Study of Maintaining Concentration by Auditory Brain Computer Interface

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Abstract

Recently, a new interaction technique which directly connects human brain and machine has been emerging; the Brain-Computer Interface (BCI). This paper describes auditory BCI system that dynamically responds in real time to P300 components of event-related potentials (ERP), which reflects the degree of concentration, in order to examine its sound designing potential. Based on the P300, the system feeds back appropriate sounds, warning tone or dulcet tone, to the user to maintain the degree of concentration in the aspect of sound environment design.

1. Introduction

The P300 event-related potential is an evoked response to an external stimulus that is observed in scalp-recorded electroencephalography (EEG). Donchin et al. have used P300 in oddball paradigm[1]. In the paradigm, subjects saw a 6 $\times$ 6 matrix containing English letters and other matrix elements. They were asked to choose one of the elements and designate it as the target. Individual rows or columns were then flashed sequentially, and the user was asked to count the number of times the target was flashed while ignoring flashes which did not illuminate the target. Target flashes produced a robust P300 response, while nontarget flashes did not. It was, therefore, possible to determine which element of the matrix the subject intended as the target simply by determining which row flash and which column flash produced a large P300. Mirghasemi et al. have also made P300-based BCI, which can discriminant in 90% probability, which requires no initial user training, which uses only 3 channels[2]. Suzuki et al. have studied the connection between P300 and concentration[3]. They insisted that the size of the amplitude of P300 is proportional to the concentration to the stimuli. It is well known that sound perception ignores the sound displayed repeatedly[4]. Actually, in our preliminary experiments, it was also shown that the constant stimulus could not keep the concentration.

The concept of soundscape is a clue to resolving the problem. Soundscape design is the study of auditory perception on the comfortable sounding environment[5]. By producing the comfortable sounds stimulus from the auditory BCI system in the view point of soundscape design, it is possible that the constant stimulus is able to manipulate the degree of human concentration continuously.

Our research aimed at creating interactive, flexible, effective and long lasting warning system suiting for each one. This paper focuses on the design and evaluation of the auditory BCI system under a computer based driving simulation environment. The system is able to control the degree of concentration, by adapting sound stimuli in real time based on real time feedback from P300 evoked potentials.

At first, this paper describes the design of the system for showing how to select the appropriate sounds. Second, the paper describes a method to discriminate the human context from the brain signal. Third, it describes the experiments for evaluating the auditory BCI system. At last, it discusses the results of the evaluation and the next phase of development.

2. System design

2.1. Sound design

To control the degree of concentration adaptively, we choose 5 sounds as the target stimuli: water, sea, siren, horn

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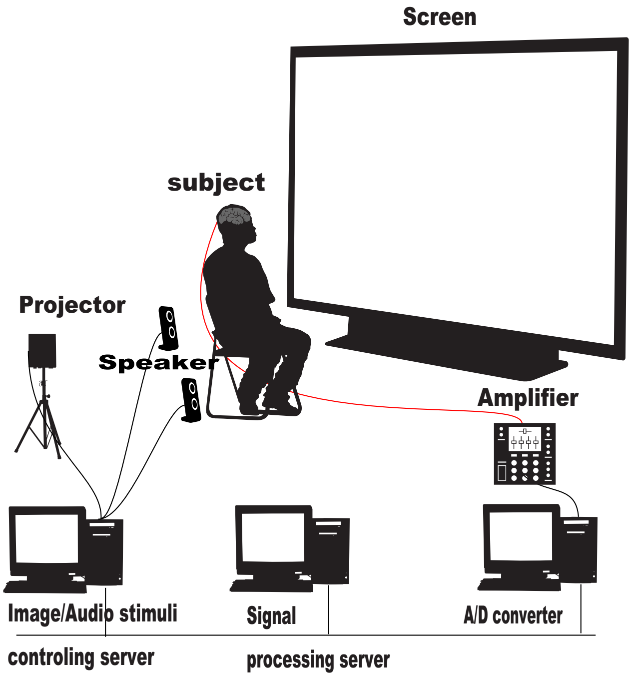

Figure 1. the auditory BCI system

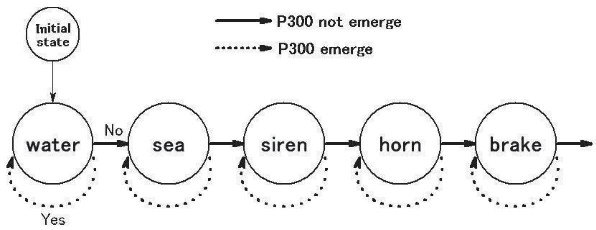

Figure 2. Experimental Protocol

auditory stimuli	category	one trial
Target	(sound of)water, sea, siren, horn, brake	1
Non target	engine	4

Table 1. category of auditory stimuli displayed

and brake(Table1). Non target stimulus is an engine sound in a car driving simulator.

Natural sound, such as sound of water, sea is categorized as soundmarks, which people want to preserve, comfort sound for them. The sound of horn, siren, brake are sounds of signals, which represent auditory warnings[6]. They evoke an image of accidents and have ability to arouse people. To control their concentration adaptively by monitoring P300 evoked potentials playing back the sound stimuli in real time, we arrange the sounds depending on the five different degrees of warnings from low to high, in the order from water, sea, siren, horn, to brake.

2.2. Design of auditory BCI

Fig1 shows the auditory BCI system. Sounds we chose as warning sounds are also categorized to keynote sound group, the group of constant sounds, in the study of Han et al[6]. That is, the behavior of these sounds varies according to the situation at that time and the condition of people hearing the sounds. Therefore We have designed auditory BCI which changes auditory stimuli, adjusting user's condition automatically. Fig2 shows the way to change stimuli, depending on P300. If the P300 is not recognized after the target stimulus, the audio stimulus changes to the next one aiming to increases the degree of the auditory excitation.

3. Experiment

Five able-bodied people(s1-s5) were the subjects in the present experiment. The EEG was recorded from Cz, CPz, and Pz in International 10/10 system [7]. Each subject underwent a total session consisted of 150 trials lasting 2.5 min. The 150 trials have 30 and 120 trials of target and non-target stimuli, respectively. The trial with feedback takes 1 second (0.6 sec of EEG measurement with sound stimuli and 0.4 sec of visual feedback displayed on the front screen(Fig1). Each subject paid attention to the target stimuli to count silently the number of times that they were presented. If P300 is recognized after the target stimuli, audio stimuli did not change, as mentioned in the previous chapter. The correct rate, the rate of brain waves reacting correctly, was calculated by Linear Discriminant Analysis (LDA) using 60 numbers of brain waves for target stimuli and 60 brain waves for non target stimulus. We adopted leave-one-out method to calculate the correct rate of the first session.

4. Results

The P300 amplitude did not diminish after a few sessions as shown Fig5. Individual amplitude is defined as the max voltage from 0.2 to 0.4 seconds. This shows that the system could maintain the degree of concentration. In Fig4, it is found that the P300 amplitude in preliminary experiment using only sound of brake as a target stimulus, diminished after a few sessions. Fig6–Fig10 illustrate the P300 waveform for all subjects. Right and left figure denotes P300 with and without auditory feedback, respectively. The amplitude with auditory feedback was larger than that without the feedback. This tendency appeared in the result of almost all the subjects except for the subject s3. That is, the degree of concentration was higher in the experiment with auditory feedback than that without the feedback. This result suggests that the auditory feedback is useful for improving

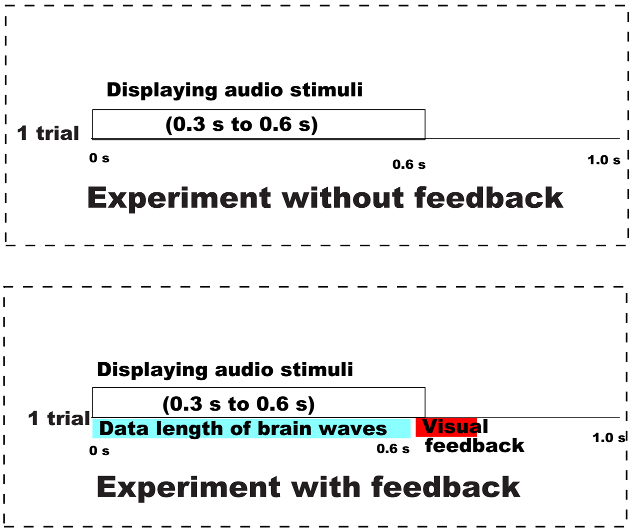

Figure 3. Protocol of a trial

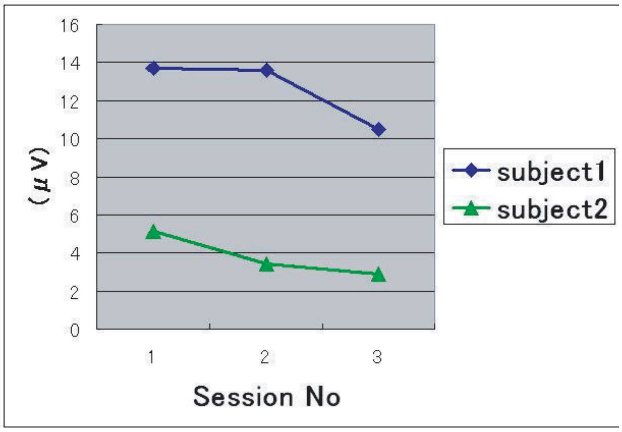

Figure 4. A transition of P300 amplitude(without auditory feedback)

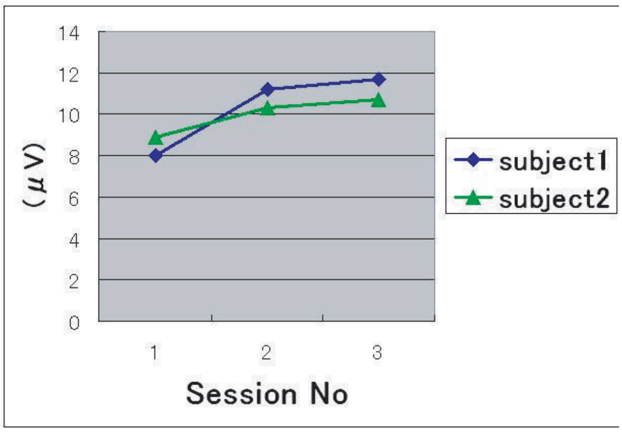

Figure 5. A transition of P300 amplitude (with auditory feedback)

subjects' concentration. Table2 and 3 shows the correct rate of the discrimination of P300 waveforms with and without the feedback, respectively. In both cases, the correct rates were around 90%. This shows that the present BCI system is reliable. In addition, the correct rate with feedback was higher than that without feedback. This indicates that subjects' concentration is improved by the auditory feedback.

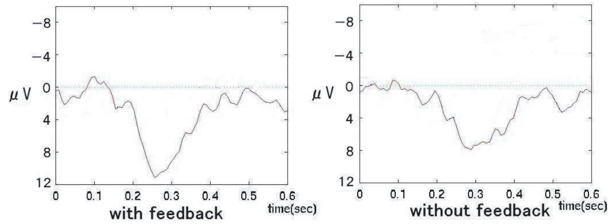

Figure 6. P300 waveforms(s1) (with and without feedback)

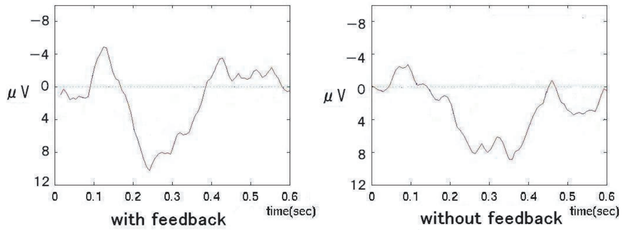

Figure 7. P300 waveforms(s2) (with and without feedback)

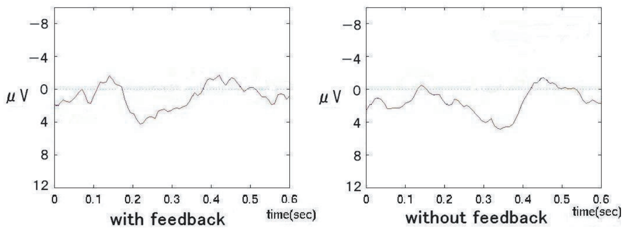

Figure 8. P300 waveforms(s3) (with and without feedback)

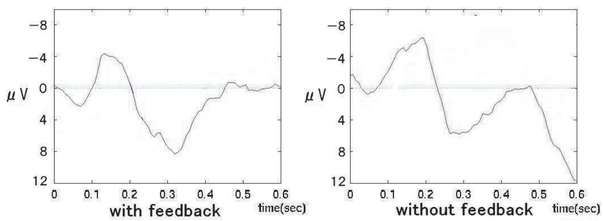

Figure 9. P300 waveforms(s4) (with and without feedback)

Subject No.	s1	s2	s3	s4	s5	ave
3-times average(%)	97.8	94.2	93.3	93.3	87.5	93.2
4-times average(%)	97.2	95.0	94.2	94.2	87.5	93.6

Table 2. Classification Performances(without feedback).

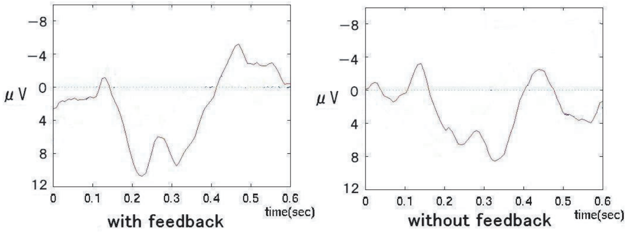

Figure 10. P300 waveforms(s5) (with and without feedback)

Subject No.	s1	s2	s3	s4	s5	ave
3-times average(%)	96.7	100.0	81.7	98.3	91.7	93.7
4-times average(%)	100.0	95.7	76.7	95.0	90.0	91.7

Table 3. Classification Performances(with feedback)

5. Discussion

Our finding is that the present system is able to quantify and manipulate the human factor accurately and permanently.

As described in the previous chapter, our system could follow the alteration of the users' brain states such as fluctuation of the degree of concentration, in detail and real time. As a result, the memory effect was not confirmed during the experiment: the effect by which the auditory impact and response discontinues when a single sound source is displayed in a specific time interval. That is, this system is able to display auditory messages to users with the adaptive alternation of its timing based on the feeds back from the brain signal in real time. These results show that sound designing is somewhat effective to improve the auditory BCI and the auditory BCI shows one way bringing in brain states to sound designing.

Thus, the present system has succeeded in monitoring human factor continuously and precisely working on sounding perception. The machine interface finally achieve manipulate the invisible human factor, the degree of concentration through its auditory perception on comfortable sounding environment.

6. Conclusion

We built an auditory BCI system using P300 for monitoring human factor, concentration. Auditory BCI is a system which connects human EEG to actuators. The system generates an interaction between warning sound world and human by using an amplifier, A/D converter, speakers. The system captures and analyzes human EEG, and displays appropriate sound. Auditory BCI is a two-way interactive process: analyzing EEG, human factor, accurately and displaying 1 sound at a time to a person among 5 sounds chosen following the concept of soundscape. To establish the interaction and effective warning, we use P300, which measures human concentration. We have successfully demonstrated interaction between human and the sound world made by machines. It was suggested that we have the probability of communication between human being and machines, taking advantage of the auditory BCI.

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