Evaluation of the gradient noise effects on EEG source localization in a combinatory study of EEG and fMRI

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Synopsis

Combinatory studies of fMRI and EEG have been increasing due to many virtues of their combination. To use the EEG data recorded during the fMRI scan in enhancing fMRI performance, the gradient switching noise should be reduced. We have evaluated effects of the gradient switching noise on EEG source localization using a phantom that has electric current dipoles mimicking a human brain. It has been found the EEG data recorded during EPI scans can be used in EEG source localization if the gradient noise is reduced down to 15-20% of the EEG signal power.

Introduction

EEG signals simultaneously acquired during fMRI scans have been used for many purposes such as epileptic spike triggered EPI scan or patient monitoring during the scan. It is expected that simultaneously acquired EEG signals can be used for many other purposes such as brain-activity source localization with combinatory data of EEG and fMRI if the MRI-related noises in the EEG data can be suppressed sufficiently. The gradient switching during fMRI scans makes the biggest noise in simultaneously acquired EEG data. Many techniques to reduce the gradient switching noise have been introduced with successful experimental results [1]. In this work we evaluated effects of the gradient switching noise in EEG signals on EEG source localization using an EEG phantom.

Methods

We constructed a spherical phantom on which 32-channel EEG electrodes are placed to record electric potential signals appearing when an electric current dipole (ECD) locating inside the phantom is activated. The spherical phantom the diameter of 20cm was filled with 0.1% NaCl solution whose electric conductivity was 0.1 S/m. The ECD was made of a thin coaxial cable and an 8 Hz sinusoidal current was fed to the ECD during the activation to mimic a neuronal activation in the brain. While performing EPI scans with various gradient strengths, we measured electric potentials at the electrodes using an MRI-compatible EEG measurement system. With the measured potential signals we performed EEG source localizations and evaluated source localization errors with respect to the gradient-noise to potential-signal ratio (*GPR*) which is defined as below,

$$GPR = \left(\sum_{i=1}^{N}\sum_{j=1}^{M} g_i^2(j)\right) / \left(\sum_{i=1}^{N}\sum_{j=1}^{M} s_i^2(j)\right) \qquad [1]$$

where $s_i(j)$ and $g_i(j)$ are the sinusoidal potential signal and the gradient switching noise signal at the *i*-th electrode, *N* the number of EEG channels, and *M* the number of signal samples. We performed EEG source localizations for three different ECD locations. In the EEG source localizations we used the simulated annealing (SA) method with some modifications [2].

Results

To analyze the effects of the gradient switching noise on EEG source localization, we measured the electric potential signals at the electrodes applying EPI scans with a 3.0 Tesla MRI scanner. *GPR* was adjusted by changing the gradient strength of the EPI scans. It has been found that the source localization errors are within the error bound of the source localization algorithm, 2-3mm, when *GPR* is less than 15-20%. However, the localization error tends to increase rapidly as *GPR* increases in the range bigger than 15-20%. The gradient switching noises (solid lines in Fig. 2) have bigger effects on the source localization than the Gaussian random noises (broken lines in Fig. 2). The source localization error for the ECD lying in the boundary region of the EEG electrode array (ECD B) is bigger than it is in the central region (ECDs A and C).

Conclusions

The experimental results suggest that EEG source localizations are feasible with the EEG data obtained during MRI scans if the gradient switching noise power is suppressed below 15-20% of the evoked potential signal power by either hardware or signal processing method. It is very likely that the EEG data acquired during the scan pause time in between consecutive slice-by-slice EPI scans can be greatly utilized in EEG source localizations.

References

[1] P.J. Allen, et al., NeuroImage 12, pp230-239, 2000

[2] K. Uutela, et al., IEEE Trans. Biomed. Eng. 45, pp716-723, 1998

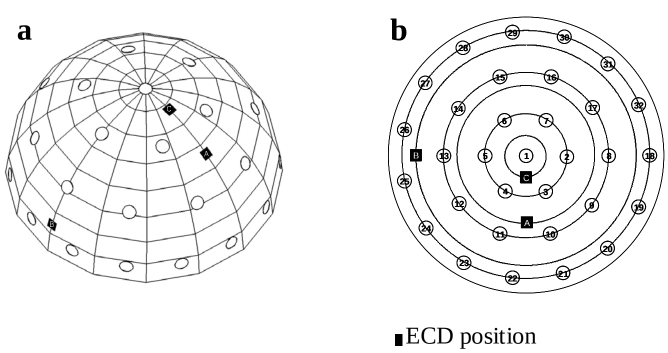

Fig. 1 A schematic diagram of the EEG phantom. ECDs represent the electric current dipoles to which 8 Hz sinusoidal currents are applied.

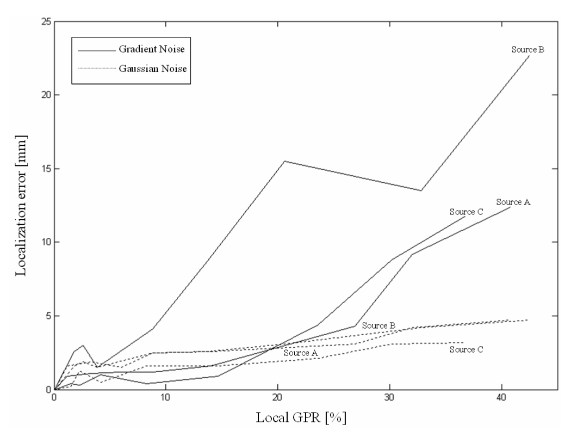

Fig. 2 The effects of the gradient switching noises (solid lines) and Gaussian noises (broken lines) on the EEG source localization.