Towards high-quality simultaneous EEG-fMRI acquisitions at 7 Tesla: detection and reduction of EEG artifacts due to head motion in B0

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Target audience: neuroscientists, engineers and clinicians interested in performing simultaneous EEG-fMRI studies at high field.

Purpose: The benefits offered by high-field imaging open exciting perspectives for simultaneous EEG-fMRI studies. However, the artifacts induced on EEG recordings by the strong magnetic fields employed can largely overwhelm the signals of interest[1]. While fairly effective approaches have been developed to minimize gradient and cardiac pulse-related artifacts, contributions due to spontaneous head motion in B_0 have received little attention[2], and can become especially problematic at higher fields, where even well-trained subjects can exhibit important motion-related artifacts in the EEG. As part of the ongoing effort towards achieving high-quality simultaneous EEG-fMRI acquisitions at ultra-high field, the aim of this work was to implement and optimize an approach for detection and reduction of EEG artifacts due to head motion in B_0.

Methods: EEG-fMRI acquisitions were conducted on 6 healthy subjects in a 7T head scanner (Siemens), equipped with an 8ch Tx/Rx head array (Rapid Biomedical). FMRI data were acquired with multislice GRE-EPI (TR/TE =2000/25ms, 1.5×1.5×1.5mm^3 spatial resolution, 25 slices). EEG data were recorded using a 64ch cap (EasyCap) connected to 2 BrainAmp MR amplifiers (Brain Products) via short bundled cables[3]. To allow for motion artifact detection, motion sensors were created as follows: 4 of the EEG cap electrodes (T7,T8,F5,F6) were isolated from the scalp and connected directly to the reference electrode (FCz) via Cu wires fitted with 5kΩ resistors (Fig.1a). This allowed recording voltage variations due to magnetic induction in the loops during motion, without capturing actual neuronal activity. During acquisitions, subjects were presented with reversing checkerboards (3Hz) for 10 blocks of 33 trials. Following acquisition, EEG data were preprocessed to reduce gradient and pulse artifacts via AAS and OBS techniques[3]. Motion artifact reduction was then applied to each channel with a varying-coefficient linear model combining the 4 motion sensors, based on a multi-channel recursive least squares (M-RLS) approach[2]. Here, without the need for real-time correction, the M-RLS approach was optimized by including both backward and forward shifts in the model filter, and by iterating the EEG timecourses forward and then backwards, so as to clean up the initial period of weight adaptation. Subsequently, data quality was further improved via ICA by excluding residuals of motion and pulse artifacts and spurious neuronal activity.

Results: Overall, motion artifact correction led to an average reduction of 2.2±0.3dB in total EEG power. Lateral electrodes exhibited the strongest effects (Fig.1b), with reductions up to 4dB, likely due to the larger loops formed by these electrodes relative to the midline. Regarding visual responses (Fig.2), motion correction produced marked effects on trial-average responses across the scalp, enhancing the expected P100 peak in occipital regions (well-known for this type of stimuli) and reducing signal variations in baseline periods before and after this component (Fig.2a-c). Although the impact of motion correction was larger on lateral electrodes, occipital channels exhibited considerable sensitivity gains at a single-trial level, with both the P100 and the smaller N75 and N140 negative components becoming evident in a large fraction of trials (Fig.2e). ICA denoising provided a useful complement to motion correction, producing further improvements in both trial-average and single-trial responses.

Conclusion: Adequate detection and reduction of motion-induced EEG artifacts can significantly improve the quality of EEG recordings performed simultaneously with fMRI, and opens up new possibilities for single-trial studies at 7 Tesla.

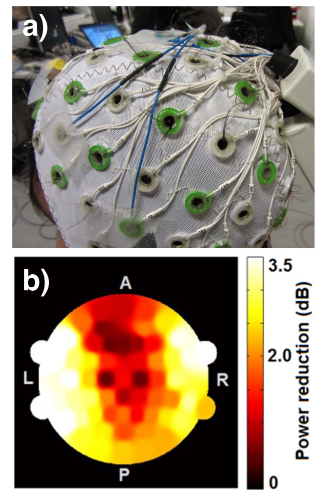

Fig.1 a) Cap modification to create motion artifact sensors (note blue wires). **b)** Group-averaged power reduction due to motion correction.

References: **(1)** Mullinger et al., NeuroImage 2008. **(2)** Masterton R, et al. NeuroImage 2007. **(3)** Jorge J, et al. NeuroImage 2015.

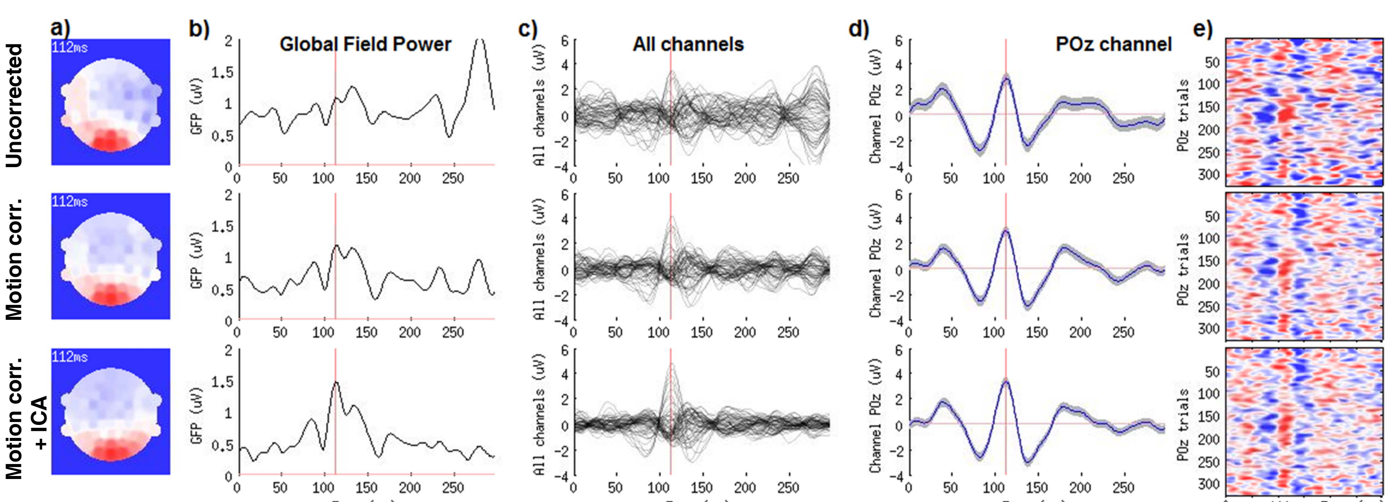

Fig.2 Visually evoked potentials (VEP) to checkerboard stimulation (onset at t = 0) in one subject, before and after motion correction, and with additional ICA denoising. The well-known P100 peak of the VEP is marked by a red line. All responses correspond to trial averages except for the single-trial POz responses in e).