VIEWING MOTION ANIMATIONS DURING MOTOR IMAGERY: EFFECTS ON EEG RHYTHMS

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ABSTRACT: The mu rhythm is an 8-13 Hz oscillation which can be detected over human sensorimotor cortex in brain signals such as the electroencephalogram (EEG). This rhythm is desynchronized by movement, observing the movement of others, and imagined self movement [3]. In this study we combine motor imagery and movement observation. We show that the majority of subjects tested produce an enhanced mu desynchronization over sensorimotor cortex when motor imagery and movement observation are combined, compared to motor imagery alone.

INTRODUCTION

Both motor imagery and movement observation have been shown to decrease mu power over sensorimotor cortex (known as an event-related desynchronization or ERD) [3], and there is some speculation that these two different findings may involve the same brain system [4]. In this study, we analyze the effects on mu rhythms of combining motor imagery and movement observation. Our technique for enhancing mu ERD during motor imagery tasks may be useful for improving brain-computer interfaces based on this signal.

METHODS

Experimental paradigm: Ten healthy, right-handed volunteers participated in this study (6 male and 4 female aged 22-32 years, mean 25). Subjects were seated in a comfortable chair approximately 85 cm from a 19 inch monitor in an electrically shielded, soundproof room.

The experiment consisted of 10-second trials during which the subject performed a motor imagery task. There were two experimental conditions which differ in the stimulus presented to the subject: fixation cross (FIX) or realistic animated video of a clenching and unclenching right-hand fist (VID). Each trial consisted of a 2.5 second presentation of a fixation cross, which brightened from second 2.5 to second 3 to indicate that the active portion of the trial was about to begin. At second 3, one of the two stimuli {FIX, VID} was displayed for 4 seconds, during which the subject was instructed to imagine clenching and unclenching his or her right hand in a manner similar to the animation. The final 3 seconds of the trial consisted of a rest period with a blank screen. The two conditions were presented in random order in 7 blocks of 20 trials, with 1-3 min rest periods between blocks, for a total of 70 trials for each condition.

EEG Recording: Continuous EEG signals were recorded from 13 scalp sites located according to the 10-20 system using an electrode cap (Electro-Cap, USA). Signals were recorded using tin electrodes with a ground at AFz and a linked mastoid reference. Voltages were amplified and digitized at 500 Hz using a NeuroScan Synamps amplifier and were bandpassed from 0.3 to 50 Hz. Data were re-referenced to a common reference and the 3-second rest period was discarded. The data were visually inspected for blink or movement artifacts, and affected trials were discarded.

Analysis: Our analysis focused on electrode position C3 because of its location near the sensorimotor hand area contralateral to the imagined movement, which makes it a good choice for detecting mu ERD from motor imagery tasks [3].

Analysis was carried out in the frequency domain using Welch's averaged modified periodogram [1] for spectral estimates. Spectra for the two trial conditions were computed for the 4 second active period of each trial, while baseline spectra were computed for the first 2.5 seconds of each trial. In order to compute the mu ERD, we first determine the peak mu frequency for each subject by locating the frequency of the average peak power of the baseline period, restricted to the expected mu frequency range of 8-13 Hz. A 2-Hz wide frequency window centered about the peak mu frequency is used to compute the mu power for each trial.

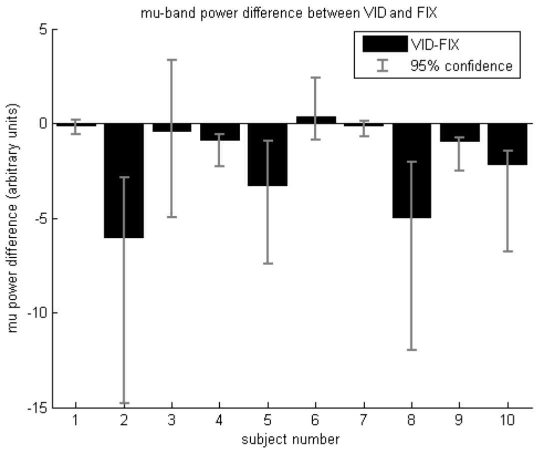

Figure 1: Mean mu power difference between conditions VID and FIX with 95% confidence intervals. Negative values indicate enhanced mu ERD in the VID condition relative to FIX.

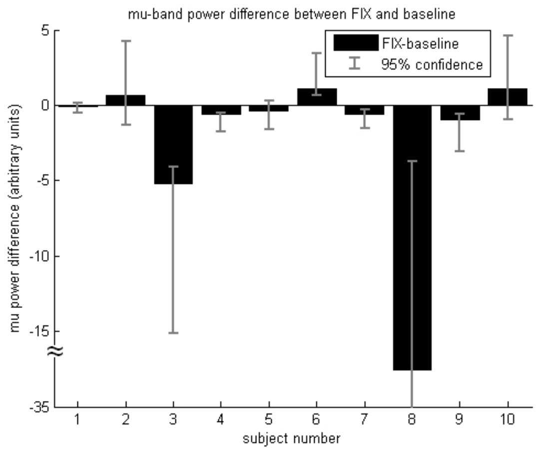

Figure 2: Mean mu power difference between FIX condition and baseline with 95% confidence intervals. Negative values indicate enhanced mu ERD in the FIX condition relative to baseline.

RESULTS

We analyzed the effect on the mu ERD of movement observation during imagined movement by comparing mu power of FIX, VID, and baseline conditions. Our analysis used a percentile-t bootstrap [5] to compute 95% confidence intervals on power differences. A mean difference is considered significant if the 95% confidence interval does not include 0.

The mu power difference VID-FIX is shown for all subjects in Fig. 1. 9 out of 10 subjects showed an enhanced mu ERD in condition VID relative to FIX, with statistical significance in 6 subjects. Fig. 2 shows the mu power difference FIX-baseline, which indicates each subject's mu ERD for motor imagery without feedback. Comparing these figures reveals that some subjects (e.g. subjects 2 and 10) with poor ERD performance in the FIX condition show marked improvement with the addition of movement observation in the VID condition.

DISCUSSION

This study indicates that presenting realistic human motion animations during motor imagery enhances the mu ERD in most subjects. Although some subjects failed to show a significant ERD enhancement in the VID condition, no subjects displayed a significant ERD decrease, indicating that there is little negative interference from observing the video.

It may be possible to increase this effect by employing imagery and animations which are more goal-directed [2] and by exploring movement observation in virtual reality settings. It is also possible that the effect would be further increased in an online setting where the user's imagined movements affect the animated hand in real time. We intend to further explore these options and eventually use the results to improve upon current mu-rhythm-based brain-computer interfaces.

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