Study of the removal of TMS induced artifacts on human EEG based on the partial cross-correlations

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Abstract. The TMS pulse in the TMS-EEG combining study introduces artifacts in the EEG electrodes. In this study a statistical method on the removal of TMS induced EEG artifacts is presented based on partial cross-correlations. The method yields estimates of linear correlations between components obtained by Independent Component Analysis (ICA) and TMS signal that are not affected by linear correlations with other artifacts. The results showed which ICA components are related to TMS induced EEG artifacts, suggesting the efficiency and the reliability of the method developed in this study.

Keywords: TMS-EEG, artifacts, ICA, partial cross-correlations, brain

1   Introduction

Transcranial magnetic stimulation (TMS) can be used to activate or deactivate a specific part of the brain non-invasively causing depolarization or hyperpolarization in cortical neurons by the electromagnetic induction. It is widely used to measure the connectivity of the primary motor cortex and a muscle to evaluate brain damage and other disorders related to the motor cortex [1] and also used to study the effects of phosphenes by stimulating the primary visual cortex [2] and the speech processing by disrupting momentarily the Broca's area [3]. EEG, a non-invasive technique records spontaneous electrical activity of the brain by measuring the voltage fluctuations resulting from ionic current flows within the neurons of the brain [4]. EEG is used to clinically observe the type of neuronal oscillations and therefore can be used to diagnose Epileptic activity, brain death, or sleep disorders from their abnormal patterns of the EEG signals [5-6].

Combining TMS and EEG offered insights into neural interaction during cognition which allows the investigation on the causal role of specific brain areas in behavior and the interactive connection between the brain areas [5-6].

The TMS pulse in the TMS-EEG combining study introduces artifacts in the EEG electrodes. The magnetic pulse of TMS affects the muscles and motor nerves underneath the coil causing the muscle activation and eye movement, which results in the induction of EEG artifacts [7-9]. Independent Component Analysis (ICA) is

applicable to separate EEG data into neural activity and artifact [10]. Many methods using ICA are applied to high-density EEG data to reject components of artifact [10-11]. However, there are few of them which resolve TMS induced artifact removal problem on EEG. In this study, a statistical method on the removal of TMS induced EEG artifacts is presented based on partial cross-correlations. The ICA components originating from the TMS-induced artifact are classified by estimating the partial cross-correlation coefficients between ICA components of single pulse TMS-EEG and sham-EEG stimulus after ICA decomposition. The results showed which ICA components are related to TMS induced EEG artifacts, suggesting the efficiency and the reliability of the method developed in this study.

2   Methods for TMS-EEG data collection

Figure 1 represents the flowchart of the overall processes of this method. EEG data were sampled preliminary at 1.45kHz and then re-sampled at 0.725kHz before filtering. The EEG data initially referenced to site Fz which is the 14th channel in this study. The referenced EEG data were filtered offline using a bandpass filter between 1 Hz and 95 Hz with a notch at 50 Hz to remove environmental noises. Next, artifactual channels are statistically classified, removed and interpolated based on their distributions and correlations to each other. The data were referenced to the average of all scalp electrodes. Then, ICA was performed with FastICA algorithm on the data and the decomposed components were analyzed for biological artifacts and TMS induced artifact using partial cross-correlations. Finally, the ICA components originating from biological artifacts and TMS-induced artifact were subtracted from each channel data.
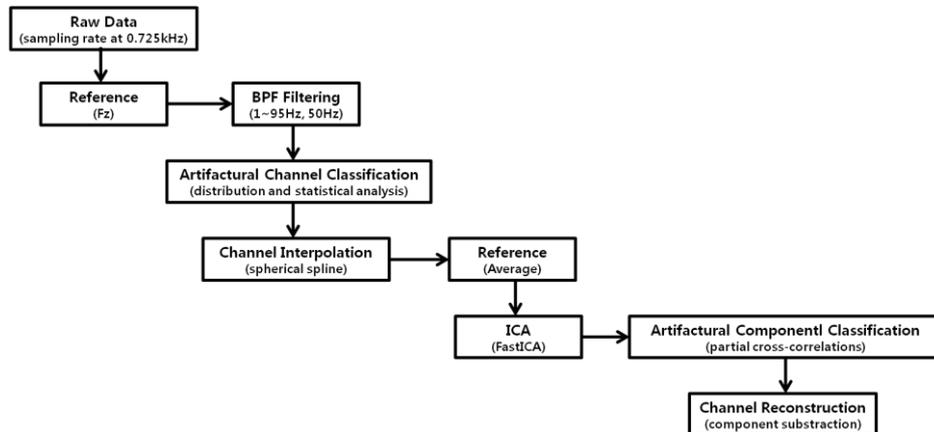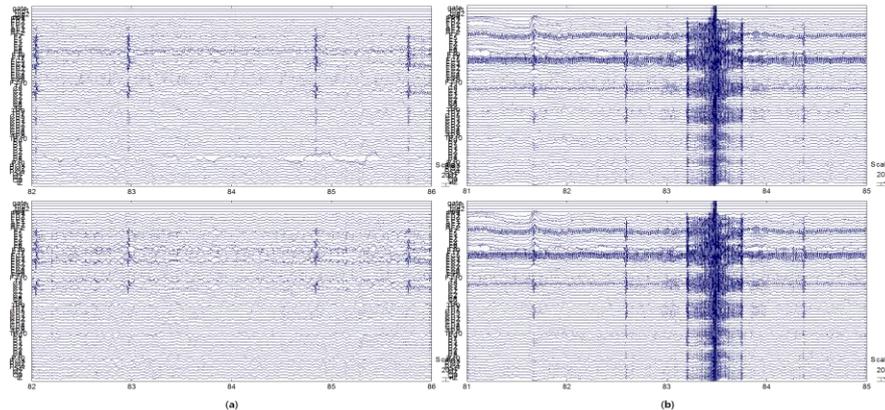

Fig. 1. The flowchart of the overall processes of this method

3   Results and Discussions

Figure 2 represents the time courses of channels for single pulse TMS-EEG data and sham-EEG data, respectively after ICA decomposition analysis (top) and TMS induced EEG artifact removal (bottom) based on the partial cross-correlations.

Fig. 2. the time courses of channels for single pulse TMS-EEG data and sham-EEG data, respectively after ICA decomposition analysis (top) and TMS induced EEG artifact removal (bottom) based on the partial cross-correlation.

4   Conclusions

In this study, a statistical method on the removal of TMS induced EEG artifacts is presented based on partial cross-correlations. The method yields estimates of linear correlations between components obtained by ICA and TMS signal that are not affected by linear correlations with other artifacts. The EEG data used in this study were obtained from four healthy subjects without any neurological disorder, who were receiving single pulse TMS-EEG and sham-EEG stimulus on the left Broca's area. ICA filters trained on the reduced version of 60 channel EEG data collected during single pulse TMS-EEG and sham-EEG recordings. The ICA components originating from the TMS-induced artifact are classified by estimating the partial cross-correlation coefficients between ICA components of single pulse TMS-EEG and sham-EEG stimulus after ICA decomposition. The results showed which ICA components are related to TMS induced EEG artifacts, suggesting the efficiency and the reliability of the method developed in this study.

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