Simultaneous EEG-fMRI acquisition: Effect of choice of MRI pulse sequence on gradient artifacts and EEG data quality

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1 Introduction

Concurrent EEG-fMRI holds promise to significantly enhance the spatiotemporal resolution of functional neuroimaging. However, to take full advantage of the merits of the two modalities, it is necessary to acquire EEG data inside the MRI scanner where strong static and time varying magnetic fields that are part of the MRI imaging process induce artifacts many orders of magnitude larger than the underlying EEG signal. For accurate interpretation of the EEG data, it is necessary that these gradient artifacts be suppressed to power levels much lower than the EEG signal. Pulse sequence design for fast and high-resolution imaging has been an area of intense research [1]. The wide variety of sequences when used in conjunction with EEG would give rise to artifacts that are diverse in shape and spectral content.

2 Methods

In order to investigate the effect of the choice of pulse sequence on the quality of EEG data, a comparative study was performed on a 1.5 T Signa-LX scanner (GE Medical Systems, Milwaukee, WI) using two pulse sequences: Echo Planar Imaging (EPI)[2] and Spiral [3]. Two subjects were each studied under conditions of activation (visual odd-ball task) and rest (visual fixation only) in separate acquisitions. Pulse sequence parameters were TR/TE/FA/FOV of 1500 msec/30 msec/90°/22 cm. Twenty-three 3-mm-thick axial slices were acquired in each TR, with an in-plane resolution of 3.44×3.44 mm. EEG data were recorded at a sampling rate of 5 kHz from 32 channels (30 EEG + EOG + ECG) of the 10-20-electrode placement system using a BrainAmpMR EEG system (Brainproducts, Gilching, Germany). The envelope of EPI and Spiral gradient spectra are shown in figure 1 and 2 respectively. Note that the Spiral imaging gradients have considerable power in the 0-100 Hz range, which is the band of interest in EEG. Gradient artifacts were removed independently using 2 different signal-processing methods: (i) Template subtraction followed by Adaptive Noise Cancellation [4] and (ii) Optimal basis set (OBS) method [5]. Ballistocardiogram (BCG) artifacts were removed from all the data sets using Independent Component Analysis (ICA). EEG data recorded under the same task and resting state condition inside the scanner with no MR acquisition, was used as the gold standard for comparing the EEG data obtained concurrently with the EPI and Spiral pulse sequence scans. Power in the delta (0-3 Hz), theta (3-7 Hz), alpha (7-12 Hz), beta (12-26 Hz) and gamma (26-70 Hz) bands of the EEG obtained with EPI and spiral were compared with that of the gold standard.

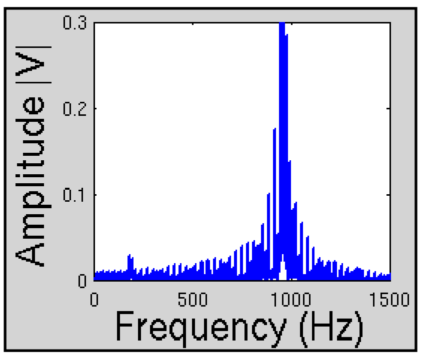

Figure 1

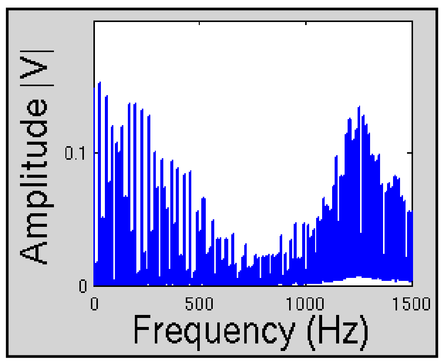

Figure 2

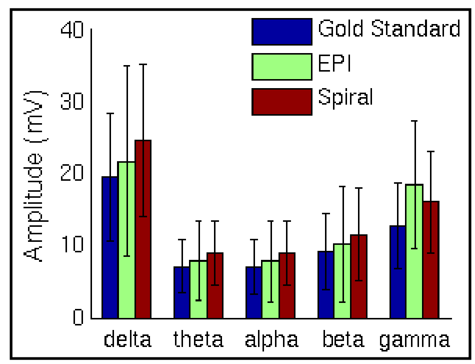

Figure 3

Figure: (1) Spectrum of the EPI X-gradient, (2) Spectrum of the Spiral X-gradient. Note the significant power in the 0-100 Hz range unlike EPI, (3) The relationship between the mean amplitudes in the various EEG bands of the gold standard, EPI concurrent EEG and Spiral concurrent EEG after artifact correction using the OBS method for a resting state acquisition. The relationship was very similar for task activation and the template subtraction method.

3 Results and Conclusions

In every band except the gamma band, for all the 4 datasets (2 subjects: Activation and resting) and using both the artifact removal methods, the average power of the Gold Standard was less than EPI which was in turn less than spiral (figure 3) on at least 26 out of the 30 EEG channels. In the gamma band (higher frequencies), the relationship was more variable. The maximum deviation from the corresponding gold standard of EPI concurrent EEG power in any band was up to 18%, whereas the Spiral concurrent EEG deviated up to 34%. The results were consistent across different channels, subjects and artifact removal algorithms. This difference can perhaps be attributed to the fact that the spectral content of the Spiral gradients, unlike EPI, overlaps significantly with the 0-25Hz band. Owing to the sheer magnitude of the artifacts, when there is spectral overlap between the fMRI gradient waveforms and the EEG bands of interest, it is possible that sophisticated signal processing methods may still leave behind traces of the artifact that are not visually apparent but important in studies which invoke temporal statistics. (e.g. Artifactual high coherence estimates in Functional connectivity studies using EEG). Hence, modifications to pulse sequences such that the gradient spectra do not overlap with the 0-100 Hz band, but achieve the same fMRI image quality should be considered for multimodal EEG-fMRI imaging.

4 References: [1] Bernstein et al., Elsevier, ISBN:0-12-092861-2, 2004, [2] Stehling et al., Science 254:43-50, 1991 [3] Noll et al., JMRI 5(1):49-56, 1995 [4] Allen et al., NeuroImage 12:230-239, 2000 [5] Niazy et al., NeuroImage 28 3:720-737, 2005.