classification accuracies far exceeded 70%, thereby fulfilling the criterion for satisfactory communication. Furthermore these preliminary results showed a high level of user satisfaction and system usability comparable to the ones exhibited with conventional/assistive input devices. Despite not conclusive, the results indicate the potential effectiveness and usability of the proposed system.

Acknowledgements

This work is supported by the Italian Agency for Research on ALS–ARiSLA.

References

Aloise F, Schettini F, Aricò P, Salinari S, Guger C, Rinsma J, Aiello M, Mattia D, Cincotti F. Asynchronous P300-based brain-computer interface to control a virtual environment: initial tests on end users. *Clin EEG Neurosci*, 42(4):219–24, 2011.

Caruso M, Cincotti F, Leotta F, Mecella M, Riccio A, Schettini F, Simione L, Catarci T. My-World-in-My-Tablet: an architecture for people with physical impairment. *HCI International*, 2013.

Cincotti F, Mattia D, Aloise F, Bufalari S, Schalk G, Oriolo G, Cherubini A, Marciani MG, Babiloni F. Non-invasive brain-computer interface system: towards its application as assistive technology. *Brain Res Bull*, 75(6):796–803, 2008.

Millán JdR, Rupp R, Müller-Putz GR, Murray-Smith R, Giugliemma C, Tangerman, Vidaurre C, Cincotti F, Kübler A, Leeb R, Neuper C, Müller KR, Mattia D. Combining Brain-Computer Interfaces and Assistive Technologies: State-of-the-Art and Challenges. *Front Neurosci*, 4, 2010.