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An Auditory Brain-Computer Interface Based on Three-Stimulus Oddball Paradigm

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Abstract. The auditory brain-computer interface (BCI) based on three-stimulus oddball paradigm was studied to obtain a binary decision in this paper. The signals were decomposed by empirical mode decomposition(EMD) in order to reduce noise and improve signal-to-noise ratio. The principal component analysis(PCA) method was used for extracting the P300 feature. The feature signals were sent to support vector machines (SVM) to be classified. Experimental results showed the classification accuracies for four participants can achieved more than 85%.

Keywords: Brain-computer interface, Auditory, P300, EMD, PCA, SVM

1. Introduction

Brain-computer interface can provide severely disabled people with non-muscular communication. However, many people with disabilities, including people with late-stage amyotrophic lateral sclerosis (ALS) who have impaired eye movements, are unable to maintain gaze and use visual BCI [Sellers et al., 2006; Klobassa et al., 2008]. In addition to the loss of act control ability, the patients may also suffer from decrease in attention span. Therefore, it is important that a paradigm optimized for ALS patients should reduce the workload. The goal of this study was to evaluate a BCI design based on a modified three-stimulus paradigm that would permit the user a binary selection with high accuracies.

2. Experiments and Methods

2.1. Experiments

EEG was recorded with six Ag/AgCl electrodes (FCz, Fz, Cz, CPz, Pz and Oz) in a standard clinical 32-channel electrode cap. The study enrolled four volunteer participants. Each participant was asked to participate in two tasks. In each task we presented three kinds of tones: two targets were pure tones, five standard tones were white noise. The two tasks varied in the frequency of the target tones while standard tones remained constant (white noise). In task 1, target one at 1000 Hz, target two at 4000 Hz. In task 2, target one at 100 Hz, target two at 4000 Hz. All the standard tones were presented to the both ears, but the target tones were mono. Each stimulus lasted 100 ms with a randomized inter stimulus interval (ISI) of 250-400 ms. The intensity of each tone was 75 dB sound pressure level.

Prior to the experiment, participants were given a question, such as ‘Is the basketball is round?’ and they would response ‘yes’ or ‘no’. Participants had to attend to target one when they want to reply ‘yes’, otherwise attend to target two. In the experiment, participants attend to the target stimulus that they wanted to choose and ignore the other target and the standard stimuli to make a binary selection. At the same time, they were asked to quietly say the direction (left or right) of the target tone without tongue movement when the target stimuli appeared. The accuracy of correct responses to the yes/no question is 100%. All participants were required to complete four runs of 20 trials.

2.2. Feature extraction and classification

The original data epoch (from 200 ms before the stimulus-onset to 800 ms after the stimulus-onset) for each stimulus was extracted. And then, all epochs were referred to the mean amplitudes of the pre-stimulus baseline. P300 response is usually elicited when a rare stimulus appears in a sequence of common stimulus. Conventionally, averaging the responses to the target stimuli of the oddball paradigm can obtained the P300 response. However, it is required long time and cannot be applied to online BCI systems. EMD was used to decompose the data after preprocessing. A sequence of superposition of components called intrinsic mode functions (IMF) was obtained. We selected the IMF in the frequency range of 0-4 Hz and reconstructed the data which eliminated the high frequency information and retained the P300 characteristic. Finally, the features were focused from reconstructed signals by the method of PCA, which reduced the data dimension. SVM [Guo et al., 2010] was used to discriminate the target and non-target by whether elicited the P300 response. For each participant, the data contained 80 trials in one task,

in which the features of 40 trials were used to train a two-class SVM classifier. The remaining trials were used to test.

3. Results

To investigate whether the P300 component can be elicited in single trial by EMD, we showed the grand average of 20 times original signals and the reconstructed EMD components in Fig. 1.

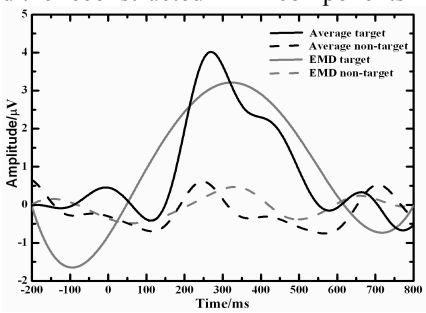

Figure 1. *The grand average of original signals and the reconstructed EMD components.*

Comparing the waveform in Fig.1, the largest difference between the target response and non-target was a positive deflection with latency of 250-550 ms. A clear P300 was also elicited in the reconstructed signals, which suggests that EMD can be used to extract the feature in single trial. The main features of 6 channels were concentrated in one component after using PCA, and the data dimension was reduced. Then the features were classified by SVM.

Table 1. *The classification accuracies of the two tasks.*

Participants	*Task 1 (%)*	*Task 2 (%)*
1	91.67±2.16	92.25±1.35
2	89.16±1.08	90.02±1.22
3	86.43±1.76	86.42±2.05
4	87.51±1.02	87.87±1.52

The classification accuracies for each participants achieved more than 85%, as shown in Table 1. Moreover, the results showed that three participants achieved better performance in task 2. The reason might be that the frequency interval of the target stimuli in task 2 is longer and participants can easily distinguish targets and non-targets.

4. Discussion

In this paper, we showed that an auditory BCI system based on three-stimulus paradigm by extracting the time-frequency features with the method of EMD and PCA is feasible. When design the experiment, the frequency interval of two kinds of target stimuli need to be longer. Then the targets and non-targets can be easily distinguished. Furthermore, the pitch, duration, ISI of the stimuli tones will be necessary to discuss.

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References

Sellers EW, Donchin E. A P300-based brain-computer interface: initial tests by ALS patients. *Clin Neurophysiol*, 117:538-548, 2006.

Klobassa DS, Vaughan TM, Brunner P, Schwartz NE, Wolpaw JR, Neuper C, et al. Toward a high-throughput auditory P300-based brain-computer interface. *Clin Neurophysiol*, 120:1252-1261, 2009.

Guo J, Gao S, Hong B. An auditory brain-computer interface using active mental response. *IEEE Trans Neural Syst Rehabil Eng*, 18:230-235, 2010.