Simultaneous fMRI and EEG source localization with visual motion stimuli

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Introduction

Simultaneous acquisition of fMRI and EEG is thought to be a potential solution for enhancing the temporal resolution of fMRI. To enhance the temporal resolution of fMRI with aids of the EEG data, it is essential to match the fMRI data precisely with the EEG data in the spatial domain. For better spatial matching between fMRI and EEG, we applied EEG source localization to the EP/ERP signal extracted from the EEG data recorded inside a 3.0 Tesla MRI system. We present experimental results of EEG source localization together with corresponding fMRI results.

Methods

We recorded 32-channel EEG signals inside a 3.0 Tesla MRI system with the interleaved data acquisition scheme of fMRI and EEG as shown in Figure 1. The EEG signals were acquired continuously during both the fMRI and EEG sessions, and the EEG data recorded in the fMRI session as well as in the EEG session were used for the BCG template calculation. An fMRI session with the duration of 2 s was followed by two EEG sessions of the same duration. For the visual stimulation, we used visual motion stimuli consisting of two states, i.e., stationary and moving states. In the moving state, concentric ring patterns were moving outward while those ring patterns were frozen in the stationary state. A stimulation block consisted of ten fMRI sessions and 20 EEG sessions, and each block was assigned alternatively to the stationary or moving states. The stationary and moving states were alternated every 60 s for a total stimuli of 480 s. Onset of 1 s and offset of 1 s were given alternatively in both the stationary and moving stimuli blocks. The first and last blocks were assigned to the baseline state in which no visual stimulations were given [1]. After removing the gradient noise from the EEG data recorded in the fMRI sessions, we calculated BCG templates for the whole time period using the correlative BCG template technique [2]. With the correlative BCG templates, we removed the BCG artifacts by subtracting the templates from the original EEG data recorded in the EEG sessions. The EP/ERP signal was, then, extracted from the EEG data. We applied the EEG source localization to the EP/ERP data. For the EEG source localization, we used the cortically constrained inverse algorithm with the 3 layer (skull, scalp, and cortex) BEM brain model. We used the distributed source model in the EEG source localization.

Results

We performed the combinatory fMRI-EEG experiments on five healthy subjects recruited in an academic environment. The first salient deflection in the EP/ERP signal was a positive wave peaking over occipital electrodes (around O1 and O2) between 120 and 150 ms, and then a higher negative wave peaking over occipito-temporal electrodes (around P7 and P8) between 180 and 210 ms (Figure 2). The EEG source localization results also show high intensity at the occipital area at the first peak and at the middle temporal area (MT, also called V5) at the second peak. The EEG source localization results are in good agreement with the fMRI results. In the fMRI results, the difference between the stationary and moving stimuli appears as activations at MT, and the difference between the stationary (or moving) stimuli and the baseline appears as activation in the occipital area. The processing area of visual motion is known as MT that has reciprocal connections with the visual cortical areas V1, V2, V3, VP and V4, as well as medial superior temporal areas (MST). This area is activated when a large visual scene contains motion and inactive when it does not.

Discussions and Conclusions

According to recent researches, the processing area of visual motion (MT) is connected with the visual cortical areas, and this study was aimed at the temporal and spatial analysis of this connection. With the visual stimulation paradigm, the fMRI results show well the activations in the MT areas when the visually moving patterns were given to the subjects. However, the fMRI results lack the temporal information regarding when the MT area was activated. The EEG source localization results give precise time information to the fMRI results. The simultaneous acquisition technique still suffers from remnant BCG artifacts. When the BCG artifacts were not reduced sufficiently due to irregular heart beats or some other unknown factors, we failed in extracting proper EP/ERP signals. We expect simultaneous fMRI-EEG acquisition technique will find many application areas in functional brain studies if more robust BCG artifact removal algorithms can be incorporated.

References

[1] O'Craven KM, et al., *Neuron*, 1997; **18**:591-8
[2] Han JY, et al., *Proc 12th ISMRM*, 2004; 1101

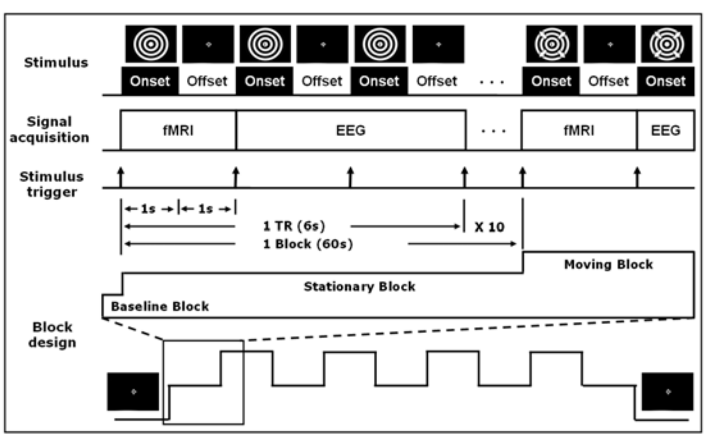

Figure 1. The interleaved fMRI-EEG sequence.

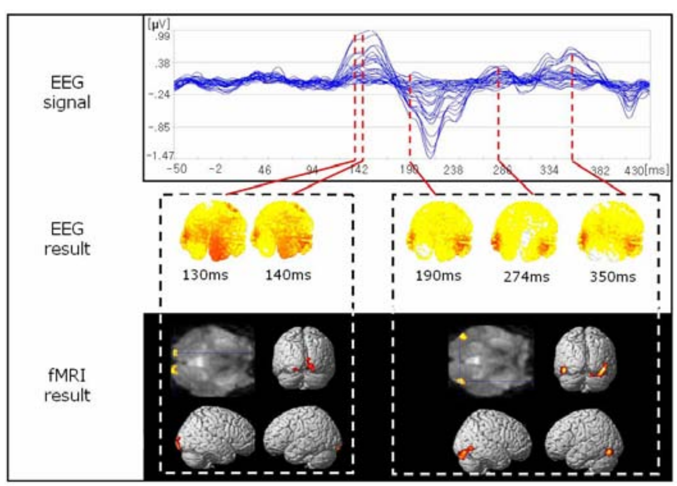

Figure 2. The EP/ERP signals (top), the EEG source localization results (middle), and the fMRI results (bottom).