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A PLEASANT AUDITORY BRAIN COMPUTER INTERFACE USING NATURAL ENVIRONMENT SOUNDS

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ABSTRACT: An auditory brain computer interface system which utilizes pleasant water-drop sounds is proposed in this study. The purpose of this study is to explore the property of the paradigm which uses water-drops as stimuli. The results show that the water-drop paradigm can improve the user friendness and get robust performance in items of online classification accuracy. The group average online accuracy is 73.33% which is acceptable.

INTRODUCTION

Brain computer interfaces (BCIs) can provide a new path to communicate with the external world for people who have lost the ability to control their muscles (such as individuals with amyotrophic lateral sclerosis (ALS)) [1]. The P300 event-related potential is a large positive component appearing at about 300 ms after a rare task-related event happened [1]. A single-modal BCI based on the P300 can be categorized into one of three groups according its modality of stimulation: visual BCI, auditory BCI or tactile BCI [2]. Our research mainly focuses on the auditory P300 BCI paradigm in this study. For people who cannot rely on visual BCIs, auditory BCIs can provide another way for them to improve their quality of life. Among the proposed works related to auditory BCIs, the acoustic stimuli used have included beeps with different frequencies, Arabic Numbers or animal vocalization [2-4]. As one kind of environmental sound which can be heard often, water drops have not been explored as stimuli in an auditory BCI system.
In this study, water drops are chosen as stimuli. Water drops are natural environmental sounds. The positive effect of using natural sounds as stimuli for auditory BCIs has been discussed in Höhne et al's work [5]. Among the existed auditory paradigms for BCIs using natural sounds as stimuli, water drop sounds remain unexploited. The use of water drops is mentioned in research related to how to reduce the noise in the environments and this research showed that water sounds are the best sounds with which to mask the environment noises and reduce the annoyance of people [6]. It should be taken into consideration that the environment of BCI usage might not be as quiet as in the lab. Hence, the water drops have its special advantage compared with other kind of sounds in the auditory paradigm. In this study, the potential of water drop sounds as auditory stimuli materials are investigated. A hypothesis that the auditory BCI system using water drops as stimuli can get good performance in terms of both accuracy and user friendness is investigated.

MATERALS AND METHODS

Stimuli

Three water-drop sounds are extracted from a music work (Fragile Hope (WANDER/WONDER, Balam Acab). The criterion of selecting the water-drop sounds is to make sure that each water drop sounded different but not obtrusive.
All the audio files are edited with Adobe Audition CS6 5.0. A pair of earphones (Sennheiser CX200) is used to play sounds. Direction cues (left, middle, and right) are added to the water-drops to decrease the difficulty of the tasks. To maximize the difference between directions, the right sound channel of the left water drops is muted and the left sound channel of the right water drop is muted. The details of the stimuli in both paradigms are shown in the Fig.1. All the stimuli lasted 200 ms, and the inter-stimulus interval (ISI) is 350 ms. The minimum TTI (Target to Target Interval) is 900 ms. In this study, the target stimulus indicated that one of the stimuli which is asked the participant to focus on and the non-target stimuli are the ignored stimuli. The probability of the target stimulus appearing is 1/3. All the stimuli are played in a pseudorandom order that the same stimulus would not appear consecutively to avoid the double-flashing effect. Although the probability of the target stimuli is fairly high, the long TTI can evoke high quality ERPs.

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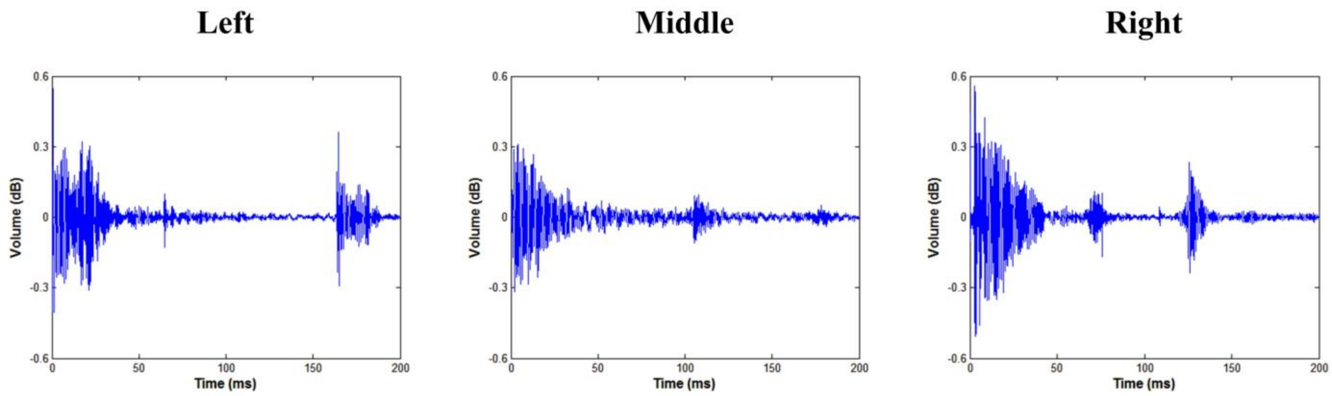

Figure1: The acoustic waveforms of the auditory stimuli.

Experiment set up

EEG data is recorded from 15 channels of a 64-channel 'g.EEGcap' EEG cap (Guger Technologies, Graz, Austria). The electrode positions used are F3, Fz, F4, T7, C3, Cz, C4, T8, CP3, CPz, CP4, P3, Pz, P4, and Oz from the international 10-20 system. The right earlobe is used as the reference and FPz is used as the ground. A 16-channel 'g.USBamp' amplifier (Guger Technologies, Graz, Austria) with a 512 Hz sampling rate is used to measure the EEG. The data is band pass filtered between 0.1-100 Hz and the notch-filter is applied at 50 Hz.

Ten healthy students (21-26 years old, mean 23.8) participated in this study. Six of them had attended BCI experiments before. The participants are asked to keep their eyes open and focus on a fixed point on the screen. They are also asked to avoid eye blinking and other body movements during the experiments. The volume of system is adjusted to a suitable level according to each participant's demand. In the offline experiments, three sessions are conducted. Each session contains five runs; each run had sixteen trials; each trial contained three sub-trials (one stimulus). Before each run, an audio cue would prompt participant the target stimulus. When participants finished one run, the offline training data of one target is collected. When participants finished one session, they had a short rest for 3 minutes. After the offline experiments, online experiments are executed. The online task had 36 given target-selections to complete. An adaptive method, proposed by Jin et al, is used in the online experiments [7]. In this study, it needed ~7 iterations for most participants to finish one target-selection. The whole online task lasted about 10 minutes.

Feature extraction and classification

A third order Butterworth band pass filter between 0.1 and 30 Hz is used to filter the raw EEG data. The filtered EEG data is downsampled from 512 Hz to 64 Hz and 1000 ms of data after each stimulus is extracted. The size of the feature vector is 15×64 (15 channels by 64 time points).

The classification algorithm in this study is Bayesian linear discriminant analysis (BLDA). BLDA has better performance on classification accuracies and lower risk of over-fitting when deal with high dimension data than Fisher's discriminant analysis (FLDA) [8].

RESULT

Online accuracy results of each participant are shown in Tab. 1. The grand average amplitudes of ERPs across ten participants are presented in the Fig.2 (A). The topographic maps of average amplitudes of the P300 and N400 are shown in Fig. 2 (B).

Table 1: The average online accuracy of each participant.

Participant	Online accuracy (%)
S1	75
S2	63.89
S3	80.56
S4	69.44
S5	80.56
S6	88.89
S7	66.67
S8	69.44
S9	69.44
S10	69.44
Avg	73.33

DISCUSSION

The goal of this study is to explore the property of water-drops as auditory stimuli and the results show that water-drops sounds can be reliable auditory materials for auditory BCI systems.

ERPs

The grand average ERP amplitude of targets and non-targets across all participants at electrodes Fz, Cz, CPz, and Pz are shown in Fig.2 (A). Obviously, the target amplitudes are different from the non-target amplitudes. No clear N1 component and N2 component are found in the early period between 0-200 ms. P300 and late negative components are the key potentials that are used to distinguish the target amplitudes from the non-target amplitudes. The spatial distributions of P300 and late negative components are presented in the Fig 2 (B).

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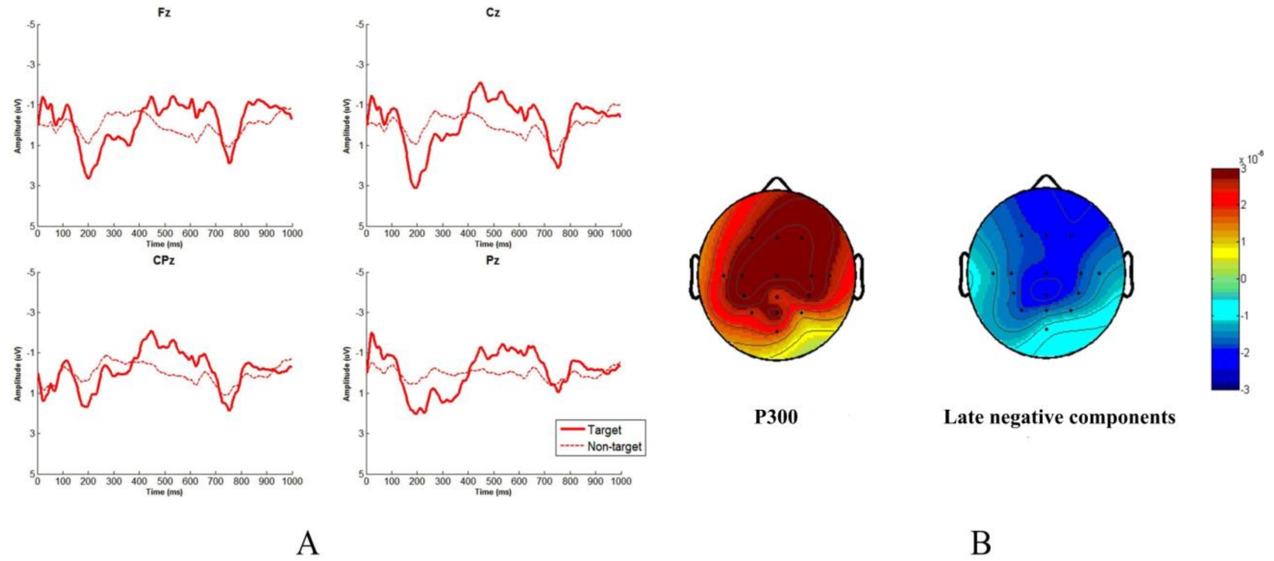

Figure 2: (A) The grand average amplitude of ERPs across ten participants at Fz, Cz, CPz, and Pz. (B) The topographic maps of average amplitudes of P300 and N400.

Online accuracy

As shown in the Table 1, the group average online accuracy is above 70%, which is considered by some to be the minimum value to meet the communication needs of BCI users [9]. Compared with other works [8, 10-12], this accuracy is in the middle level. The mental fatigue increases during the online task that explores the performance of this BCI system in a long-term usage. A phenomenon, observed in most participants, is that during the online period, the accuracy would decrease after finishing some targets and then increase after a short time (the time varies with individuals). The jitter of the accuracy might be caused by the level of fatigue when the participants are executing the task.

CONCLUSION

This paper proposed an auditory BCI paradigm with water-drops as stimuli and verified its utility. The online results shown that this paradigm could be a reliable choice for auditory BCI systems to provide a better experience for users. The future work is to increase the classes of this paradigm and optimize the water drops to get higher performance on classification accuracy while retaining the pleasant user experience.

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