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Examination of auditory brain-computer interfaces using virtual sound by shortening stimulus onset asynchrony

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Introduction: A brain-computer interface (BCI) is a system that can operate several devices using only brain signals. It has been actively studied in recent years. There are many studies using event-related potential (ERP), which is a brain signal that occurs in relation to some event. The use of the virtual sound sources using out-of-head sound localization has been suggested as a possibility to estimate the intention direction [1]. In this study, we propose a BCI system for estimating the intended sound source direction of the user by using EEG (P300) when out-of-head sound localization is used. By changing stimulus onset asynchrony (SOA), the accuracy of the auditory BCI using virtual sound sources we examined was improved.

Material, Methods and Results: This study was approved by the ethics board of the Nagaoka University of Technology. Nine healthy people (8 males and 1 female, mean age 22.5) participated. All subjects were given information on the experiment and signed consent forms.
In this study, we used an oddball experiment using virtual sounds [1]. The sound image was located at six different directions (30°, -30°, 90°, -90°, 150°, -150°) with 0° being the direction facing the user directly. We changed the SOA for every task, that is 1100, 800, 700, 600, 500, 400, 300 and 200 ms trials were considered for comparison. The EEG data was sampled at 256 Hz, filtered using a Butterworth band-pass filter (0.1 to 8 Hz) and classified using Fisher discriminant analysis (FDA) to estimate the parameters for the particle swarm optimization (PSO) algorithm [2].
Fig.1 presents the identification rate of direction. Fig.2 shows results of ITR at identification rate of direction.

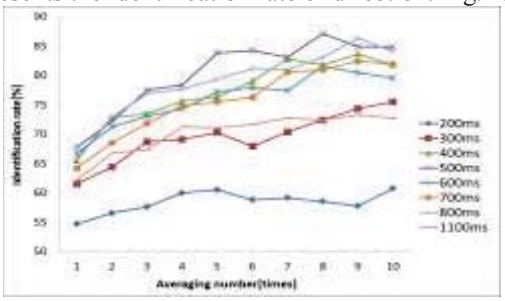

Figure 1. *Classification accuracy*

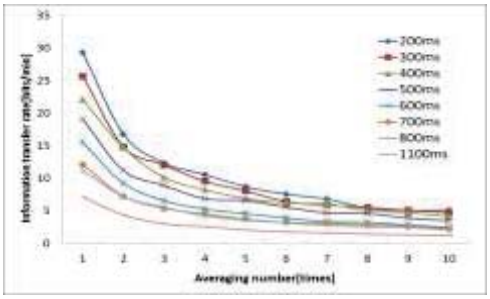

Figure 2. *Information transfer rate*

The direction identification rate was 87.1% for the SOA of 500 ms averaged 8 times, 86.3% for the SOA of 800 ms averaged 9 times and 84.9% for the SOA of 500 ms averaged 9 times.
The max ITR is 29.31 bits/min at SOA of 200 ms averaged 1 time. The ITR is 1.22 bits/min at SOA of 1100 ms averaged 10 times, which is 24 times slower than that observed in the best scenario. However, the increasing of ITR is higher when the number of averaged times decreases. These results alone can be misleading if identification rate is not considered as well. We determined appropriate identification rate when results were higher than 70 %. Fifty six results met this condition. Under this condition, max ITR is 14.72 bits/min at SOA of 400 ms averaged 2 times.Compared to it, the SOA of 1100 ms averaged 10 times is 12 times slower.

Discussion: For direction identification rate, the SOA of 1100 ms averaged 10 times was used as base for comparison with the SOA of 400 ms averaged 2 times, because it has more than 70 % identification rate and the maximum ITR. As a result, it can be observed that the ITR is around twelve times higher in the SOA of 400 ms and its required estimate time is about a twelfth of that in the SOA of 1100 ms.
As the increasing of identification rate is always pursued, in order to build an improved BCI system, for future work it is being considered the application of different algorithms for classification as well as changing the time used for direction estimation.

References

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