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Listen to the Frog! An Auditory P300 Brain-Computer Interface With Directional Cues and Natural Sounds

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Abstract. A new auditory brain-computer interface (BCI) using natural sounds with directional cues was investigated in a healthy sample. Eleven participants reached within two sessions mean classification accuracies of 70% and 90% and information transfer rates of 4.23 and 5.45 bits/min.

Keywords: EEG, auditory P300, spelling, natural sounds, directional cues

1. Introduction

Severely disabled patients such as in late stage of amyotrophic lateral sclerosis (ALS) might lose eye gaze and thus, the ability to control an eye tracking system for communication. These patients are in the utmost need of brain-computer interfaces (BCIs). The paradigm presented here combined approaches of different auditory BCIs [Furdea et al., 2009; Klobassa et al., 2009; Schreuder et al., 2010; Käthner et al., 2013] by using natural sounds with directional cues as auditory stimuli for a P300 BCI. Natural sounds were selected as they showed best differentiation in a pretest.

2. Material and Methods

2.1. Participants

Eleven healthy participants (mean age 24.27 years, *SD* = 7.14), naïve to auditory BCIs took part in the study.

2.2. Auditory speller with directional cues

In this auditory P300 speller, the letters were arranged in a 5 x 5 matrix. Five different animal sounds coded both rows and columns of the matrix. Directional cues [Käthner et al., 2013] were added to the animal sounds for an easier differentiation. For the selection of a letter, the participant selected in a first step the target row and after a short break the target column of the letter within ten sequences. A visual support matrix was displayed on a screen.

The measurements took place on two consecutive days. After a screening phase (15 letters) in the first session the participants wrote 48 letters in the Copyspelling mode with online feedback in both the first and second session. For the online classification of the second session, the classifier was again trained with the screening runs of the first session.

2.3. Data acquisition and processing

The electroencephalogram (EEG) was obtained from 28 active Ag/AgCl electrodes (Easycap, Germany) at the positions F3, Fz, F4, C5, C3, C1, Cz, C2, C4, C6, CP5, CP3, CP1, CPz, CP2, CP4, CP6, P3, P1, Pz, P2, P4, PO7, PO3, POz, PO4, PO8, Oz. The EEG was sampled at 500 Hz and filtered between 0.1 and 30 Hz with an additional notch filter (50 Hz) with a BrainAmp amplifier (Brain Products, Germany). The BCI2000 software in combination with the BrainVision Recorder 2.0 controlled stimulus presentation, recording and online classification.

Stepwise linear discriminant analysis (SWLDA) was used for classification of the data.

3. Results

3.1. Classification accuracy

Mean classification accuracies of the new auditory P300 speller are listed in Table 1. Significantly higher classification accuracies could be found in session two when retraining the classifier with the first three runs of the second session ($Z = -2.67$, $p < .01$) instead of using the screening block of the first session for classification. For the offline classification accuracies the remaining 32 letters had been classified.

Table 1. *Classification accuracies of both sessions.*

	Session 1 (online)	*Session 2 (online)*	*Session 2 (offline)*
% correct letters (*SD*)	76.72 (21.63)	69.64 (13.64)	90.18 (9.27)
% correct selections (*SD*)	86.64 (14.84)	82.73 (9.22)	94.82 (4.85)

3.2. Information transfer rate (ITR)

The online information transfer rate (ITR) in the first session ranged between 0.4 and 6.31 bits/min ($M = 4.23$ bits/min). After retraining the classifier offline ITR in the second session ranged between 3.84 and 6.65 bits/min ($M = 5.45$ bits/min).

4. Discussion

The results of the healthy sample show the feasibility of the auditory spelling paradigm with online accuracies of 70% and higher. After retraining the classifier significantly higher accuracies could be reached in the second session. This indicates a training effect which might be based on the higher complexity and workload of the auditory speller. The use of natural sounds in combination with directional cues is promising for auditory spelling. Investigations in patients without and with visual impairments will indicate the applicability in the target groups. In contrast to the first group, patients with visual impairments would not be able to use the visual support matrix. In this group, however, the letter matrix is widely used for communication and only the allocation of the sounds to the rows and columns would need to be learned by the patients.

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