Correction of micro-motion artifacts in simultaneous EEG-fMRI

Concurrent EEG-fMRI is a unique neuroimaging method allowing the non-invasive monitoring of neuronal activity with complementary high temporal and spatial resolutions. This multimodal technique can be used to address a wide variety of fundamental research questions related to the timing and localization of perceptual and cognitive cerebral processes. Moreover, EEG-fMRI is becoming increasingly prevalent in clinical settings, particularly for the diagnosis and presurgical evaluation of focal epilepsy patients, in whom targets for either invasive investigations or resective surgery can be delineated. However, the recording of EEG inside the MR scanner leads to a severe degradation in EEG signal quality, which limits the potential applicability of simultaneous EEG-fMRI well below what could be expected from the properties of each modality taken separately.

EEG artifacts are caused by Faraday induction in the EEG wires due to both 1) magnetic field variations during gradient switching and 2) motion of the wires in the magnet. In the first case, the periodic nature of the gradient waveforms during fMRI acquisition makes the identification, modeling, and subtraction of the gradient artifacts relatively straightforward (Allen et al., 2000). However, any intervening motion will modulate the high-frequency gradient waveforms and thus destroy their periodicity. In the second case, even microscopic motion will induce high-amplitude artifacts in the strong magnetic field; one important and unavoidable source of such motion is the ballistocardiogram, which is only partially periodic and thus cannot be easily modeled.

Consequently, all of our EEG-fMRI recordings now include precise and high temporal resolution motion tracking (Moiré Phase Tracking, Metria Innovation Inc., Milwaukee, USA). The measured motion parameters are used to regress out modulations of the gradient artifact waveforms (Fig. 1) as well as ballistocardiographic artifacts (Fig. 2), leading to unprecedented improvements in EEG signal quality and opening new avenues for investigation of clinically relevant neuronal signals such as evoked potentials or interictal epileptiform discharges (LeVan et al., 2013).

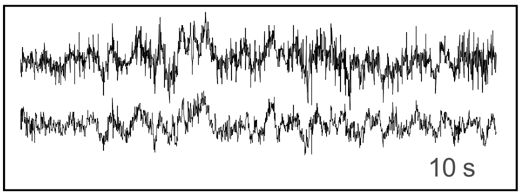

Figure 1. Top: Residual high-frequency gradient artifacts after standard averaged artifact subtraction method. Bottom: After modeling gradient artifact modulation by measured motion.

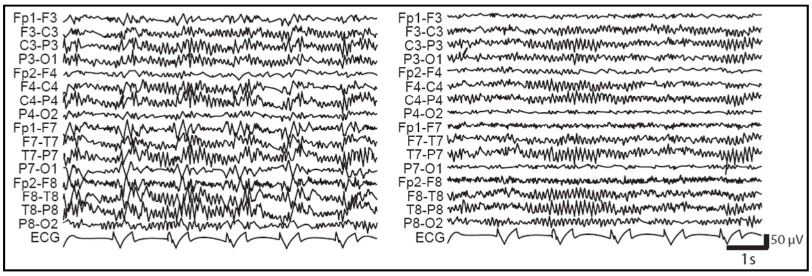

Figure 2. Left: EEG showing partially periodic ballistocardiographic artifact following each heartbeat. Right: After correction by regressing out measured motion parameters.

References

Allen PJ, Josephs O, Turner R (2000). A method for removing imaging artifact from continuous EEG recorded during functional MRI. Neuroimage 12(2):230-9.

LeVan P, Maclaren J, Herbst M, Sostheim R, Zaitsev M, Hennig J (2013). Ballistocardiographic artifact removal from simultaneous EEG-fMRI using an optical motion-tracking system. Neuroimage 75:1-11.