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Poster

Tactile Pin-pressure Brain-computer Interface

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Abstract **The abstract presents a tactile pin-pressure stimulus-based brain-computer interface (BCI) paradigm. The 3x3 pressure pin matrix stimulus patterns are presented to the users in an oddball paradigm allowing for brainwave "aha-responses" generation to attended targets. Our research hypothesis is confirmed with the results with five users performing online BCI experiments.**

Keywords **Brain-computer interaction; BCI; P300; sEEG; brain signal processing.**

I. Introduction

A brain-computer interface (BCI) is a technology that uses neurophysiological signals (brainwaves) of users to allow communication with others or a control of external devices without any muscle movements [1]. The majority of BCI applications are based on a visual modality. However, disabled people with impaired vision need other types of the BCI for communication. The tactile BCI seems to offer the better communication options in comparison with visual and other modalities in case of locked–in–syndrome (LIS) patients [2]. The paradigm proposed in this abstract is a BCI using tactile pin-pressure stimulus generated by solenoids, which we refer to in brief as tactile pin-pressure BCI (tpBCI). The presented approach allows for faster and more precise delivery of tactile pin-pressure stimuli comparing to the previously proposed vibrotactile stimulator-based approaches, and it is not limited to finger tips only [3]. The goal of this study is to evaluate the performance of the novel tpBCI paradigm proposed and developed by our team. We present the concept of the novel tpBCI and results obtained with five healthy users tested in online BCI experiments.

II. MATERIALS AND METHODS

Tactile stimulus was generated via the tactile pin-pressure generator composed of nine solenoids arranged in the 3 × 3 matrix as depicted in Figure 1.

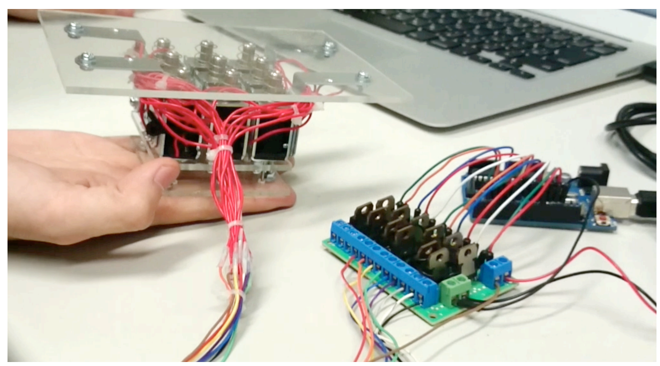

Figure 1. The tactile pin-pressure generator put on the user's dominant hand covering index, middle and ring fingers.

There were six linear patterns of tactile pin-pressure stimuli delivered in random order to the user fingers. Three of them were horizontal lines ordered from the top to bottom of user's fingers respectively. The remaining patterns were the vertical lines in left to right position order. The solenoids generated pin-pressures 100 ms long each time. The psychophysical experiments were conducted to investigate the influence of tactile pin-pressure stimulus on the user behavioral response time and accuracy. The behavioral responses were collected using a trigger button on the keyboard and a MAX 6 [4] program.

A single trial was composed of six tactile pin-pressure patterns delivered to the user fingers in randomized order with an inter-stimulus-interval (ISI) of 900 ms. One session was composed of ten trials for each tactile pin-pressure target. We conducted a session with each user.

In the BCI experiments EEG signals were captured with a portable EEG amplifier system g.USBamp by g.tec Medical Instruments, Austria. Eight active wet EEG electrodes were used to capture brainwaves. Those were attached to the head locations Cz, Cpz, P3, P4, C3, C4, CP5, and CP6. A reference electrode was attached to a left earlobe and a ground electrode on the forehead at FPz position respectively. The users put on polyethylene gloves to limit any electric interference. The users were also requested to limit their eye-blinks and body movements to avoid electromagnetic and electromyography interference. The EEG signals were recorded and preprocessed by an in-house enhanced BCI2000-based application [5], using a stepwise linear discriminant analysis (SWLDA) classifier [6] with features drawn from ERP intervals of 0~800 ms. The sampling rate was set to 256 Hz, the high pass filter at 0.1 Hz, and the low pass filter at 40 Hz. The ISI was 400 ms and each stimulus' duration was of 100 ms.

III. RESULTS

The psychophysical experiment accuracy results are depicted in form of a confusion matrix in Figure 2. This result confirmed the stimulus similarity since the behavioral responses for all the patterns were basically the same. This finding validated the design of the following tpBCI EEG experiment.

The online tpBCI accuracies (see **Table 1**), the four out of five users scored well above the chance level of 16%, which is a good outcome of the proposed prototype. Based on the obtained accuracies we calculated, to allow simply comparison of the proposed tpBCI paradigm with other published approaches, the ITR scores that were in the range from 0.16 bit/min to 3.83 bit/min.

Table 1. Online BCI experiment SWLDA accuracy results and ITR of three experimental sessions with averages (avg)

User	#1	#2	#3	#4	#5	avg
Accuracy [%]	50	38.9	55.6	5.6	90.6	48.1
ITR [bit/min]	0.84	0.40	1.13	0.16	3.83	0.76

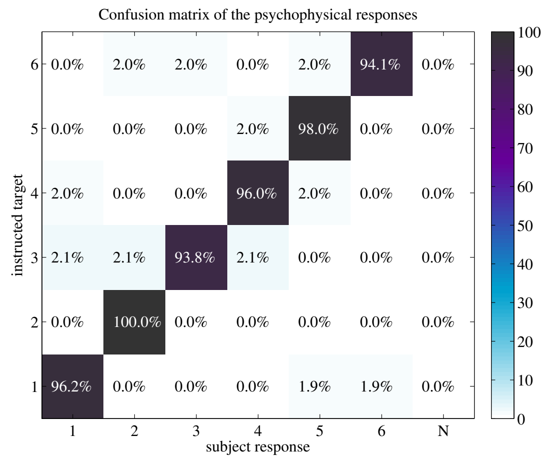

Figure 2. Tactile pin-pressure psychophysical experiment results in form of the confusion matrix of the grand mean averaged user accuracy results.

IV. CONCLUSIONS

According to the results obtained from the online EEG BCI experiments, a single user could score once with perfect accuracy and above 90% on average. Encouraging results support the initial research hypothesis of tactile pin-pressure–based stimulus validity for the BCI paradigms.

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