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INVESTIGATION OF NEEDS AND CHARACTERISTICS OF END-USERS, FOR A FUTURE INCLUSION OF BCIS IN AT-CENTERS

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ABSTRACT Brain-Computer Interface as an alternative channel to access Assistive Technologies for communication disorders is not currently available in the AT-centers portfolio. A step forward such availability would consist in BCIs integration with existing AT inputs thus, resulting in a personalized hybrid BCI-based communication device.

The overall aim of the study is to generate profiles of patients that would potentially use the BCI as an additional/alternative channel for AT-access.

In an AT-center, we have started to systematically screen patients with different degree of disability. Currently, 10 patients have been screened in relation to their needs by means of the Individual Prioritised Problems Assessment (IPPA) and the matching AT solutions.

Preliminary results of IPPA showed that the most common problems to be solved with AT were "reading/writing" (N=8), "communication" (N=7) and "phone access" (N=6). AT solutions were mostly characterized by input devices (touch screen, eye tracker) controlling a customized user interface.

As a next step, participants will be screened for P3-based-BCI control.

INTRODUCTION

Communication is a basic need and right of every human being. Many common brain disorders or neuromuscular diseases lead to severe and complex impairments of communication and interaction abilities. These disabilities could create social isolation and dependency, having a considerable impact on a person's quality of life (QoL). Assistive technologies (ATs) could restore basic communication capabilities and improve interaction in people with complex communication needs, alleviating dependency and supporting the participation in society. This would significantly improve their own and their caregivers' QoL.

AT was defined as "an umbrella term indicating any product or technology-based service that enables people of all ages with activity limitations in their daily life, education, work or leisure" [1]. The definition includes both "mainstream" technologies (general-purpose technologies) and "assistive" technologies (purposely designed for people with disabilities), whose assembly varies case-by-case, depending on the individual characteristics of the person, the activities he/she is intended to perform, and the physical and human context where he/she lives [1]. Current ATs provide a powerful array of communication, information, organization, and social networking options for individuals with complex communication needs [2].

Several AT solutions are available for end-users to improve accessibility to communication and environmental control technologies: those are based on various technological approaches and interaction modalities (e.g. eye-trackers, adapted joysticks, speech recognition …) which are available in the portfolio of the AT-centers. AT-centers are AT service delivery, where AT experts with various backgrounds (such as therapists, psychologists, engineers, medical doctors) are responsible for the selection of AT solutions and for their customization to users' needs and their motor, sensory and cognitive impairment (disabilities). Furthermore, AT experts are responsible for training the users in the AT daily-life usage.

Brain-Computer Interfaces (BCIs) measure signals related to specific brain activity and translate them into outputs to control external devices for a range of applications such as communication, environmental control, movement control and motor rehabilitation [3]. It was widely demonstrated that BCI can provide people with communication disorders with an AT, restoring their interaction with the environment [4, 5, 6]. Thus, the primary motivation of BCI research in this field has

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been the reestablishment of communication and facilitation of daily life activities for people with communication and interaction disabilities, due to many common disorders such as neurodegenerative diseases (amyotrophic lateral sclerosis-ALS, spinal muscular atrophy –SMA), spinal cord injury (SCI), acquired brain injury (ABI).

Currently, BCIs are not available in the portfolio of AT-centers for a full deployment to end-users even though BCI technology could improve the inclusiveness of AT solutions. A step forward for the inclusion of BCIs in AT-centers is their integration with existing (available in the market) assistive or mainstream technologies. This integration would result in a hybrid BCI-based communication device [7] that will allow more end-users to use standard means of communication integrating a BCI with their residual muscular activity [4]: the end-users will be able to switch to BCI channel when the muscular one is fatigued or weak (e.g. touch screen, buttons, eye tracker, joysticks); alternatively, he/she will use them as complementary channels.

The first step to bridge the translational gap between BCI development and end-users, by incorporating BCI technology into an AT device for everyday communication and interaction, consists in the clear definition of the users' characteristics and their relation with the abilities to control a BCI. Indeed, the development of prototypic BCIs and ATs, as well as the definition of their specifications, often take place in research laboratories, whit exiguous contact with end-users. The involvement of AT centers in the development of innovative devices and in their customization and validation could bridge this gap.

ALS patients were often considered as the target population of BCI technologies, because of the neurodegenerative characteristics of the disease [8]: it leads to a progressive muscular paralysis causing a loss of communication and interaction ability. However, users attending AT centers are affected by many different diseases with many different etiologies, and complex sensorial, physic, functional and cognitive disabilities.

Here we present a study aimed at investigating the characteristics of patients attending an AT-center (needing an AT for communication and environmental interaction), who could take advantage from BCI introduction in AT-centers as an additional/alternative AT channel. Ten patients were involved in this preliminary study: they underwent multidisciplinary evaluation and AT training, performed in the AT-center of Fondazione Santa Lucia, Roma, to identify the problem (related to communication and environmental interaction) that they wished to solve with the AT and also to identify the best AT solution to solve such problems. Such users will be screened in a following session for their abilities to control a P3-based BCI.

We will analyze the clinical, functional and neurophysiological features influencing such ability. Furthermore, during the BCI control evaluation users' eye movements will be recorded, in order to evaluate if they influence the BCI classification and how the two control channels (eyes and brain) can be used complementary and/or alternatively as part of an AT solution.

MATERIALS AND METHODS

Participants. Ten patients (43.3 ± 9.9 years old, 2 men) with different diagnosis were enrolled in the study: 1 participants with traumatic brain injury (TBI), 3 with amyotrophic lateral sclerosis (ALS), 1 with Friedreich's ataxia, 1 with autosomal dominant leukodystrophy, 2 with hemorrhagic stroke, 1 with encephalitis, 1 with multiple sclerosis (MS). All patients had undergone a multidisciplinary evaluation and an AT training in the AT-center (SARA-t) in Fondazione Santa Lucia, IRCCS, Rome, because they were limited in (at least) one aspect related to interpersonal communication and/or interaction with digital technologies (smartphone, PC, Tablet).

Participants were recruited through the AT-center SARA-t, where the study was conducted.

Patients with other concomitant neurological or psychiatric disorders, any impediment in the acquisition of electroencephalography (EEG) data from the scalp (e.g. wounds, dermatitis), severe concomitant pathologies (fever, infections, metabolic disorders, and severe heart failure), global cognitive impairment, aphasia, or episodes of reflex epilepsy were excluded from the study.

Participant's functional disability was assessed by means of the "World Health Organization Disability Assessment Schedule 2.0 (Whodas, 12 items version [9]). Whodas investigates the functioning level in six life domains with 2 items each: understanding and communicating, getting around, self-care, getting along with people, life activities (i.e., household, work, and/or school activities), and participation in society. Each item asked the participant to rate how much difficulty, (from 1="none" to 5="extreme or cannot do") he or she has had in specific areas of functioning during the past 30 days. 12 items Whodas 2.0 scores range from 0 ("no disability") to 100 ("full disability"). Mean Whodas scores was 67.08 ± 15.6 (range from 45.83 to 85.42). Patient's demographic and clinical information are reported in Table 1.

Table 1: Demographic and clinical information

Participant	Age	Gender	Diagnosis
P1	46	F	ALS
P2	30	F	Encephalitis
P3	58	M	Hemorrhagic stroke
P4	47	F	Hemorrhagic stroke
P5	48	F	ALS
P6	33	F	Friedreich's ataxia
P7	30	F	TBI
P8	50	F	Leukodystrophy
P9	53	F	ALS

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Participant	Age	Gender	Diagnosis
P10	38	M	MS

Protocol. The protocol consists of two parts, *i)* need assessment protocol (results presented here) and *ii)* Brain-Computer Interface protocol (presented here and to be performed in a following study). The study was approved by the Independent Ethics Committee of Fondazione Santa Lucia, IRCCS, Rome.

Needs assessment protocol. Patients were administered with the Individual Prioritized Problems Assessment (IPPA [10]) questionnaire during the multidisciplinary evaluation. They were asked to list (a maximum of seven) problems that they wished/expected to improve/solve with the AT. Moreover, they had to score the perceived importance (1 = "not important at all" to 5 = "most important") and the difficult (1 = "no difficulty at all" to 5 = "too much difficulty to perform the activity at all") associated to each problem. After the needs assessment participants were involved in the AT training. The training was aimed at the identification of the AT solution matching user's need and their motor, sensorial and cognitive characteristics. Table 1 lists the problems reported by participants and the AT solution used by each participant. Patients were proposed to and agreed to participate in the BCI session, which will be performed in the next weeks.

Brain-computer Interface protocol. Scalp potential will be acquired by means of a 16-channel amplifier (g.USBamp, g.tec, Austria) from 16 active electrodes (g.Ladybird, G.tec, Austria) placed according to 10-10 international standard (Fz, Cz, Pz, Oz, P3, P4, PO7, PO8, F3, F4, FCz, C3, C3, CP3, CPz, and CP4 (right ear lobe reference; left mastoid ground). Signals will be digitized at 256Hz. Stimulus paradigm and online delivery will be managed by means of the BCI2000 framework [11]. A P3-speller [12] interface (5 by 6 matrix of alphabetic items) will be displayed full screen, placed approximately at eye level and at a distance of 60 cm.
In the calibration phase (i.e., no feedback on performance), subjects will be asked to focus on 15 items forming 3 predefined words (3 runs; 5 items for each run). The target to focus on will be shown to the participant by a single flash, after which rows and columns will randomly be intensified for 125ms, with an inter stimulus interval (ISI) of 125ms (Stimulus Onset Asynchrony, SOA, 250ms). A stepwise linear discriminant analysis (SWLDA) will be applied offline to determine the classifier coefficients [13] for the testing phase. During the testing phase (i.e., provision of feedback on performance), participants will have to spell four predefined (copy mode) words (4 runs; 5 items for each run 20 characters in total).

The Tobii Technology 4C eye-tracker will be used to collect eye-gaze data. The 4C is a binocular, IR eye tracker that samples at a frequency of 90 Hz. The eye-tracker estimates the user's gaze or point of focus on the monitor in both the vertical and horizontal axis. The initial calibration will be performed using Tobii's calibration software Gaze Point Bundle (version 2.0.8). This software allows also for mouse pointer control. During EEG recording mouse pointer will be not visible and its x and y-coordinates will be recorded and synchronized with EEG signal as a BCI2000's state. The monitor used in this experiment has a resolution of 1280 × 1024 (width × height) pixels and is 17″ along the diagonal.

RESULTS

Needs assessment protocol. The mean total IPPA Score was 19.58 (± 3.04 SD, min = 15, max = 25). Fifty-eight problems in total were identified, with an average of 5.8 problem for participant (SD = ±1.9; min = 1, max = 7). Problems identified were grouped in the following 10 categories:
1) *Reading/Writing*, reported by 8 patients; 2) *Communication*, reported by 7 patients; 3) *Phone access* reported by 6 patients; 4) *TV access*, 5 patients; 5) *Social Network access*, reported by 5 patients; 6) *PC access*, reported by 4 patients; 7) *Listen to music*, 4 patients; 8) *Relationship/Social life*, 3 patients; 9) *Turn on/off the light*, 1 patient. The AT solutions matching with the problems that users wished to solve with the AT solutions and with their motor, sensorial and cognitive characteristics are reported in the following. The touch screen was used as input by 4 patients, the eye tracker was used by 3 patients and the head tracker was the AT commercial input used by 2 patients. One patient used mainstream accessibility settings to improve control accuracy in controlling the PC and 5 patients accessed to the device by mean of a customized user interface.
Problems pointed out from and AT solutions identified for each patient are reported in Table 2.

Brain-Computer Interface protocol. Significant relationships between patients clinical (e.g. aetiology, onset, score in the functional scales, lesion...) and neurophysiological characteristics (e.g. ERPs amplitude and latency) and BCI control performance will be reported. Influence of the number of fixations on the target and off the target, and influence of the mean duration of single on-target fixation (measured by means of the eye tracker) on BCI control will be investigated and reported.

Table 2: problems identified with IPPA and AT solutions

Participant	IPPA	AT solution
P1	Phone Access TV Access	Customized User Interface

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	PC Access Reading/Writing Communication	Input device: eye tracker to control mouse cursor and mechanical switch to perform clicks
P2	Social Network Phone Access Reading/Writing Music TV Access	Customized User Interface Input device: touch screen
P3	Communication	Commercial text-to-speech application Input device: Touch screen
P4	Relationship/Social Life Communication Reading/Writing Music Social Network TV Access	Accessibility settings to improve accuracy using PC
P5	Relationship/Social life Communication Reading/Writing Music	Customized User Interface Input device: eye tracker
P6	Communication Relationship/Social Life Music Social Network Phone Access	Customized User Interface Input device: eye tracker to control mouse cursor and mechanical switch to perform clicks
P7	Communication Reading/Writing Social Network	Commercial text-to-speech application and accessibility settings Input device: Touch screen
P8	Phone Access PC Access Reading/writing TV Access Social Network	Accessibility settings to facilitate the access to tablet Input device: Touch screen
P9	Reading/writing Phone Access Communication PC Access	Customized User Interface Input device: head tracker to control mouse cursor and mechanical switch to perform clicks
P10	Phone Access Reading/Writing PC Access TV Access Turn on/off Light	Head tracker

DISCUSSION

The assumption of this study is the need and potential benefit to include BCIs in AT-centers as an alternative/additional input channel. Indeed, despite the demonstration that BCI can provide people with communication disorders with an AT, such technology is currently absent in the AT-centers portfolio. We propose, as a step forward to such inclusion, BCI integration with existing AT as a hybridization of the BCI-based communication device.

To meet this aim, we propose a screening of the ability to control a P3-speller BCI, in a group of participants with various diseases considering their needs and their clinical and neurophysiological characteristics. Participants involved were attending the AT-center SARA-t during the period of neurorehabilitation that was taking place in Fondazione Santa Lucia. They needed an AT for communication to support daily interaction with communication partners, to access to mainstream communication devices (tablet, smartphone, personal computer) and also to support the process of neurorehabilitation.

Preliminary results on their need (IPPA) and the matching AT solutions showed their need of an AT to improving reading and writing abilities (8 participants), communication abilities (7 participants) and smartphone access possibility (6 participants). AT solutions were identified as matching participants needs and their motor, sensorial and cognitive (dis)abilities and were various input devices (e.g. touch screen, buttons, eye tracker) mostly controlling a customized user interface.

As a next step, participants will be screened for their ability to control a P3-based BCI (P3-Speller) recording eye movements during the BCI session.

Aim of this second part of the protocol is to investigate the relationship between participants' clinical and neurophysiological characteristics and BCI control. This will allow the definition of various profiles of BCI accessing to different versions of personalized hybrid BCI for communication. Such personalization will match end users' motor, sensorial and cognitive characteristics.

The hybridization of the BCI based communication device by mean of BCI integration with existing AT would lead to the concept of a highly personalized (hybrid) BCI customized for each user and merged with input channels specific for each user. This would follow the patient in the course of neurorehabilitation consequently improving their QoL and also the quality of rehabilitation and will open the way for multicentric studies to be performed in different AT-centers.

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CONCLUSION

In the present study, involving 10 patients with different degree of disabilities, we reported preliminary data about the screening of needs of potential end-users of a hybrid-BCI device for communication and we also reported the matching AT solutions. The overall aim was to generate profiles of patients that would potentially use the BCI as an additional/alternative channel for AT-access.

Results showed that a range of input channels customized on the basis of patients motor, sensorial and cognitive (dis)abilities was used to solve/improve problems related to reading and writing abilities, communication ability and smartphone access ability.

In the next step, their performance in controlling a P3-based BCI for communication will be investigated and the relationship with the user's characteristics (among witch eye movement's peculiarities) will be established. We consider this as an important step for the integration of BCI with daily/commercial AT devices, for the consequent development of a personalized hybrid BCI device for communication and for BCI inclusion AT-centers portfolio.

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REFERENCES

[1] Andrich R, Mathiassen N-E, Hoogerwerf E-J, Gelderblom GJ. Service delivery systems for assistive technology in Europe: An AAATE/EASTIN position paper. Technol Disabil 2013;25:127–146.
[2] Abbott C, Brown D, Evett L, Standen P. Emerging issues and current trends in assistive technology use 2007-2010: practising, assisting and enabling learning for all. Disabil Rehabil Assist Technol 2014;9:453–62.
[3] Wolpaw J, Wolpaw EW. Brain-computer interfaces: principles and practice. OUP USA; 2012.
[4] Riccio A, Holz EM, Aricò P, Leotta F, Aloise F, Desideri L, et al. Hybrid P300-based brain-computer interface to improve usability for people with severe motor disability: electromyographic signals for error correction during a spelling task. Arch Phys Med Rehabil 2015;96:S54–S61.
[5] Schettini F, Riccio A, Simione L, Liberati G, Caruso M, Frasca V, et al. Assistive device with conventional, alternative, and brain-computer interface inputs to enhance interaction with the environment for people with amyotrophic lateral sclerosis: a feasibility and usability study. Arch Phys Med Rehabil 2015;96:S46–S53.
[6] Zickler C, Riccio A, Leotta F, Hillian-Tress S, Halder S, Holz E, et al. A brain-computer interface as input channel for a standard assistive technology software. Clin EEG Neurosci 2011;42:236–244.
[7] Müller GR, Breitwieser C, Cincotti F, Leeb R, Schreuder M, Leotta F, et al. Tools for brain-computer interaction: a general concept for a hybrid BCI. Front Neuroinformatics 2011;5:30.
[8] Riccio A, Schettini F, Simione L, Pizzimenti A, Inghilleri M, Olivetti-Belardinelli M, et al. On the Relationship Between Attention Processing and P300-Based Brain Computer Interface Control in Amyotrophic Lateral Sclerosis. Front Hum Neurosci 2018;12:165..
[9] Üstün TB, Kostanjsek N, Chatterji S, Rehm J. Measuring health and disability: Manual for WHO disability assessment schedule WHODAS 2.0. World Health Organization; 2010.
[10] Wessels R, Persson J, Lorentsen Ø, Andrich R, Ferrario M, Oortwijn W, et al. IPPA: Individually prioritised problem assessment. Technol Disabil 2002;14:141–145.
[11] Schalk G, McFarland DJ, Hinterberger T, Birbaumer N, Wolpaw JR. BCI2000: a general-purpose brain-computer interface (BCI) system. IEEE Trans Biomed Eng 2004;51:1034–43.
[12] Farwell LA, Donchin E. Talking off the top of your head: toward a mental prosthesis utilizing event-related brain potentials. Electroencephalogr Clin Neurophysiol 1988;70:510–23.
[13] Krusienski DJ, Sellers EW, Cabestaing F, Bayoudh S, McFarland DJ, Vaughan TM, et al. A comparison of classification techniques for the P300 Speller. J Neural Eng 2006;3:299–305.