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UMA-BCI SPELLER, A P300-BASED SPELLING TOOL

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ABSTRACT: The brain-computer interface research group of the University of Malaga (UMA-BCI) has developed a speller application based on the well-known P300 potential which can be easily installed, configured and used. The application supports the common P300 paradigms: the Row-Column Paradigm and the Rapid Serial Visual Presentation Paradigm. The inner core of the application is implemented with a widely used and studied platform, BCI2000, which ensures its reliability and allows other researchers to apply modifications at will in order to test new features. There are many studies regarding brain-controlled spellers; however, these systems do not usually leap out of the lab because of technical and economic requirements. As a consequence, the potential end users do not benefit from these scientific advances in their daily life. The objective of this paper is to present a novel brain-controlled speller designed to be used by patients due to its versatility and ease of use.

INTRODUCTION

Most of the studies regarding Brain-Computer Interface (BCI) research are carried out in experimental environments with healthy subjects. Even when patients suffering from different kinds of paralysis participate as subjects, they usually do it only for a few sessions in order to validate the proposed BCI systems. Several authors have also studied the use of BCIs taking into account the perspective of patients, caregivers, and professionals:

- A recent study by Wolpaw et al. [1] found that, although there are more than 4000 research studies regarding BCI systems, only three cases corresponded to independent home use of a BCI for communication. Encouraged by these case reports, they carried out a research with 37 ALS patients who initially began to use a BCI system at home; when the study ended (after up to 18 months), only 7 patients kept the BCI for further use. The authors mention several reasons that explain this difference: 13 patients died during the study or abandoned it because of a rapid disease progression, 9 patients could not use it, 4 lost interest and 2 preferred another assistive communication device, among other minor reasons.
- The results of Taherian and Davies [2] showed that BCIs are not suitable for independent use outside experimental environments. For them, "the hardware needs to be configurable, comfortable and accommodate physical support needs. The training approach needs to be less cognitively demanding, motivating and support personalized mental tasks". They also cite how the reliability should improve and the need for adequate technological support.
- Liberati et al. [3] concluded that four reasons were fundamental to understand the low intensity use of BCI: "i) lack of information on BCI and its everyday applications; ii) importance of a customizable system that supports individuals throughout the various stages of the disease; iii) relationship between affectivity and technology use; and iv) importance of individuals retaining a sense of agency".

Taking into account these results, the BCI research group of the University of Malaga (UMA-BCI) decided to implement a BCI system based on a P300 speller that helped to solve some of the previously mentioned issues in order to be used by patients and caregivers at home. It should be an easy to install and use tool and it should be modular and configurable to support personalization. At the same time, the developed tool should be flexible enough to be used by researchers in the field in order to study variations and alternative paradigms. Both Row-Column Paradigm (RCP) and Rapid Serial Visual Presentation (RSVP) P300-based paradigms should be supported. The target tool should include the possibility of providing dynamic spellers, i.e., spellers that change the items in their layout depending on previous selections. One last specification of the application is that it should be free and open source.

Three options were available: i) to fully develop a custom BCI system; ii) to use a general purpose platform to implement the desired speller; and iii) to partially develop a custom BCI system based on a BCI platform. We declined the first option because it would require a lot of development and testing in order to get a reliable application. The second option would avoid these processes, but it would be limited in its functionality and it would require advanced technical skills. Finally, we decided to benefit from the extended use of platforms to use reliable signal acquisition and signal processing modules, thus using a general purpose platform as the internal core of a custom application.

There exist multi-purpose platforms for BCI analysis and development for scientists to carry out their research; a complete survey on these platforms can be found in [4]. As previously mentioned, the aim of this work is to provide end users with an easy to use P300 speller that is flexible enough to be useful for researchers as well. From this point of view, BCI2000 [5] and OpenViBE [6] are the most interesting among the BCI platforms as they are both widely used, with up-to-date software releases, documentation and support. These two platforms are intended to build end user BCI applications, however, they still require technical skills in order to implement a P300 speller. As both are general-purpose platforms, with a high degree of configurability, it may be complex to parameterize them in order to obtain the desired speller. Besides, the tool proposed in the present paper is intended to be easily configurable for researchers as well, in such a way that the testing of new spelling modalities using alternative stimuli may help in their research (e.g., through the use of images or the independent customization of each cell). BCI2000 is used notably more by researchers in their works [4], so a speller based on it could be easier to use and modify by the scientific community than one based on OpenViBE. This was the main reason to choose BCI2000 as the software core of the speller implementation.

BCI2000. This platform allows a system to be implemented using three modules: *signal source*, *signal processing* and *application*. Each one of these modules can be independently configured in order to adjust them to the desired system. The user can modify many parameters in order to configure the three modules:

- The *signal source* module supports multiple data acquisition hardware that can be selected. Besides, manufacturers can create their own C++ modules to be included.
- The *signal processing* module allows the processing of the most common EEG signals (P300, steady-state visual evoked potential (SSVEP), sensorimotor rhythms (SMR), slow cortical potentials (SCP) etc.) with predefined or custom-implemented algorithms.
- The *application* module contains several basic graphical applications which use the data coming from signal processing as input.

All these parameters can be modified and saved through a tab-based GUI provided together with BCI2000 and they are stored in a parameters file with the extension *.prm*. The use of parameterization allows a high degree of customization, but at the same time it makes the application harder to configure. Among the pre-defined BCI2000 applications, the platform includes implementations of the RCP speller (*P3Speller*) and RSVP paradigm (*StimulusPresentation*). The *UMA-BCI Speller* here presented is built using these two BCI2000 presentation paradigms.

This paper is a short version of a full length manuscript sent to a scientific journal. On the date this paper is written the full length version is under review.

MATERIALS AND METHODS

The *UMA-BCI Speller* is a P300-based speller application that is built using BCI2000, that simplifies the use of it and extends its functions acting as a wrapper of BCI2000 (see Fig. 1).

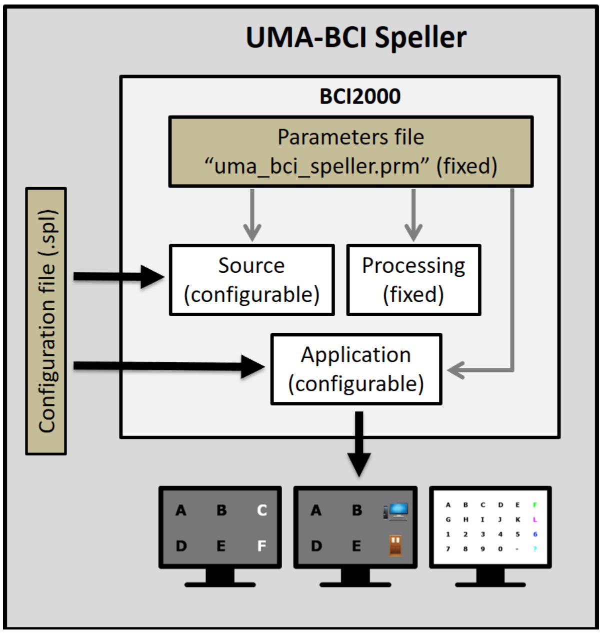

Figure 1: *UMA-BCI Speller* scheme. The application acts as a wrapper of BCI2000.

Most of BCI2000's configurability is intentionally limited because *UMA-BCI Speller*'s aim is to easily implement a P300 speller. For this reason, the BCI2000 signal processing module is fixed to *P3SignalProcessing*, as well as the majority of the application module parameters (fixed to be *P3Speller* or *StimulusPresentation* for RCP or RSVP, respectively) and the source module (which loads the common electrode positions for a P300 experiment). These predefined settings are applied to BCI2000 through a parameters file (*uma_bci_speller.prm* or *uma_bci_speller_rsvp.prm*) that is loaded automatically. Through the *UMA-BCI Speller* GUI, users can indirectly modify some BCI2000 parameters that affect the source signal selection and the number of elements of the speller matrix (see Fig. 1). Besides, users can control the visual appearance of the speller through new options outside BCI2000 that let them change colours and add images. The set of configuration parameters that users can modify is grouped in a new configuration file **.spl*. Thus, users only control a reduced set of parameters in order to use and personalize their own P300 speller keyboard. Advanced users (i.e., users who already know how to manage BCI2000) can edit the mentioned "uma_bci_speller.prm" file in order to customize the application beyond what *UMA-BCI Speller* offers by default (e.g., parameters regarding the timing of the speller).

The customization of *UMA-BCI Speller* is achieved

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through the GUI configuration, which can be modified in two ways: i) by changing the values of the parameters that are related to the general appearance of the speller (number of rows and columns, space in between them, background colour...) and to all the cells equally; and ii) by particularizing the appearance and function of each individual cell. There are two menus to modify these two sets of parameters, the grid parameters and the cell parameters menus, which will be described in their respective sections below. The *UMA-BCI Speller* configuration files (with extension *.spl*) save both types of parameters.

Fig. 2 shows the top partial view of the main screen which contains a toolbar with the most common functionality: to create, open and save configurations; to start and stop experimental runs; to access the settings menu; to toggle full screen mode, RCP/RSVP paradigms and calibration/online test mode; to set the calibration text, the number of sequences, the subject name and session; and to launch the classifier tool. The image shows a calibration session with the word "text" in which the two first letters have already been calibrated; the central column is being highlighted.

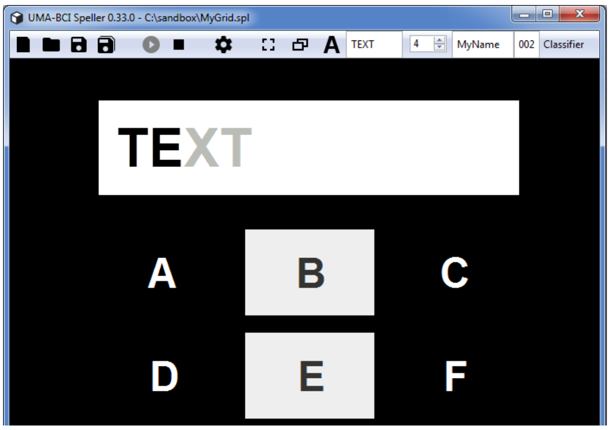

Figure 2. *UMA-BCI Speller* partial screen capture.

Grid parameters. This set of parameters (Fig. 3) is accessed by double-clicking in the idle part of the GUI (i.e., the speller background). Users can modify the number of rows and columns of the display and specify the size of the cells, as well as the empty space in between. The typing bar layout is defined here as well. There are some other parameters that allow the user to make changes on the keyboard letters' font type and size, as well as the cells' background colour for either the idle or highlighted state. Through this menu, users can fix also the size of the stimulus in the case of activating the RSVP paradigm. These parameters affect all cells equally.

The grid parameters shown in Fig. 3 configure the layout in Fig. 5b with four rows and three columns, highlighting the letters in blue.

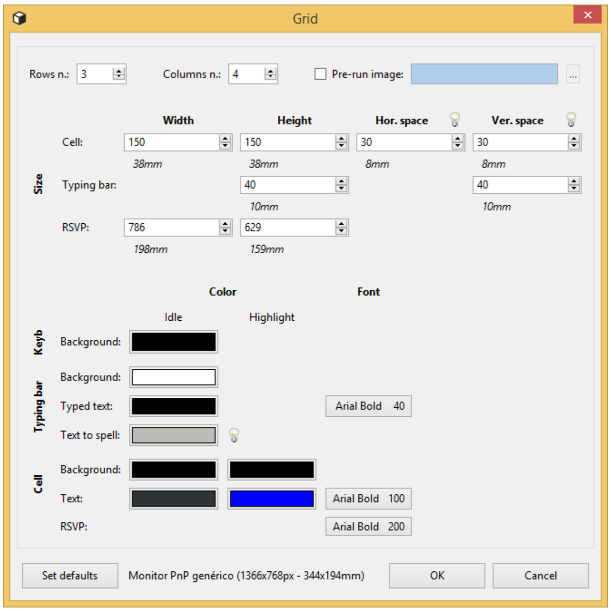

Figure 3. Grid parameters menu.

Cell parameters. The capability to customize each individual cell beyond the general appearance of the grid parameters is one of the main aspects of the *UMA-BCI Speller*. If users want to change a single cell's appearance, they can do it by double-clicking on a particular item; a cell-specific menu will appear (Fig. 4). In this menu, two columns of parameters are present, *Idle* and *Highlight*, for the case of the cell being in idle or highlighted state, respectively. The cell text and background colour for both states can be modified; if not marked in this menu, the values defined in the general grid parameters menu will apply.

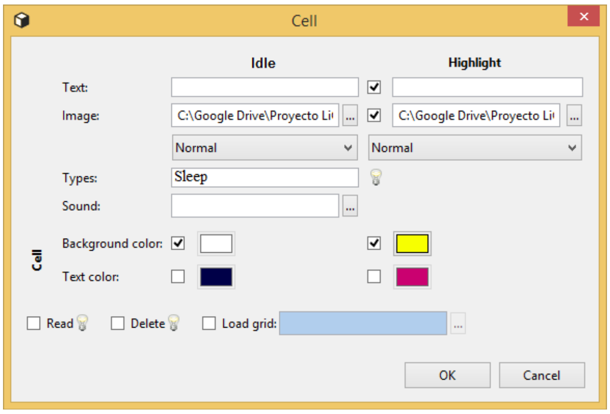

Figure 4. Cell parameters menu.

Another important feature is that images can be included here instead of text, for both idle and highlight states (field *Image*). The images presented this way will fit the space of the corresponding cell determined through the grid parameters.

In the field *Types*, users can set the text to be written in the typing bar when the cell is selected. In the common case of a speller matrix containing characters, the *Types*

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text should be a single character corresponding to the one actually shown. However, in other situations the *Types* field may be a whole word or sentence; that would be the case of cells containing pictograms that could mean "water", or "turn on the light", for example. The field *Sound* allows a sound to be loaded to be heard when this cell is presented in the RSVP paradigm.

Two checkable options are present, *Read* and *Delete*. With the first one, the user indicates that when this cell is selected, the system "reads" with a synthesized voice all the characters spelled to this point. The other option is used to include a *Delete* cell that removes the last spelled character.

Finally, the *Load grid* option allows the speller elements to be changed to a previously saved grid. In this way, the elements in the speller are updated depending on previous selections, so users can navigate through several keyboards, as in [7].

In the case of using the RSVP paradigm, only the *Highlight* parameters apply, as the symbols are presented serially in their highlighted state.

The cell parameters in Fig. 4 define the appearance of the upper-right cell in Fig. 5d: there, the same image with alpha channel is used for the idle and highlighted state; however, the highlighting is achieved through the use of a yellow background. When this cell is selected, the speller writes the word "Sleep".

P300 Classifier automatic calling. The offline signal processing procedure of the calibration data is simplified in the *UMA-BCI Speller*, as it is integrated with the tool: once the training session is finished, one single action groups all the subject's EEG raw signals and performs the necessary steps to obtain the optimal classifier. Clicking on the button Classifier (see Fig. 2) causes the system to open a window to select the files with the calibration data. Once selected, an internal process uses the BCI2000 tool *P300 Classifier* to obtain the classifier parameters to be used in the free spelling session. Another window with the results of the process is then shown, which indicates if a classifier could be obtained with the supplied data and the classification accuracy corresponding to the number of sequences. This information can be used to determine the optimal number of sequences to be applied in the free spelling mode.

Settings Menu. This menu allows the user to parameterize some miscellaneous aspects of the application. One option in this menu is the signal source selection: the process for using a bio-signal amplifier in *UMA-BCI Speller* is the same as in BCI2000: a specific module needs to be provided by manufacturers, which may be a *.exe* and a *.dll* file or source code to be compiled. In both cases, once the BCI2000 system is ready to use them, the *UMA-BCI Speller* just needs the user to select the desired option in the *Source* selector.

The Settings menu also allows the user to add an additional *.prm* parameters file that directly affects any aspect of BCI2000, beyond the default settings determined by the automatically loaded parameters files (*uma_bci_speller.prm* or *uma_bci_speller_rsvp.prm*) mentioned before. The parameters loaded in this way overwrite those automatically loaded, but they do not persist for the next runs. If the users want to persistently update these parameters, the default parameters files need to be directly modified (e.g., with a text editor).

GUI configuration examples. Fig. 5 shows four variations obtained by modifying grid and cell parameters; the last column is highlighted in all the examples. Fig. 5a corresponds to a common implementation of a P300 speller. Fig. 5b is the result of applying grid parameters to increment the number of rows and columns and to change the highlighting colour to blue (for details see Fig. 3). In Fig. 5c the highlighting and cell background colours are different in the last column cells, it is achieved through the use of cell parameters. Finally, Fig. 5d shows the use of images in cell parameters: every cell contains a pictogram with white background while the highlighting consists of a changing the background colour; the upper-right cell parameters are detailed in Fig. 4.

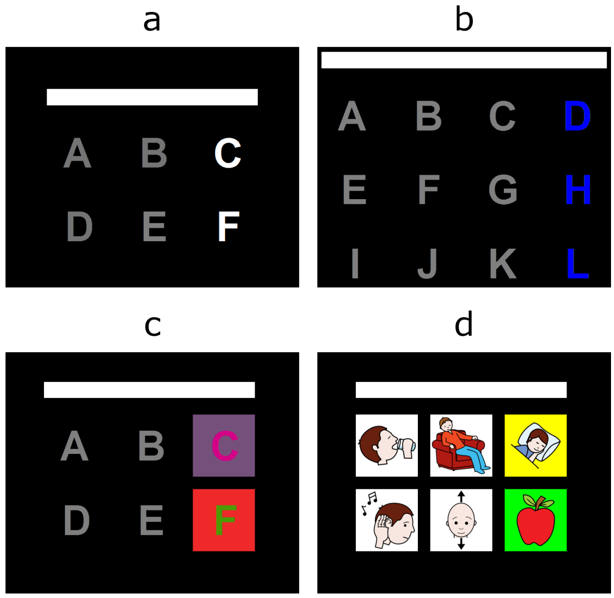

Figure 5. GUI configuration examples.

Hardware and software requirements. The *UMA-BCI Speller* application does not require any special features. As it wraps BCI2000, the whole system requirements would be those of BCI2000. The BCI2000 platform is not a heavy software, it only requires a Windows-based operating system (Windows 2000 or newer) and one of the data acquisition devices that BCI2000 supports [8]. BCI2000 can also run on Linux and OS X systems, but there is no binary distribution for these systems (users would need to compile BCI2000 before using it). Besides, only a minority of source modules support operating systems other than Windows (those modules that receive data through a TCP connection [9]).

Licensing and availability. The *UMA-BCI Speller* application is implemented using BCI2000, which is available under the GNU General Public License (GPL). As a consequence, the use and distribution of

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UMA-BCI Speller is protected by the same GPL license. This means that anyone can use *UMA-BCI Speller*, that the source code is publicly available, and that anyone can develop and distribute derived software products under any terms, provided that the full source code of the derived product is made publicly available for download under the terms of the GPL.
The installation files of *UMA-BCI Speller*, the full source code and a detailed User Manual with all the information regarding the installation, configuration and use can be accessed in the following URL: https://proyectos.diana.uma.es/umabci_speller.

CONCLUSION

We have presented in this paper a BCI tool focused on a speller application: the *UMA-BCI Speller*. The aim of this tool is to provide end users with an easy to use open source P300 speller. It is based on the widely used platform BCI2000, so it takes advantage of the reliability that such a platform offers. The *UMA-BCI Speller* wraps BCI2000 in such a way that its configuration and use is more visual and easier, a fact that can enhance the use of BCI systems at end users' homes. The UMA-BCI Speller allows new features to be added in order to test different variations of the speller layout, a capability that BCI researchers can exploit. The *UMA-BCI Speller* supports two P300 stimulations: RCP and RSVP. Users can configure their speller more appropriately using characters, images or sound cues, and they can navigate through different layouts, thus opening the door to complex speller configurations.

The *UMA-BCI Speller* uses the current release of BCI2000 (v3.0.5); however recent beta versions (e.g. BCI2000 v3.6) include new features that enable a "quasi-asynchronous" control and let the system dynamically change the number of stimulus repetitions through the use of the parameters MinimumEvidence and AccumulateEvidence [10]. Upcoming versions of *UMA-BCI Speller* will be updated to include the new features of BCI2000 beta releases.

Other features to be included could be the support of variations of the RCP (e.g. the Checkerboard paradigm [11]) and RSVP (e.g. Triple RSVP [12]). Other current trends on BCI could help to reduce the calibration time, like the use of generic models or adaptative calibration techniques. It would be interesting also to adapt the interface in order to extend its functionality beyond spelling, for example, use it to browse the internet or to activate external actuators.

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REFERENCES

[1] J. R. Wolpaw et al., Independent home use of a brain-computer interface by people with amyotrophic lateral sclerosis, Neurology, p. 10.1212/WNL.0000000000005812, 2018.
[2] S. Taherian and T. C. Davies, Caregiver and special education staff perspectives of a commercial brain-computer interface as access technology: a qualitative study, Brain-Computer Interfaces, vol. 5, no. 2–3, pp. 73–87, 2018.
[3] G. Liberati et al., Developing brain-computer interfaces from a user-centered perspective: Assessing the needs of persons with amyotrophic lateral sclerosis, caregivers, and professionals, Appl. Ergon., vol. 50, pp. 139–146, 2015.
[4] C. Brunner et al., BCI Software Platforms, in Towards Practical Brain-Computer Interfaces, 2013, pp. 303–331.
[5] G. Schalk, D. J. McFarland, T. Hinterberger, N. Birbaumer, and J. R. Wolpaw, BCI2000: A general-purpose brain-computer interface (BCI) system, IEEE Trans. Biomed. Eng., vol. 51, no. 6, pp. 1034–1043, 2004.
[6] C. Arrouët, M. Congedo, J.-E. Marvie, F. Lamarche, A. Lécuyer, and B. Arnaldi, Open-ViBE: A three dimensional platform for real-time neuroscience, J. Neurother., vol. 9, no. 1, pp. 3–25, 2005.
[7] G. Pires, U. Nunes, and M. Castelo-Branco, GIBS block speller: Toward a gaze-independent P300-based BCI, Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS, pp. 6360–6364, 2011.
[8] G. Schalk and J. Mellinger, A Practical Guide to Brain-Computer Interfacing with BCI2000. Springer London Dordrecht Heidelberg New York, 2010.
[9] BCI2000 Binaries - BCI2000 Wiki. [Online]. Available: https://www.bci2000.org/mediawiki/index.php/BCI2000_Binaries#Non-Windows_Operating_Systems. [Accessed: 31-Jan-2019].
[10] User Reference:P3SpellerTask - BCI2000 Wiki. [Online]. Available: https://www.bci2000.org/mediawiki/index.php/User_Reference:P3SpellerTask#MinimumEvidence. [Accessed: 31-Jan-2019].
[11] G. Townsend et al., A novel P300-based brain-computer interface stimulus presentation paradigm: Moving beyond rows and columns, Clin. Neurophysiol., vol. 121, no. 7, pp. 1109–1120, 2010.
[12] Z. Lin, C. Zhang, Y. Zeng, L. Tong, and B. Yan, A novel P300 BCI speller based on the Triple RSVP paradigm, Sci. Rep., vol. 8, no. 1, pp. 1–9, 2018.