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EEG-Based Communication With Patients in Minimally Conscious State

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Abstract. We investigated an EEG-based approach for communication with minimally conscious state (MCS) patients. In a mental imagery paradigm, the patients were instructed to perform imagined sports, navigation and feet movements. Classification accuracies above chance level were reached by three of the four patients performing mental imagery tasks, indicating the feasibility of this paradigm for communication with MCS patients.

Keywords: EEG, BCI, mental imagery

1. Introduction

Brain-computer interfaces (BCIs) based on electroencephalography (EEG) can provide severely motor-disabled people with a new output channel for communication [Birbaumer et al., 1999]. To provide a simple and robust means of communication, the BCI should reliably detect one specific brain pattern such as task specific event-related (de)synchronization (ERD(S)) patterns. A group of patients who are unable to perform any motor movement to use an assistive device are people in a minimally conscious state (MCS). Some of these patients have been proven to be consciously aware [Monti et al., 2010]. Those patients might benefit from such a single-switch BCI. The aim of this work is to investigate whether complex mental imagery and attempted feet movement can be reliably detected in patients with disorders of consciousness, with the general goal to establish an EEG-based communication device.

2. Material and Methods

Four male patients in minimally conscious state (Coma recovery scale was between 9 and 18) aged between 21 and 65 years participated in this study at Albert Schweitzer Clinic in Graz. Informed consent was obtained from the patients' legal representatives. This study was approved by the Ethics Committee of the Medical University of Graz.

Monopolar EEG was recorded from 32 positions with active Ag/AgCl electrodes and a sampling rate of 512 Hz. The patients were either sitting in a wheelchair or lying in bed with their upper part of the body slightly elevated. Each patient participated in three to four mental imagery sessions.

The patients were instructed to perform different mental imagery tasks which should induce distinctive ERD(S) patterns [Goldfine et al., 2011]. In the sports task (S), they should imagine performing one sport of their choice. In the navigation task (N), they should imagine navigating through their house and looking around in each room. In the feet task (F), they should repeatedly attempt to perform dorsiflexion of both feet.

One trial lasted about 12 s, whereas the cue indicating the beginning of the task was presented from second 2 to 3. The task had to be performed between second 3 and 12. All instructions were given verbally. A total number of 45 trials, separated in three blocks by short breaks, was recorded for each task.

A linear discriminant analysis (LDA) classifier based on logarithmic band power features calculated for multiple frequency bands (ϑ: 4-7 Hz; α: 7-13 Hz; β_L: 13-19 Hz; β_M: 19-25 Hz; β_U: 25-30 Hz) was used. A nested blockwise cross-validation (10x10 inner fold; leave-one-out-block outer fold) was applied to estimate the accuracy of each task versus reference (0.5 s before cue) from beginning to the end of a trial.

3. Results

In Table 1, all significant results of the mental imagery paradigm together with the mean Coma Recovery Scale-Revised (CRS-r) scores of the patients across all sessions are summarized. In the mental imagery paradigm, classification accuracies above chance (α = 1%) were reached by three patients in the F or S task. Only the Laplacian channel derivation yielding the highest accuracy is reported. In Fig. 1, the ERDS map of one patient can be seen.

Table 1. *Summary of all significant results of the mental imagery paradigm.*

Patient ID	*Mean CRS-r*	*Mental Imagery*				
		Session	*Task*	*Accuracy*	*Channel*	*Band*
PA_{01}	18	1	F	70 %	Cz	α
		1	S	68 %	C2	α
		2	S	76 %	C2	α
PA_{02}	14	1	F	69 %	FC1	ϑ
		1	S	75 %	Fz	ϑ
		3	F	71 %	FC1	ϑ
PA_{04}	9	1	S	69 %	Fz	α
		2	S	68 %	CPz	β_m

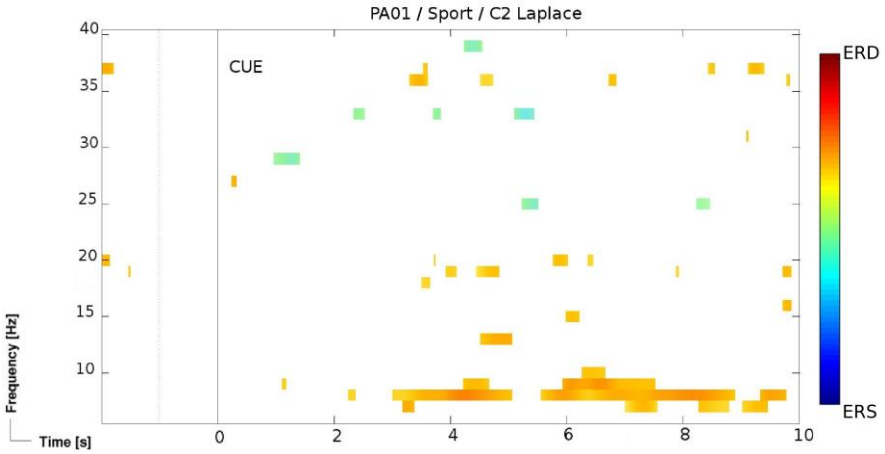

Figure 1. *ERDS map of participant PA01 for the sport task of the second session.*

4. Discussion

Using mental imagery seems to be a promising approach for some of the patients in minimally conscious state to communicate their intent using EEG. Classification accuracies above chance were reached in the foot (F) or sport (S) task but not in the navigation (N) task. This is in line with previous findings indicating that, among other tasks, motor imagery results most frequently in better classification performance than spatial navigation [Friedrich et al., 2012]. As a next step it is planned to perform online experiments and to apply an auditory scanning method as recently described in a study with healthy subjects [Müller-Putz et al., 2013].

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