Ballistocardiogram artifact removal from the EEG signals recorded inside a 3.0 Tesla MRI magnet

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Synopsis

Ballistocardiogram artifact(BA) in the EEG signal measured inside an MRI magnet is very troublesome in combinatory studies of EEG and fMRI. We propose a correlative template method to remove BA in the EEG signal. Using the correlative template method, BA has been removed from the EEG signals recorded inside a 3.0 Tesal MRI magnet, and visual evoked potential signals have been extracted from the BA-removed EEG signals. Using the visual evoked potential signals, we have obtained EEG current source maps on the cortical surface. The EEG source maps obtained inside the magnet are similar to those obtained outside the magnet.

Introduction

EEG and fMRI have their own advantages in functional brain studies, and combination of EEG and fMRI has been tried to improve the spatio-temporal resolution in the functional brain studies. In combinatory fMRI/EEG studies, it is very essential to keep the mental status of the subject unchanged. Simultaneous acquisition of fMRI and EEG is the ultimate goal of the combinatory fMRI/EEG study. In the combinatory study, however, EEG signals are corrupted by many kinds of MRI-related noises. Ballistocardiogram (BCG) artifact (BA) is one of the noises. Without proper removing of BA, evoked potential signals cannot be extracted from the EEG signals. In this study, we propose a correlative template method to remove BA and we present EEG current source maps calculated from the BA-removed EEG signals.

Methods

Since BA has time-varying nature, BA cannot be completely removed from the EEG signals by using the simple BA template subtraction method [1]. To account for the time-varying nature of BA, we used the correlative template subtraction method. First, BCG segments were extracted from the EEG signals based on the QRS timing. For the *i-th* (i=1,…,N) BCG segment, the cross correlation coefficient was calculated from the rest of the BCG segments. Correlative BCG segments, named *cBCG*, which have greater cross correlation coefficients than a threshold, were selected. Among the *cBCG* segments, the median value was chosen to create the correlative template. The main concept of the correlative template subtraction technique is illustrated in Fig. 1. After building up all the correlative templates, the *i-th* BA-removed EEG segment was calculated by,

$$EEG_i = BCG_i - median(cBCG_{ij})(j = 1,\ldots\ldots, M, M < N). \quad [1]$$

EEG measurements with a 32-channel MRI-compatible EEG recording system have been performed inside and outside the 3.0 Tesla MRI magnet. For the stimulation, checkerboard reversal onset patterns have been used. After removing BA from the EEG signals, visual evoked potentials (VEPs) were extracted from the EEG signals. To evaluate efficacy of the correlative template method, EEG current source imaging has been performed. In the EEG current source imaging, we used the cortically constrained approach with a realistic brain surface boundary element method (BEM) model derived from the 3D magnetic resonance images.

Results

We observed that the BA patterns of all the subjects are different and even the BA patterns of a single subject also vary depending on the heart beat pattern. In both experiments performed inside and outside the magnet, we acquired the VEP data for about 300s with each epoch period of 430 ms. In the calculation of VEPs, epochs containing signals greater than 50 μV were rejected and the BAs were removed with the proposed technique. In Fig. 2, we show the EEG current source maps of two human subjects as representative examples of the successful cases. The current source maps were calculated at the time of maximum VEP peaks. The colored regions in the figures represent the area on which current densities are greater than 20% of the peak current density. The figures clearly demonstrate strong similarity between the current source maps obtained inside and outside the magnet.

Conclusions

Using the correlative template method and the cortically constrained current source imaging technique, we obtained current source maps on the cortical surface from the visually evoked potential data recorded inside a 3.0 T MRI magnet. The experimental results of 10 volunteer studies suggest that EEG current source imaging is feasible in the 3.0Tesla MRI magnet with the proposed BA-removal method.

References

[1] P.J. Allen, et al., NeuroImage 8, pp229-239, 1998

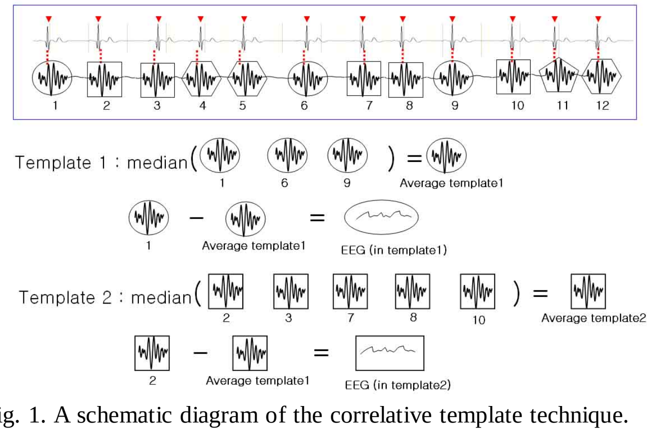

Fig. 1. A schematic diagram of the correlative template technique.

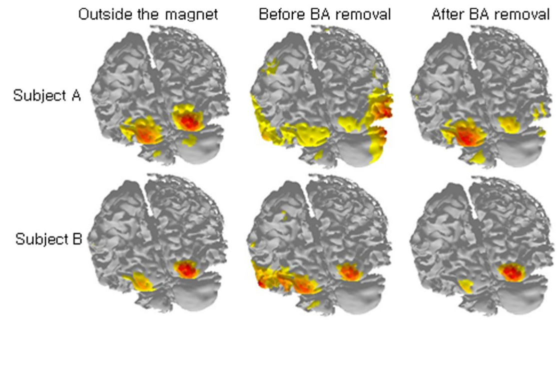

Fig. 2. Results of two subjects inside and outside magnet and with and without BA removal