On Oscillatory EEG During Palm and Finger Movements

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Abstract. The 63-channel EEG responses of four healthy human subjects to the movements of palm, index finger and little finger of the right hand were investigated as a preliminary study of the EEG-based BCI to detect motor imagery of fingers. The spatial distributions of the sensory motor rhythm (SMR) components on mu, beta and gamma bands were evaluated. It was shown that the mu band ERD during movements and beta band rebound ERS were observed in the hand area on sensorimotor cortex of three subjects, and the high gamma band ERS responses during palm grasping were observed in the contralateral hand area of one subject. It was also shown that clear high gamma band components could be extracted from the responses of one subject to the three tasks by using ICA.

Keywords: EEG, Motor Execution, Sensory Motor Rhythm (SMR), ERD/ERS, High Gamma Band, ICA

1. Introduction

Recently, [Darvas et al., 2010] showed the possibility to detect high gamma (HG) band activity from EEG during motor task execution. It is hypothesized, that information transfer rates of sensorimotor rhythm (SMR) based brain-computer interfaces (BCIs) can be increased by using higher frequencies compared to the slower mu and beta rhythms. In this study, SMR responses in mu, beta and gamma band frequency range to the grasping of palm, tapping of index finger and little finger were investigated with respect to improving BCIs based on motor imagery.

2. Material and Methods

Four right-handed able-bodied male subjects (22-24 years old) participated in the experiments. The study was reviewed and approved by the Ethics Committee on Clinical Investigation, Graduate School of Engineering, Tohoku University. Subjects were seated in sitting inside an armchair in an electromagnetically shielded room and asked to execute one out of three motor tasks (MTs) with their right hand: palmar grasp, index finger tapping and little finger tapping. On each trial, subjects were asked to grasp or tap rapidly three times with a self-paced interval which was longer than 4 seconds. One session consisted of 25 movement trials; MTs were fixated prior each session. Four sessions for each MT were recorded on two different days. The order of the MTs was randomized.

EEG was recorded from 63 Ag/AgCl electrodes placed over the whole head based on the extended international 10-20 system (reference and ground were right and left earlobe, respectively). Additionally, a bipolar EMG was recorded from the extensor digitorum muscle. Signals were bandpass-filtered between 1 and 500 Hz and sampled at 2500 Hz. No notch filter was applied.

The EEG was re-referenced with respect to the common average and time-frequency event-related desynchronization/synchronization (ERD/ERS) [Pfurtscheller and Lopes da Silva, 1999] maps were computed for each MT (frequency step 1 Hz, band width ± 1 Hz, reference period -2 to -1 s prior to movement onset). The onset time of the motor execution was detected from the envelope of the EMG data calculated by the Hilbert transform. Additionally, independent component analysis (FastICA [Hyvärien and Oja, 1997]) was applied to the EEG and identified independent components were analyzed with respect to HG activity.

3. Results

One of the subjects was excluded from further analysis by the excess artifacts. In three subjects, mu band ERD during movements and beta band rebound ERS were observed in the hand area over sensorimotor cortex (Fig. 1(a) left). The responses to finger movements were smaller than those to palm movements, and the spatial distributions of these responses were similar. A HG ERS (maximum at 82 Hz) during palm movements was observed in one of the three subjects (Fig. 1(a) right).

ICA analysis led to significant HG responses in one subject. MT-related unmixing matrices (left) and the ERD/ERS activity in the band (same as in Fig. 1(a) right) of the decomposed data (right) are shown in Fig. 1(b). The

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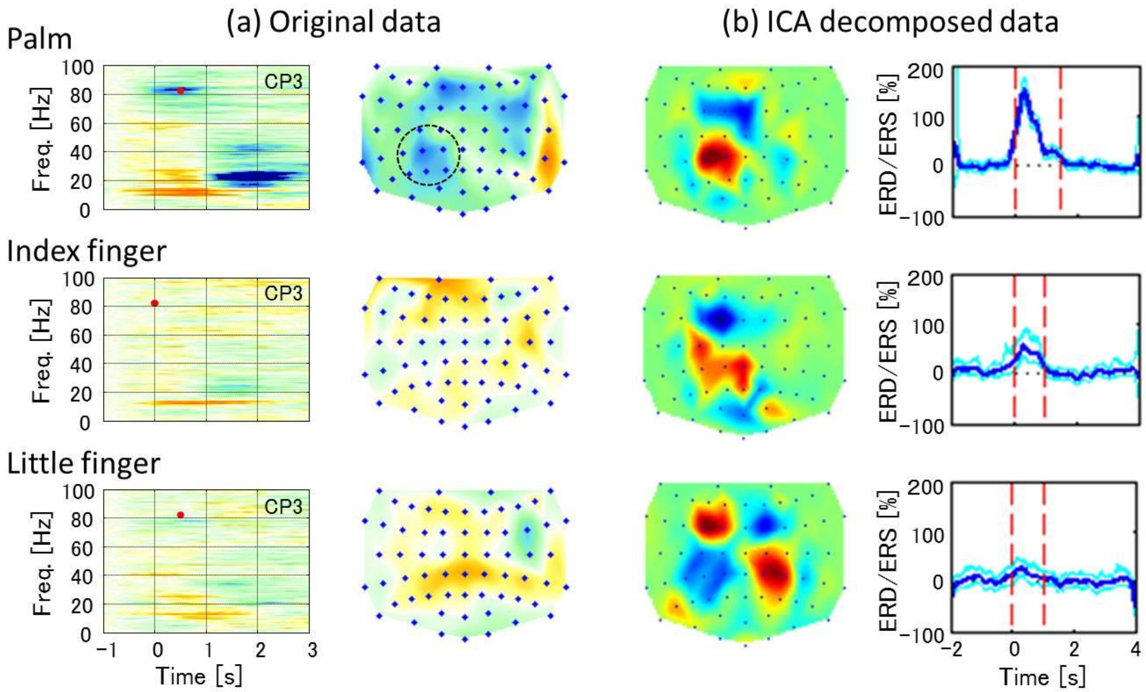

Figure 1. *Responses to the movements of palm, index finger and little finger on one of the subjects. (a) ERD (orange) and ERS (blue) responses of the original EEG. Time-frequency map of ERD/ERS of the measured EEG taken from CP3 (left), and the spatial distribution of the HG response at time and frequency shown on the map by red point, on which the maximum ERS was observed during movement at 80-100 Hz (right: frequency band width is same as the condition for calculating the ERD/ERS maps (±1 Hz)). (b) A selected unmixing matrix obtained by ICA (left), and the ERD/ERS of the corresponding HG independent component at the same frequency and band width shown in the right figures in (a). The Bootstrap confidence intervals (99%) were displayed by cyan lines (right).*

result shows that HG components induced by the movements of palm, index finger and little finger are represented by different independent components. The weight values of the unmixing matrices were localized near to the contralateral (and ipsilateral on little finger) hand area on sensorimotor cortex.

4. Discussion

Mu and beta band ERS/ERD responses were observed in three subjects, whereas the HG response was only found during the palm grasping task in one of the subjects. In this subject, no or poor response in the HG band was observed during or after the rest of the tasks (tapping of index or little fingers). This might be because the magnitudes of the muscle contraction on finger tapping tasks were smaller than that on palm grasping task.

It was found that the ICA could decompose the EEG signal measured from this subject to the significant HG components during all the tasks, as well as the mu and rebound beta band components. The ICA might be useful for designing spatial filters with local spatial distribution for decomposing the target responses to classify motor tasks [Kanoh et al., 2012].

The spatial distributions of the ERD/ERS responses on these frequency bands and the ICA unmixing matrix were similar between three movement tasks. The cortical mapping of the SMR might help to classify precise hand and finger movements or their motor imagery.

References

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