High-frequency SSVEP based Speller

Contact: Dong-Ok Won (wondongok@korea.ac.kr)

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Experimental paradigm

The experiment included 26 healthy participants (22 male and four female; aged 27.2 ± 2.5). All the participants had no history of visual disorders and had either normal or corrected-to-normal vision. All the experiments were conducted according to the principles described in the Declaration of Helsinki. This study was reviewed and approved by the Institutional Review Board at Korea University (1040548-KU-IRB-15–8-A-1). Written informed consent was obtained from all participants prior to the experiment.

In this study, we tested three different duty-cycles (50%, 60%, and 70%) in the higher frequency stimulation conditions. A higher duty-cycle stimulus at the same stimulation frequency uses a higher light energy in the same stimulation conditions because an LED is turned on for a longer time. A frequency array was specifically designed for the LED lights (Figure 1), such that the minimum difference between neighboring LEDs was 1.2 Hz. We used different resistances that guaranteed the use of an almost identical amount of light power for the three duty cycle conditions (e.g., 50%: 120 ohms (Ω), 0.0349 wattage (W); 60%: 144 Ω, 0.0344 W; 70%: 168 Ω, 0.0344 W). A higher resistance was used for a higher duty-cycle stimulus to reduce the brightness of the LED stimulus appropriately, thereby making the different duty-cycle stimuli use an almost identical amount of light energy.

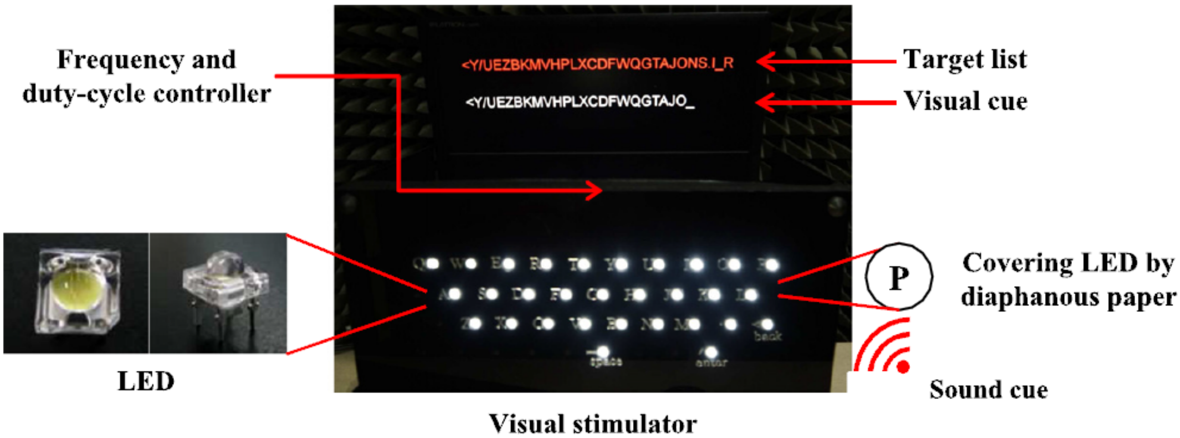

Figure 1. Experimental apparatus and environment.

There are four different experimental conditions: low frequency stimuli with duty-cycle 50% (LFS 50), higher frequency stimuli with duty-cycle 50% (HFS 50), higher frequency stimuli with duty-cycle 60% (HFS 60), and higher frequency stimuli with duty-cycle 70% (HFS 70). Conditions with a duty-cycle of less than 50% were not employed, as they are associated with high visual fatigue. All the subjects performed four experimental sessions, denoted A, B, C, and D. Each session included four experimental runs. Session A comprised LFS50, HFS50, LFS50, and HFS50 runs. Session B consisted of HFS50, LFS50, HFS50, and LFS50 runs. Session C comprised HFS60, HFS70, HFS60, and HFS70 runs, and session D used HFS70, HFS60, HFS70, and HFS60 runs. The order of sessions was either A, C, B, and D or D, B, C, and A to alternatively test the four experimental conditions. The counterbalanced experiment could prevent potentially biased results for the two independent factors, stimulation frequency, and duty-cycle. Furthermore, the first session order (A, C, B, and D) was used for almost half of the subjects (12 of 26 subjects), and the second one (D, B, C, and A) was used for the others for more counterbalancing of the experiment. In each experimental run, participants were asked to spell all 30 characters once with a random order, for which verbal instruction was used. The time used for spelling one character was 5.5 s, and a break of 3 s was given between characters (Figure 2). All data analyses were conducted off-line after the experiment.

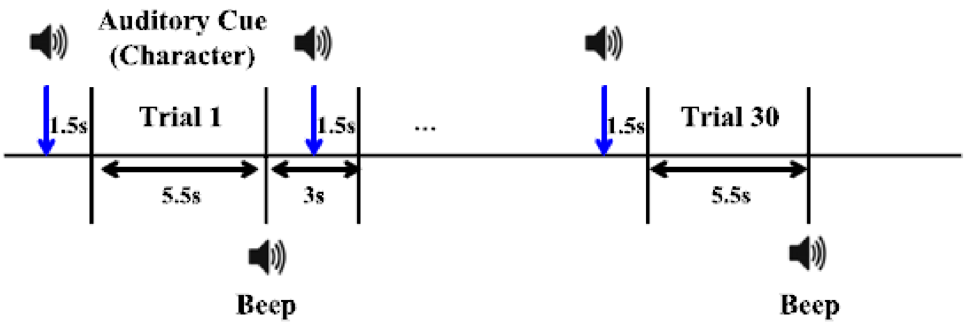

Figure 2. The timeline of the experimental paradigm.

Data recording

EEG data were recorded from 32 electrodes attached according to the international 10–20 system using BRAINAMP (Brain Products, Germany) (figure 3). Because strong SSVEPs are mainly observed on the back of the head, the recording electrodes were placed most densely over the occipital lobe.

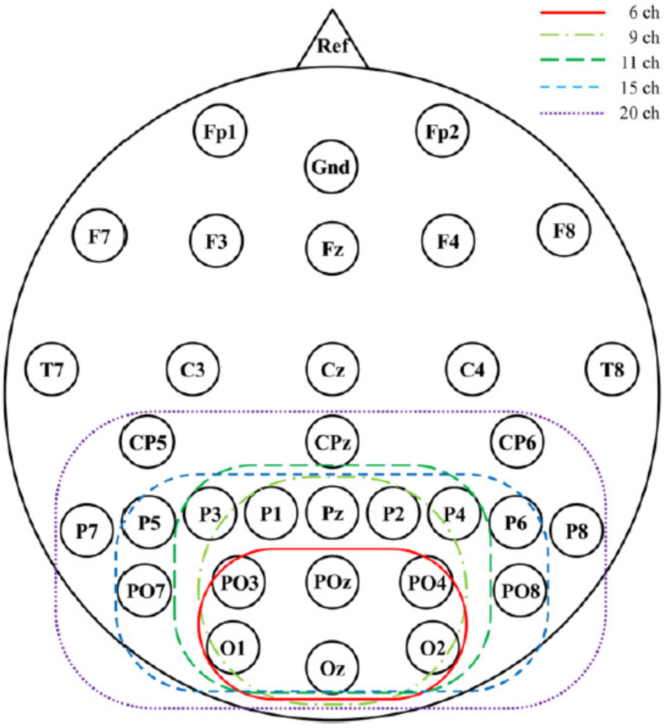

Figure 2. Channel configurations.

Data file description

We provide raw data that can be converted to any form. All data sets are basically stored in the General Data Format for biomedical signals, one file per subject. Each subject in the one folder contains three pieces of data. The EEG data is stored in a binary .eeg file. It consists of 32-channels which all “measured” a sinusoid signal. The files with .vhdr and .vmrk directly belong to the .eeg file specifying additional information. In contrast to the actual data, they are not in a binary format, so you can open them. The vhdr-file contains general additional information and the vmrk file contains name and time point of the markers you see above.