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Poster

Multi-command Tactile Brain-computer Interface Using the Touch-sense Glove

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Abstract **The project reported in this abstract aims to confirm whether a tactile stimulator ”touch–sense glove” is effective for a novel brain-computer interface (BCI) and whether it would improve BCI classification accuracies. We also report that tactile stimuli delivered to fingers could be utilized to evoke event related potential (ERP) responses with an attention modulation. The designed new stimulator device is presented in detail together with psychophysical and EEG BCI experiment protocols. Results supporting the proposed ”touch–sense glove” device are presented in form of online BCI classification accuracies.**

Keywords **Brain-computer interface (BCI); tactile BCI; event related potential (ERP); EEG; P300.**

I. Introduction

Brain computer interface (BCI) technology shall allow disable people, e.g. the amyotrophic lateral sclerosis (ALS) users, to operate devices without any muscle activity involved. The most popular BCI modality is the visual one, however, it prevents users from paying attention to the surrounding environment making often operation an application impossible. Such BCIs are also not available for users suffering from lost or bad vision [1,2,3].

Our research project proposes to use a tactile BCI (tBCI) modality. This modality shall derive P300 responses, which are usually obtained by attending to a specific target. P300 response is a part of an event related potential (ERPs) [4].

Recently BCI, which utilizes ERP, has been actively researched [1,2,3,4]. So far, the most popular tBCIs use fingertip stimulation to evoke P300 responses [3]. However, this modality accuracy is still low, thus, we propose to expand conventional stimulation to the whole finger surfaces. Our research aims to improve tBCI classification accuracy and to develop the novel and practical stimulation device.

II. Methods

We propose to utilize the P300 responses in the tBCI paradigm and a classification method based on a classical oddball paradigm [4]. The P300-based BCI discriminates the attended stimulus (the target) and ignored stimulus (non-target) from the differences in ERP potentials. We propose a new stimulator as type of a glove named ”touch-sense glove”. The 12 vibrotactile exciters are attached to user fingers. Each finger has one to three attached vibrotactile exciters. Signle exciter is attached on the thumb; two on the little finger; three on the forefinger, the middle and the ring fingers. In psychophysical and EEG experiments, there are five stimulus patterns. The reason why the vibrotactile excites are attached to a glove is to enhance a convenience of an experimental setup avoiding manual attachment of the 12 devices separately each time.

III. EEG Experiment conditions and results

In the psychophysical experiments, user button press responses were recorded. Based on the recorded responses, we analyzed the correct answer rates and the response delay times. We confirmed the users could identify stimulus patterns. In order to evaluate the P300 response occurrences and the further possible online BCI good classification accuracies, we conducted a series of EEG experiments with the same users as in the previous psychophysical experiments. The EEG experiments did not require the users to respond behaviorally by pressing a button, but only mental responses were instructed. The user’s brainwaves were captured using wet active EEG electrodes. Then, the captured and filtered brain signals were segmented and classified after a training of the step-wise linear discriminant analysis (SWLDA) classifier [5]. The EEG recording detailed conditions have been summarized in Table I. The brainwaves have been depicted in form of grand mean averaged (all users and sessions) ERPs in Figure 1. Online tBCI experiments results have been also summarized in form user achieved accuracies (a chance level was of 20%) and information transfer rates (ITR). The accuracy and ITR results are presented in the Table II.

Table I. The EEG experiment conditions

Condition	**Detail**
Number of users	5
Inter-stimulus-interval	500 ms
Stimulus duration	100 ms
Number of stimuli	5 (thumb; forefinger; middle finger; ring finger: little finger
EEG electrode positions	Cz, CPz, P3, P4, C3, C4, CP5, and CP6
High-pass; low-pass; notch	0.1 ; 60 ; 48 ~ 52 (Hz)

Table II. BCI accuracies and ITR scores

User number	**The best BCI accuracy**	**The best ITR**
1	100%	4.46
2	100%	4.46
3	100%	4.46
4	100%	4.46
5	60%	1.10

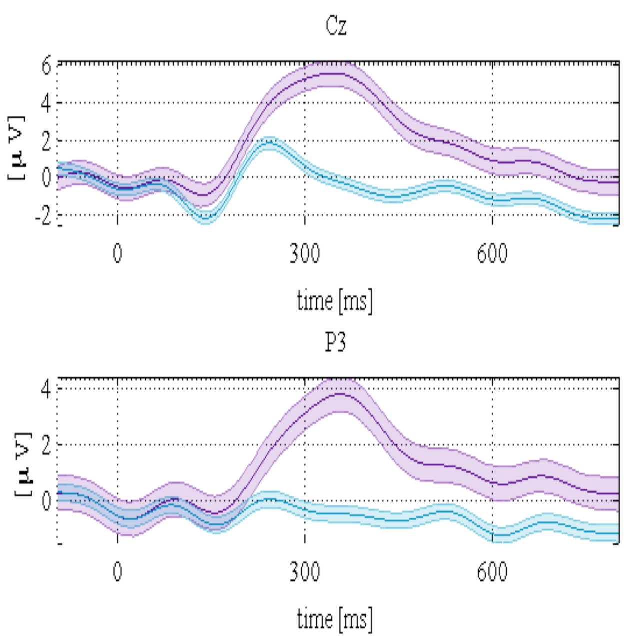

Figure 1. Grand mean averaged brainwave ERPs results of the two channels with blue lines depicting ignored non-targets and purple the intended targets with P300s.

IV. CONCLUSIONS

In the series of psychophysical and EEG experiments we confirmed that the users could distinguish five vibrotactile stimulus patterns delivered to all the fingers by the touch–sense glove. We could also observe clear and possible to discriminate brainwave P300 responses. The obtained results have shown that the averaged classification accuracies resulted above the chance level scores of 20%. The EEG experiments resulted with the easily discriminable P300 responses leading to the classification accuracies and ITR scores above the chance levels, or even with perfect scores within the limitations of the experiential settings. We consider continuing our research in the near future to conduct experiments with shorter inter-stimulus-intervals and with single trial-based classification sequences in order to bring closer the proposed paradigm to the real users in need.

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