The helium Pump artifact in simultaneous EEG-fMRI does not affect ERP signal-to-noise or topological consistency.

Johan N van der Meer[1], André Pampel[2], Jennifer R Ramautar[3], German Gomez-Herrero[3], Jöran Lepsien[2], Harald Möller[2], and Martin Walter[1]

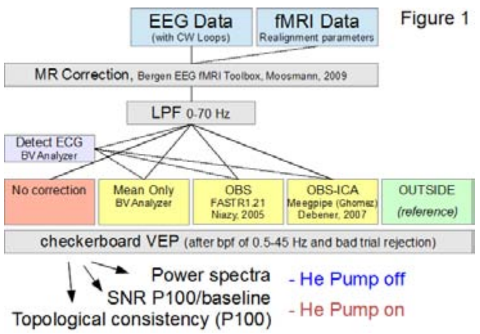
[1]*Clinical Affective Neuroimaging Laboratory, Department of Behavioral Neurology, Leibniz Institute for Neurobiology, Magdeburg, Germany,* [2]*Nuclear Magnetic Resonance Unit, Max Planck institute for human cognitive and brain sciences, Leipzig, Germany,* [3]*Department of Sleep and Cognition, Netherlands Institute for Neuroscience, Amsterdam, Netherlands*

Target audience

Neuroscientists involved in simultaneous EEG-fMRI, MRI core facility staff, MRI vendors

Purpose

While simultaneous EEG-fMRI has the potential for real-time combination of two powerful neuroimaging techniques, the signal-to-noise ratio (SNR) of the EEG suffers from severe artifacts due to the MRI environment. Although artifacts resulting from the switching of magnetic gradient fields can be largely removed due to their periodicity, artifacts due to movements (e.g., related to blood pulsation or the pump cycle of the helium coolant system) lack such strict periodicity and are much more difficult to correct. As a consequence, the helium pump is routinely deactivated during simultaneous EEG-fMRI[1]. Such practice poses the risk of damaging the MRI system in the long run and necessitates more frequent and expensive He refills to compensate for increased boil-off. In this work, we analyse how severe the He pump affects quantities that are routinely extracted from the EEG in simulteneous EEG-fMRI studies, such as event-related potentials (ERPs) and or EEG frequency band(s).



Methods

Two volunteers were examined on a 3T TIM Trio scanner (Siemens, Erlangen, Germany) with simultaneous EEG-fMRI while performing a simple alternating visual checkerboard task with checks of 1 degree visual angle and inter-trial interval of 0.5 sec[2]. Measurements were performed three times – once outside the scanner room and twice inside during scanning. One scan was performed with the He pump off, and one with the He pump on. The EEG was recorded with a Brain Products MRI-compatible 32-channel EEG system at 5000 Hz and processed with several commonly used artifact correction pipelines (Figure 1). Data were corrected for the MRI gradient artifact with the Bergen EEG-fMRI toolbox[3], downsampled to 1000 Hz and low-pass filtered at 70 Hz. Subsequently, data were either not corrected for the ballistocardiogram (BCG) artifact, corrected with the mean BCG artifact in Brainvision Analyzer, corrected with the Optimal Basis Set (OBS) method[4], or corrected with the combination of OBS with individual component analysis (OBS-ICA)[5]. This yielded, for both volunteers, four different EEG traces for the He pump-off condition, four traces for the He pump-on condition, and one reference trace recorded outside the MRI scanner (without any gradient or BCG correction). Subsequently, for each of these traces, the data were band-pass filtered between 0.5 and 45 Hz, segmented (−0.05 to 0.35 sec around the checkerboard reversal events) and averaged to create visual ERPs called visual evoked potentials (VEPs). To assess EEG quality, we compared: (1) the SNR of the VEP P100-vs-baseline (at 117 msec for both subjects) between all EEG traces, where the signal is the mean peak and the noise is the standard deviation across trials (see Figure 3A); (2) the average correlation across trials of the topographical distribution of the VEP waveform with the mean topological distribution (see Figure 3A); and (3) the EEG autospectrum across all channels of data before it was segmented.

Results

The EEG autospectra (see Figure 2 for Subject 1; Subject 2 had almost identical spectra) reveal that the power in the spectral range of 0-30 Hz was up to 20 dB higher if EEG was recorded during MRI scanning as compared to the reference EEG spectrum. For the mean-only, OBS, and OBS-ICA artifact corrections, the EEG power was up to 10 dB lower as compared to results without corrections. When the He pump was switched on, several new peaks appeared at frequencies above 30 Hz, but there was no observable change in the EEG power below 30 Hz. Here, the OBS-ICA performed less well in the frequency range between 3-8 Hz as compared to when the helium pump was off. For all EEG spectra recorded inside the scanner, however, the power was about 10-15 dB higher than in the reference spectra. The SNR ratio (see Figure 3B) of the P100-vs-baseline was almost 2 times lower for subject 1 and 5 times lower for subject 2; this difference was partly due to lower VEP in subject 1. Applying the mean-only or the OBS method indicated an improvement in SNR above no correction. Switching He pump on had no discernable effect on the SNR. The topological correlations showed similar findings (Figure 3B); lower consistency for the measurements during MRI scanning, and almost no effect of the He pump status.

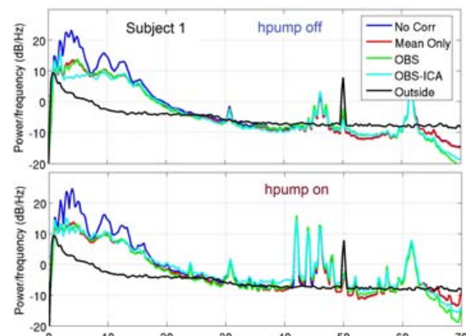
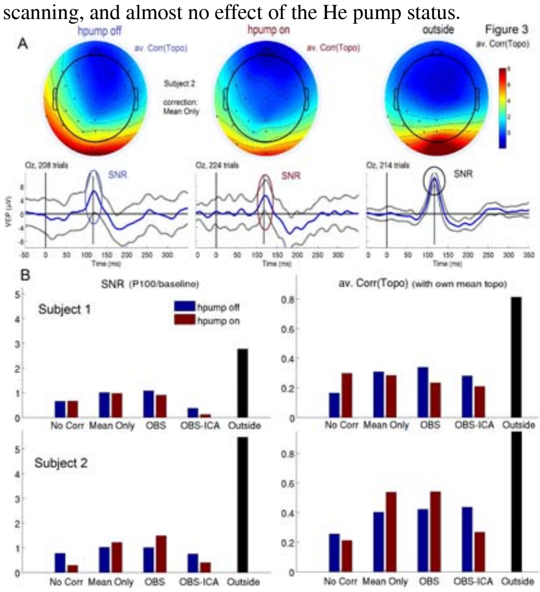


Figure 2



Discussion

Our experiments showed two main findings. Firstly, the EEG noise produced by the He pump had negligible effects on the SNR or topological collelations of the ERPs. Secondly, the EEG data recorded during scanning suffered from major spectral distortions. The EEG data recorded during and did not reach the quality obtained with recordings outside the scanner, even when current state-of-the-art artifact correction methods were used.

Conclusion

Our findings indicate that there is no need to switch off the He pump in simultaneous EEG-fMRI experiments with ERPs. However, the quality of the EEG data is still poor—compared to reference EEG scans recorded outside the MRI, so undertaking resting state or spectra-based EEG-fMRI studies could be very unreliable. Hence, better EEG artifact correction methods, likely to be more hardware-based [6-7] are required for improved performance.

References

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