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The MOPS-Speller: An Intuitive Auditory Brain-Computer Interface Spelling Application

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Abstract

In auditory Brain-Computer Interface (BCI) systems for communication, usually the letters of the alphabet are grouped to be spelled since presenting them all one after another would be too time consuming. Each group is usually assigned a number or a sound and letters are selected by making several grouping choices in a row. Herein we introduce the MOPS-Speller, which uses natural language words for grouping. The desired letters can be selected intuitively as they appear in the grouping word, thereby presenting an intuitive auditory spelling paradigm for communication.

1 Introduction

To allow for BCI based communication even in patients who are unable to control their eye movement and therefore, cannot benefit from visual input has been one crucial research goal in Brain-Computer Interfacing (BCI). In the P300-based auditory paradigm presented by Schreuder and colleagues (2011) letters of the alphabet were divided into six groups and each group was represented by one sound (consisting of a base tone ranging between 440 and 1099 Hz and a noise ranging between 3 and 10.5 KHz) presented from spatially distributed loudspeakers. The six loudspeakers were arranged in a circle around the person (in a distance of 60° from each other) and one could choose a letter group by focusing attention to the sound as well as the direction from which the sound was presented (spatial information). After the group was selected, single letters were presented to the participant and the desired letter could be chosen. Another promising P300-based approach was presented by Höhne and colleagues who combined sound frequency (high=708Hz, medium=524Hz and low=480Hz) and spatial information (right ear, left ear, both ears) via headphones in a paradigm that was based on the T9 system that is used for mobile phones. By focusing attention on the desired group of letters, possible letter combinations were narrowed down to one single desired word and the user could spell fast and easy.

However, in both systems, the letters or groups of letters were represented by sounds in combination with spatial information. Therefore, one has to keep in mind which group is represented by which tone and from which direction. Also the presentation of a visual support matrix decreases external validity as in case visual input cannot be perceived, the presentation of a support matrix would not represent a realizable solution for a patient. Thus, in this paper, we present a speller which uses natural words as stimuli and thereby allows intuitive communication for which no visual support matrix is needed. Spatial information was not implemented in the here presented speller as we aimed at an intuitive and easy-to-set-up solution for auditory BCI use in people with motor impairment.

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2 Methods

2.1 Participants

We tested N=2 severely motor impaired patients. Participant A was paralyzed in a wheelchair because of a traumatic accident, participant B was diagnosed with muscle dystrophy (Duchenne) and also used a wheelchair. Both participants were male and 43 and 49 years old. Both participants used assistive devices for communication but could communicate single words by voice. Participants gave informed consent for the study, which had been reviewed and approved by the Ethical Review Board of the University of Würzburg.

2.2 Material and Procedure

In the MOPS speller the German words “MOPS”, “BUCH”, “KLANG”, “FEDER”, “WITZ” and the non-word “JQVXY” represented the letter groups. Additionally the word “RÜCK” (engl: “undo”) which allows for correction of a false choice was added. Participants underwent a calibration in which all word stimuli were presented 10 times. While participant A needed 10 sequences for spelling 80% correct which was judged to be sufficient, participant B needed 6 sequences according to calibration results. For the online spelling, stimuli were presented to the participants in random order while they focused on the word containing the letter they intended to select. After correct choice of this word, the single letters of the word were presented to the user in random order. Thus, for every letter to spell one word and one letter had to be correctly selected. The lengths of the auditory stimuli varied between 401 and 1162ms, the Inter-Stimulus-Interval (ISI) was set to 800ms. During the copy-spelling task, participants were told to spell the words “BOJE”, “SYLT” and “HARZ”. They were also informed which word to focus on first and after that choice, which letter to spell. Their spelling progress was fed back by presenting to them the single letters already spelled. All stimuli were recorded with the Cubase LE5 Software (female speaker).

2.3 Data Acquisition and Analysis

Stimulus presentation was controlled via Python© (version 2.5, Python Software Foundation) and was linked via UDP to BCI 2000 (version 3, Schalk et al., 2004) in which data were recorded and stored. For EEG acquisition we used 12 passive Ag/AgCl electrodes on the locations Fz, PC1, PC2, C3, Cz, C4, P3, Pz, P4, O1, Oz, O2 according to the international 10-20 system. Each electrode was referenced to the right and grounded to the left mastoid. The EEG was amplified using a 16-channel g.USB amplifier (Guger Technologies, Austria), sampled at 256 Hz, and bandpass filtered between 0.01 – 30 Hz. Fifty Hz noise was filtered using a notch filter implemented in the BCI2000 software. Data processing, storage and stimulus presentation was controlled with an LG computer (Intel Core 2 Duo, 4 GHz, Windows 7), loudspeakers were Hama AL-140 Stereo Speaker (Monheim, Germany). The EEG data were corrected for artifacts and baseline (-100 to 0 ms) using MATLAB© (v2011b). The P300 was defined as the maximum positive peak occurring between 200 and 800 ms after stimulus onset. As the here presented sample exists of two participants only, we did not perform statistical analysis on the data but present the results descriptively. To generate the feature weights for the classifier in the online spelling as well as for offline classification accuracy calculation after artifact removal, stepwise linear discriminant analysis (SWLDA) was used.

3 Results

Participant A spelled very successfully with the MOPS Speller with an average online accuracy of 90% correctly selected letters. The three times he had to use the undo function, he corrected his previous false choice properly and spelled correctly all three words “BOJE”, “SYLT” and “HARZ”. His offline classification accuracy was 100% after 7 sequences (see figure1). Participant B was less successful with the MOPS-speller and reached an average accuracy of 53% correctly selected letters online. His offline classification accuracy was 65% with 10 sequences of stimulus presentation (see figure1).

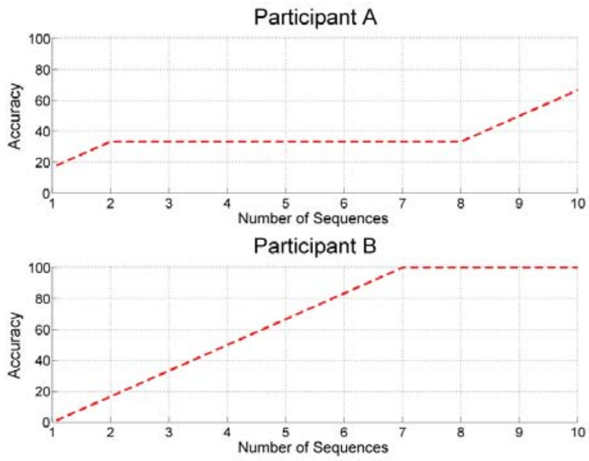

Figure 1: Classification accuracy as a function of number of presented sequences.

In line with the presented spelling result we found main differences for signal distinction between targets and non-targets between the two patients. While in participant B, the P300 is very clearly detectable (see figure 2), targets and non-targets were less distinguishable in participant A (see figure 2). The Information Transfer Rate (ITR) was 0.30 for participant A and 1.04 for participant B.

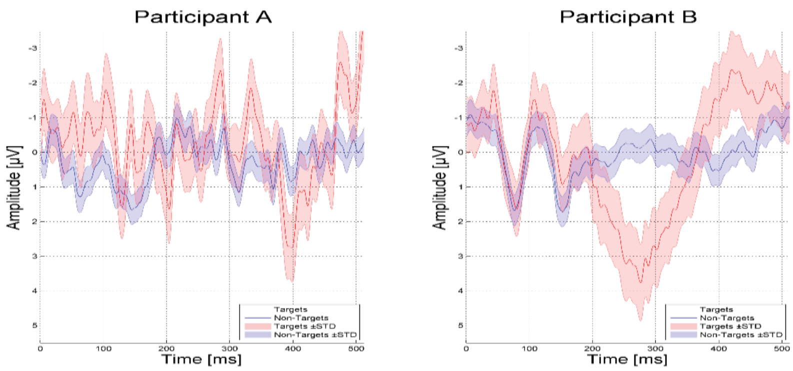

Figure 2: P300 evoked by targets (red) compared to non-targets (blue). Red and blue shades indicate the standard deviation (SD) of EEG signals.

4 Discussion

With the here presented auditory speller, we showed that intuitive auditory communication independent from a visual support matrix can be used successfully by people with severe motor impairment. However, we cannot judge general usability of the MOPS-speller as we only included two patients, and one did not reach sufficient accuracy for meaningful communication (Kübler et al., 2001), but we demonstrated the proof-of-principle.

Our major goal of using intuitive stimuli in an easy-to-setup-paradigm was very well accepted by the participants. They reported the auditory stimulation with natural words to be pleasant and simple to understand, even though after spelling the second word, they started to feel exhausted. Also the stimuli themselves were long and together with the here implemented ISI, ITR is low. Nonetheless, we believe that for a patient who is unable to use the visual input channel, the time that is needed for spelling would still be acceptable.

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