EFFECTS OF VISUAL FEEDBACK ON COHERENCE BETWEEN HUMAN BRAIN AND MUSCLE

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Abstract-**Previous studies of oscillatory interaction between signals of human motor cortex and its peripheral muscle using electroencephalography (EEG) and surface electromyography (EMG) observed rhythmic activities in the frequency band 15-35 Hz. In the present study, we compare three different reference methods of the EEG recording and investigate the effects of visual feedback (VF) on the oscillatory interaction between human motor cortex and first dorsal interosserous (FDI) muscle.**
Keywords-**Coherence, EEG, EMG, visual feedback**

I. INTRODUCTION

Voluntary movements involve the cooperation of many muscles. Communications are believed to exist between the peripheral muscles and the sensorimotor cortex which control the movement functions in the brain. Conway et al. had showed that there was a significant coherence in the frequency band 15-35Hz between 1 channel MEG and EMG of the FDI hand muscle [1].

Following this, coherence between EEG and EMG also have been reported. However, MEG and EEG recordings use different reference electrodes. MEG assumes an infinite reference electode,whereas EEG a reference electrode from either one of these:

1) electrode placed at ear-lobe (EAR);
2) average voltage value of all the electrodes on the scalp (AVR);
3) current source density that assume absolute zero voltage by converting voltage from all the electrodes on the scalp to current density (CSD);

and etc. In the present study, we compare these three different reference methods of the EEG recording and investigate the effects of visual feedback (VF) on the oscillatory interaction between the human motor cortex and the FDI muscle.

II. METHODOLOGY

A. Subjects and Data Acquisition

Seven normal subjects aged between 21 $\sim$ 24 years participated in the study. Surface EMG was recorded from subject's right hand FDI muscle. Subjects were asked to hold an equipment with pressure gauge sensor at its center between the thumb and the index finger. The task was a weak contraction between 10-20% of maximum voluntary contraction (MVC).

Firstly, VF of the force level was given to subjects prior to EEG and EMG recordings. The EEG and EMG were recorded during the contraction for 1 minute, repeated 4 times with intervening rest periods to avoid fatigue (1 min/trial x 4).

The EEG signals were recorded with the AVR reference from 19 electrodes which were placed on scalp base on the international 10-20 electrode placement system. The same data sets were used to get EAR reference digitally using EEGFOCUS 2.1 software. Another reference method, CSD was estimated using spherical spline interpolation method.

Recorded EEG and EMG signals were stored in a personal computer with sampling frequency 1 kHz. Signals were segmented into 1024 point, resulting in 232 epochs. Epochs with eye-movements were excluded and only artifact-free epochs were analyzed.

Secondly, the same procedures were used for the VF trials. Experiment conditions for the first 4 trials remain unchange, followed by another 4 trials with VF given to subjects for the entire recording. In the last 4 trials, subjects are required to control and maintain the accuracy of the contraction level. thus attention was divided between maintaining the force and the task itself.

B. Coherence

To investigate linear correlation between two signals, a coherence function was introduced. It is calculated using the fast Fourier transform (FFT) of 1024 points with frequency resolution of 0.98 Hz and can be expressed as

$$r^2_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_{xx}(f)G_{yy}(f)} \leq 1$$

where $G_{xy}(f)$ is the estimated cross-specral density function and $G_{xx}(f)$, $G_{yy}(f)$ are the estimated auto-spectral density function for signals $x(t)$ and $y(t)$, respectively. Signal $x(t)$ represents EEG while $y(t)$ represents rectified EMG signal.

Coherence value can be any real number between 0 and 1 with 1 indicating perfect linear correlation between the two signals while 0 showing the opposite. Coherences were considered to be significant above the 95% confidence limit.

III. RESULTS

A. Coherence estimate

Fig. 1 shows the estimated coherence between the C_3 scalp electrode and the FDI muscle in Subject 1 by all derivation methods. We found that significant corticomuscular coherence was present at 18 Hz for the EAR,

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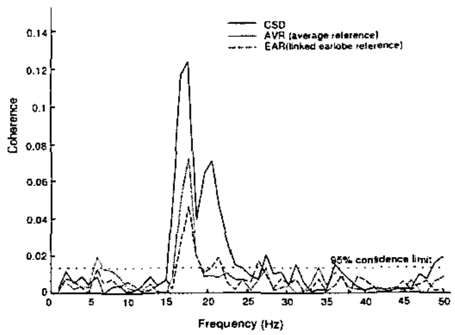

Figure 1: Coherence estimate between the EEG (C_3 electrode) and EMG signals of the FDI muscle in Subject 1. Significant coherence was found in the range of 16 - 27Hz for the CSD method.

AVR and CSD reference method. The peak coherence was 0.12, 0.07 and 0.05 for CSD, AVR and EAR methods, respectively.

Similar results with CSD reference showed the highest coherence were obtained for almost all subjects. Mean peak coherence was 0.07, 0.05 and 0.03 for CSD, AVR and EAR, respectively. The mean frequency showing the highest coherence was 21 Hz, 20 Hz and 20 Hz for CSD, AVR and EAR reference method respectively.

B. Visual Feedback

Since CSD reference method showed the highest mean value of coherence between EEG and EMG, it was used for the VF effect analysis.

Fig. 2 shows the mean ± SD peak coherence of the experiment with and without VF. No significant difference in the mean coherence was found between both of them.

We also investigated the coherence for each trials in the experiment with and without VF. Fig. 3 shows the mean ± SD of the coherence obtained in each trials. Again, no significant difference in peak coherence was found for trials with and without VF and for inter-trials in both with and without VF.

IV. Discussion

This study showed significant coherence in beta band

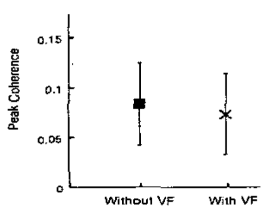

Figure 2: Mean ± SD of the coherence for accumulative trials in with and without VF.

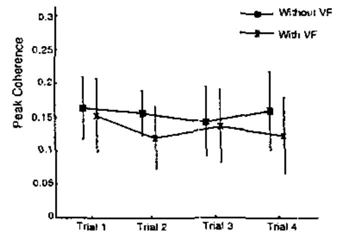

Figure 3: Mean ± SD of the coherence for each trials.

at 15 ~ 32 Hz between EEG signals in the contralateral sensorimotor areas and surface EMG signals from right hand FDI muscle during isometric contraction, result similar to those found using MEG with improved EEG-EMG coherence by CSD method.

In VF experiment, we found that peak coherence for accumulative trials without VF was slightly higher than the one with VF. This indicates that with VF given to subject prior to recording, a learning process took place and a feedback network was created. This feedback network might be working during the task without VF and lead to synchronization of the corticomotor cortex and the FDI muscle. Furthermore the mean coherence in each trials of task without VF didn't fluctuate very much and the fluctuation seems to be no different than with VF.

For all trials, subjects were required to maintain a force level at 15 ± 5 % of the MVC. Even in low precision force level, the peak coherence and the frequency that showed significant coherence were higher than those in [2]. These differences might be assume as the result of different force level, i.e. under 10% MVC in [2] compared to above 10% in this trials.

V. Conclusion

We conclude that coherence analysis using the EEG produce similar result as the MEG with current source density of Laplacian derivative improved cortico-muscular coherence and visual feedback of contraction level has no effects on the cortico-muscular coherence.

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