Quality of Single-Trial Discrimination in Simulataneous EEG/fMRI

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Objective:

Simultaneous EEG/fMRI has the potential to yield high resolution spatio-temporal information about brain function. However, because of the low signal-to-noise and signal-to-inference ratios of these imaging modalities, most EEG and fMRI analysis methods estimate relevant activity through trial or event-locked averaging. However, averaging places a limit on the utility of EEG/fMRI, as it does not permit assessment of inter-trial variability critical for understanding the relationship between neural processing and variation in behavioral responses. Single-trial variability may arise as a result of changes in attention, adaptation, or habituation, as well as changes in the recording environment. Our group has developed single-trial EEG analysis based on linear discrimination [1,2] which enables one to relate response variability across trial/stimulus presentation to the underlying electrophysiological variability [3,4]. In this study, we assess whether EEG acquired simultaneously with fMRI is of high enough quality to allow use of such single-trial techniques.

Methods:

To assess the effect of the MR radio-frequency pulses, and static and magnetic fields on the EEG, data was acquired on 10 healthy adults for an auditory oddball paradigm (80% standard=350Hz, 20% target=500Hz, 85dB at headphones, ISI 2-3s) both inside (IS) and outside (OS) the MRI scanner. In the OS condition, subjects remained on the scanner gurney but were moved outside the 5 Gauss line and sounds of the fMRI sequence (Philips 1.5T, TR/TE 3000/50 ms, 3.125x3.125x8 mm voxels, 15 slices), matched for dB, were played over speakers. EEG was acquired using a custom-built magnet-compatible system [5] with 36 EEG electrodes, EOG, and ECG, with analog to digital sampling synchronized to the scanner clock with each TR. Gradient artifacts were then removed from the IS data by subtracting the average across TRs. A 10 ms median filter was applied to eliminate the minimal remaining RF artifacts. As in our standard EEG processing, a software based 0.5 Hz high pass filter was used to remove DC drifts and 60 Hz and 120 Hz (harmonic) notch filters are applied to minimize line noise artifacts. Ballistocardiogram (BCG) artifacts were estimated by finding the first two principal components across bipolar EEG channels that were low-pass filtered at 4 Hz. The sensor weights derived from PCA were then applied to EEG not filtered at 4 Hz, and this BCG estimate projected into each electrode and subtracted from the data.

Results:

Figure 1A demonstrates removal of MR induced artifacts in the EEG (BCG + gradients). Using our post-processing algorithms, we were able to reduce the average total artifact power at the artifact frequencies (1, 5, 10, 15, 20, and 40 Hz) by more than 95% across all 10 subjects. Next, maximum difference between activity for targets and standards was calculated on a single-trial basis using a linear discriminator based on logistic regression [1,2], and ROC results (including area under the curve (Az) for each 50ms discrimination window, calculated via leave-one-out (LOO)) compared for IS and OS data. Single-trial target vs. standard discriminability for IS data from 0 to 1000 ms post stimulus (in 50-ms increments) was 94% of that for OS data (Fig. 1B). During the physiologically relevant interval for this experiment (250-500ms, time of the P300) the ratio of inside to outside the scanner Az was 95%.

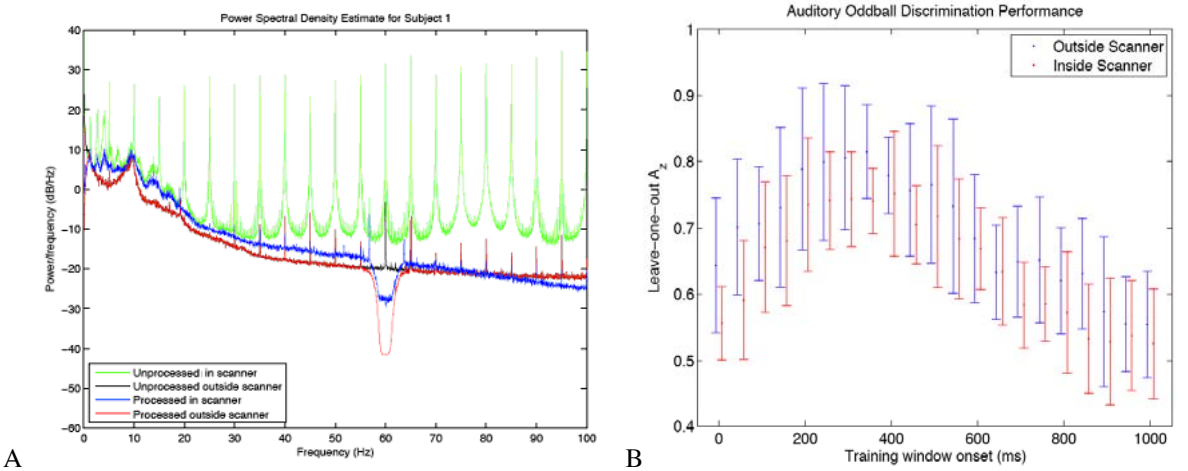

Figure 1. (A) Example power spectrum of the EEG acquired outside the scanner but before filtering (black), outside the scanner after filtering (red), inside the scanner before filtering (green), and inside the scanner after artifact removal (blue). (B) Leave-one-out (LOO) A_z's for single-trial discrimination of targets vs standards outside (blue) and inside (red) the scanner.

Conclusions:

EEG recorded in the adverse environment of the MRI scanner can be of high enough quality to use single-trial analysis methods to assess trial-to-trial variability in the EEG. This single-trial variability can potentially be useful as input for fMRI analysis to localize the underlying generators of the EEG variability.

References & Acknowledgements:

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