Steady-State Visual Evoked Potential (SSVEP) under Ambulatory Environment

Contact: No-Sang Kwak (nskwak@korea.ac.kr)

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Experimental paradigm

Seven healthy subjects, with normal or corrected-to-normal vision and no history of neurological disease, participated in this study (age range: 24±30 years; 5 males, 2 females). The experiments were conducted in accordance with the principles expressed in the Declaration of Helsinki. This study was reviewed and approved by the Institutional Review Board at Korea University [1040548-KU-IRB-14±166-A-2] and written informed consent was obtained from all participants before the experiments.

We designed an experimental environment for SSVEP based exoskeleton control following. In particular, we used a powered lower-limb exoskeleton (Rex, Rex Bionics Ltd.) with a visual stimulus generator attached to the robot for stimulating SSVEPs in an ambulatory environment. The visual stimulus generator presented visual stimuli using five light-emitting diodes (LEDs: 9, 11, 13, 15, and 17 Hz with a 0.5 duty ratio) which were controlled by a micro controller unit (MCU; Atmega128), as shown in Fig 1.

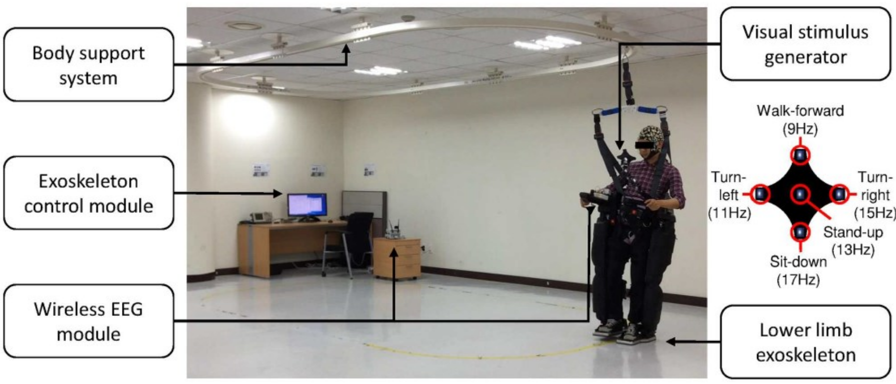

Figure 1. Experimental environment.

We acquired two SSVEP datasets under static and ambulatory conditions, respectively, to compare the performance of the SSVEP classifiers. From Task 1, we collected SSVEP data with the exoskeleton in a standing position (static SSVEP). In Task 2 (ambulatory SSVEP), the SSVEP signals were acquired while the exoskeleton was walking. In both tasks, we performed the experimental procedure described in Fig 2. After the random auditory cue was given, a start sound was presented 3 s later, and then the subjects attended the corresponding visual stimuli for 5 s. The auditory cue was given in random order to prevent potentially biased results for the stimulation frequency, the start sound gave the subjects time to prepare to focus on the visual stimuli. The auditory cues were guided by voice recordings to indicate commands such as “walk forward”, “turn left”, “turn right”, “sit”, and “stand”, and were approximately 1 s in length. Note that during the experimental tasks, all LEDs were blinking simultaneously at different frequencies.

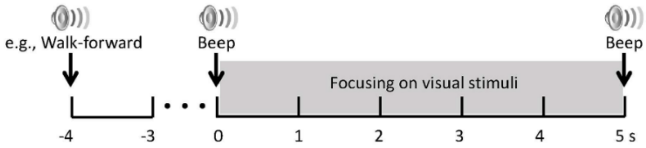

Figure 2. Experimental procedure.

Task 1 (Static SSVEP): The subjects were asked to focus their attention on the visual stimulus in a standing position while wearing the exoskeleton. Corresponding visual stimuli were given by auditory cue and 50 auditory cues were presented in total (10 times in each class).

Task 2 (Ambulatory SSVEP): The subjects were asked to focus on visual stimuli while engaged in continuous walking using the exoskeleton. The exoskeleton was operated by a wireless controller, per the decoded intention of the subject. A total of 250 auditory cues were presented (50 in each class).

Data recording

The EEG was acquired from a wireless interface (MOVE system, Brain Products GmbH) using 8 Ag/AgCl electrodes at locations PO7, PO3, PO, PO4, PO8, O1, Oz, and O2, with reference (FCz) and ground (Fpz) electrodes, illustrated in Fig 3. Impedances were maintained below 10 kO and the sampling frequency rate was 1 kHz. A 60 Hz notch filter was applied to the EEG data for removing AC power supply noise.

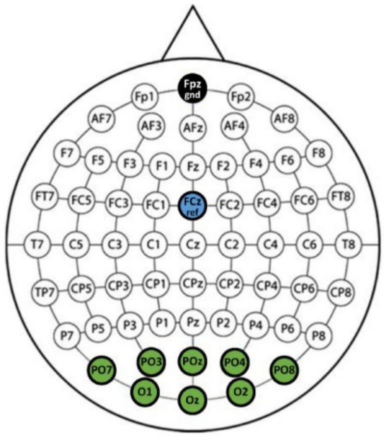

Figure 2. EEG channel layout.

Data file description

We provide raw EEG data (.eeg) files that can be converted to any form. Header (.vhdr) and Marker (.vmrk) files directly belong to the corresponding (.eeg) file. The (.vhdr) file contains general information. And the (.vmrk) file includes marker information with the time position that specifies the starting time to focus on the visual stimulus. The five markers ‘S 1’, ‘S 2’, ‘S 3’, ‘S 4’ and ‘S 5’ indicate “walk forward”, “turn left”, “turn right”, “sit”, and “stand” commands, respectively. Note that in some data the total number of markers could exceed than described above. We ignored last markers of each class in our analysis.