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Auditory Brain Computer Interface Using Natural Sounds

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Abstract. This study is about user-friendly Brain Computer Interface (BCI) paradigms using Auditory Steady State Response (ASSR). Stimulation methods used in previous ASSR-based BCI studies have a problem that stimulation sounds induce auditory stress to subjects. We replaced high-frequency mono-tone carriers of stimuli with natural sounds. In our experiment, stimuli were composed of two different amplitude modulated natural sounds (water streaming, cicada singing). In stimulation periods, subjects selectively concentrated on one sound. Three subjects participated in the experiment, 50 trials were performed for each subject. Averaged classification accuracy was 90%. Subjects felt more comfortable when using our proposed stimulation than mono-tone carrier stimulation. This result shows that natural sounds are suitable stimulation carriers for long-term ASSR-based BCI applications.

Keywords: EEG, Brain Computer Interface, Auditory Steady State Response, Natural Sound, Auditory Stimuli

1. Introduction

Total locked-in syndrome is a condition in which a patient is aware and awake but cannot move due to complete paralysis of nearly all voluntary muscles in the body, including their eyes [Smith et al., 2005]. Patients with total locked-in syndrome have no way to communicate with the outside world. Recently, there are many studies trying to apply ASSR to BCI [Lopez et al., 2009; Kim et al., 2011]. However, stimuli used in previous ASSR studies were harsh sounds that made subjects uncomfortable when using the system. In this study, we suggest a new stimulation method which can reduce subject's auditory stress.

2. Methods

2.1. Stimuli

Proposed stimuli were composed of water streaming sounds on the left side and cicada singing sounds on the right side. Each side of sound was amplitude modulated with different frequencies. (Left: 38 Hz, Right: 42 Hz)

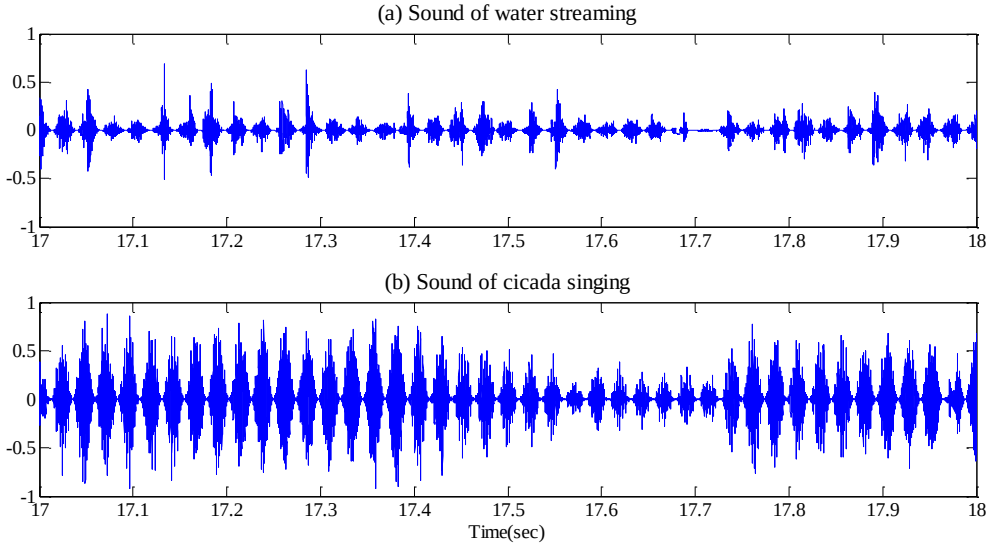

Figure 1. *Amplitude modulated natural sound stimuli. (a) sound of water streaming, (b) sound of cicada singing.*

2.2. Data acquisition

The conventional physiological signal acquisition system (QEEG-8, LAXTHA Inc., Daejeon, Korea) was used for measuring electroencephalogram. EEG signals are measured at electrodes Cz, Oz, T7, T8 (international 10-20 system). Measured analog EEG signals converted to digital signals with 16-bit resolution and 512 Hz sampling rate by National Instruments data acquisition system (NI-USB-6255, National Instruments, Texas, USA). Data storing and analysis were performed using Matlab (Matlab R2012b, The MathWorks Inc., Massachusetts, USA).

2.3. Experimental protocol

Subject sat in comfortable chair wearing earphone (MX400, Sennheiser Ltd, Bucks, UK). One trial was defined as auditory instruction (5 s) and auditory stimulation (20 s). In stimulation period, subject were presented with water streaming sound with 38 Hz modulation frequency on the left ear and cicada singing sound with 42 Hz modulation frequency on the right ear. When stimulation started, subject focused on the sound selectively according to the instruction [Heo et al., 2012].

2.4. Feature extraction and classification

Features were extracted from power spectral density of each electrode. Spectral power of 38 Hz and 42 Hz in each electrode (Cz_38, Cz_42, Oz_38, Oz_42, T7_38, T7_42, T8_38, T8_42) and ratios between the spectral powers of 38 Hz and 42 Hz in each electrode (Cz_38/Cz_42, Oz_38/Oz_42, T7_38/T7_42, T8_38/T8_42) were selected.

For the classification, Linear Discriminant Analysis (LDA) was used. 5-fold cross-validation was performed because of small number of trials. Classification accuracy was calculated with respect to each feature.

3. Results

Table 1 shows best features and their classification accuracy for each subject. Maximum classification accuracy was 92%, minimum accuracy was 88% and average classification accuracy was 90%.

Table 1. *Best features for each subject and classification accuracy*

	Subject #1	*Subject #2*	*Subject #3*
Best Feaures	Cz_38 Hz, Oz_38 Hz	Cz_38 Hz, Oz_38 Hz	Oz_38 Hz
Classification accuracy	0.92	0.88	0.90

4. Discussion

As shown in the results section, natural sounds are available carrier for auditory stimulation in ASSR-based BCI. Users feel more comfortable when using natural sounds than mono-tone sounds used in previous studies. For practical BCI, user comfort is one of the important factors. So, natural sound is more suitable than mono-tone sound for practical long term BCI applications.

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