An EEG system with carbon wire electrodes and an anti-polarization circuit for simultaneous EEG-fMRI recording

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Background

Simultaneous EEG-fMRI (Electroencephalography-functional Magnetic Resonance Imaging) recording offers high temporal resolution electrophysiological recording and high spatial resolution hemodynamic recording from the same experimental runs. Carbon wire electrodes (but not solid electrodes with carbon leads) are suitable for simultaneous EEG-fMRI recording, especially in high field MRI, because they cause less RF (Radio Frequency) heating (Bonmassar, 2004) and less susceptibility artifacts (Krakow et al., 2000) than metallic electrodes. In addition, carbon wire electrodes are comfortable to wear during long recording sessions. However, carbon wire electrodes have not been used widely in human EEG because of its relatively high impedance and the electrode polarization, or imbalance of DC potentials among electrodes. The problem associated with the high impedance is negligible, especially with EEG recorders with high input impedances. Electrode polarization causes randomly fluctuating potentials and saturation of the EEG recorder. In this study, we developed a prototype EEG system with three carbon wire electrodes and a in-house made pre-amplifier that was equipped with an anti-polarization mechanism. The system was evaluated in an auditory ERP (event-related potential) experiment.

Method

A prototype EEG cap with two pairs of carbon wire electrodes (Cz-Fz, Fz-Nose) was built for assessing the feasibility of measuring low-amplitude ERPs using carbon wire electrodes. A pair of EEG electrodes were made of the tips of carbon wires (CPVC4050, World Scientific Inc., Sarasota, FL) wrapped in fine polyester mesh, which in turn were attached to flaps on the EEG cap. Conductive paste (Quik-gel, Compumedics, Charlotte, NC) was applied between the polyester mesh and the scalp, and the flaps were closed with adhesive tape. The EEG cap also had three mutually orthogonal carbon wire loops for detecting the gradient artifacts. Outputs from these loops were used to remove MR artifacts from the EEG signal using an adaptive noise cancellation algorithm. The EEG leads were connected through patch panel filters (BLP10.7, Mini-Circuits, Brooklyn, NY) to a pre-amplifier that was equipped with an anti-polarization circuit (Fig. 1). The anti-polarization circuit provided a 0.07 Hz low-pass filtered, negative feedback to each carbon wire electrode. EEG was recorded during gradient-echo fMRI scanning (3T Trio, Siemens, Erlangen, Germany; TR=1550 ms, TE=60 ms, FA=80, 25 slices, FoV=240 mm, base resolution=128).

An auditory ERP experiment was designed to elicit MMN (mismatch negativity), a pre-attentive negative component that typically occurs150 to 250 ms after the presentation of rare stimuli (oddballs) embedded in regular, frequent stimuli (standards) (Näätänen et al., 2007). To suppress attention-related components associated with the oddball stimuli, the subjects were instructed to silently count the incoming stimuli. The amplitude of the MMN is small (about 2 microvolts) and thus is a challenge for simultaneous EEG-fMRI. Fifteen healthy subjects participated in the study after informed consent.

Result

Data from five subjects out of fifteen subjects were discarded due to excessive movements. After adaptive noise cancellation, data with movement artifacts (including eye movement artifacts) were removed, yielding 936 oddball epochs and matching 943 standard stimuli in total. In these epochs, neither MR nor cardiac artifacts was visible in the EEG. A grand average of the Cz-Fz potential from these subjects clearly shows the MMN component, a negative shift (> 2 microvolts) around 250 milliseconds post-onset of the oddball stimuli (Fig.2).

Conclusion

We confirmed that high quality EEG can be acquired using carbon wire electrodes during fMRI scanning. Signals from the gradient artifact detector loops were effectively used to reduce the scanner artifacts and the ballistocardiogram artifacts.

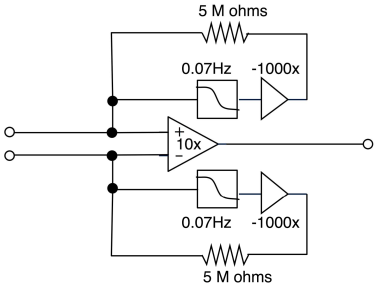

Fig. 1. A differential amplifier with an anti-polarization circuit. Each input terminal receives a negative feedback after 0.07 Hz low-pass filtering.

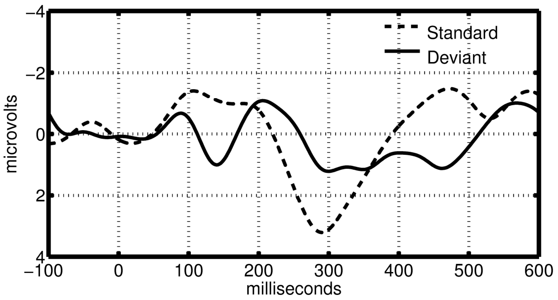

Fig. 2. Grand average ERP of ten subjects corresponding to the standards (broken line) and the deviants (thin solid line).

Acknowledgements

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