Single-Trial EEG Discriminant Components Acquired During 3T fMRI

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Introduction

We previously demonstrated that single-trial variability (STV) of EEG components recorded simultaneously with 1.5T fMRI can yield task-relevant BOLD activations that are unobservable using traditional fMRI analysis methods [1]. A higher field MR system provides greater SNR of the fMRI BOLD signal, and it enables acquisition of functional images with increased resolution in both time and space. However, this comes at the cost of reduced SNR in the EEG due to increased magnitude of gradient, BCG, and motion artifacts. Since our STV method [1] depends upon high fidelity EEG, a major concern was loss of statistical power in the BOLD correlates due to reduced discrimination of EEG acquired during 3T scanning.

Methods

Seventeen subjects participated in a standard auditory oddball paradigm, during which we acquired data using our custom-built 43-channel EEG system [1] in a 3T Philips scanner. After performing gradient artifact removal and standard EEG preprocessing offline, we utilized our logistic regression classifier with the sliding window technique [2]. For both stimulus-locked and response-locked epochs, we selected 50 ms training windows with varied onsets. Area under the ROC curve (Az) with leave-one-out cross validation was used to assess classifier performance.

We performed bias field correction on all images to adjust for artifacts caused by the EEG wires, and then we performed standard filtering and motion correction on the 3x3x4 mm functional EPI data. We first ran a traditional fMRI analysis, using event-related average response and response time variability regressors in our GLM. For the STV fMRI analysis, we modeled the variability of the neural response using an additional two regressors - one each for targets and standards. The regressor height was modulated using the classifier output for each trial, which is interpreted to represent the subject's internal attentional state (i.e. task engagement) during that trial. We used a randomization technique [3] to correct for multiple comparisons by determining a p=0.01 cluster threshold specific to our data set.

Results

We were able to discriminate oddball vs. standard EEG trials at a higher Az level than our prior results [1] and found a similar double-peaked temporal pattern of discrimination (Figure 1). Stimulus-locked performance peaked at 225 ms (Az=0.84) and 375 ms (Az=0.81). Response-locked classification yielded even higher Az values, with peaks at 25 ms (Az=0.93) and 150 ms (Az=0.89).

Our traditional fMRI results were consistent with previous findings [4], showing widespread activations throughout cortical and subcortical structures. In the EEG-based analysis, we found significant positive and negative BOLD correlations in multiple windows (see Figure 1). Most notably, we found bilateral occipital negative correlations for the response-locked 150 ms window (Figure 2). This is consistent with our previous result that found right occipital negative correlations in the same window. Our right occipital cluster exceeded our previous result in both voxel size (440) and max z-score (3.51) but did not spatially overlap with it. However, this repeated finding that visual areas are negatively correlated with endogenous auditory attention further supports our hypothesis of cross-modal latent attentional modulation [1].

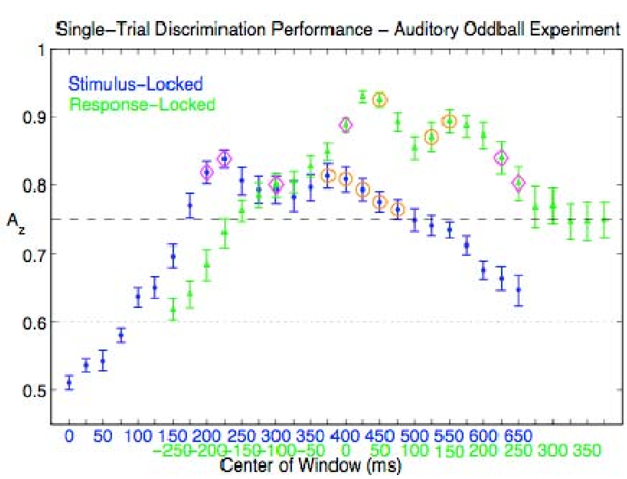

Figure 1 (left): Group averages and standard errors of EEG discrimination performance for both stimulus-locked (blue) and response-locked (green) analyses. The dotted line represents p=0.01 significance as determined by a bootstrapping method. The fMRI analysis was run for all EEG training windows exceeding a group mean Az value of 0.75 (dashed line). Windows with significant fMRI BOLD correlations are specified with orange circles (negative) and magenta diamonds (positive).

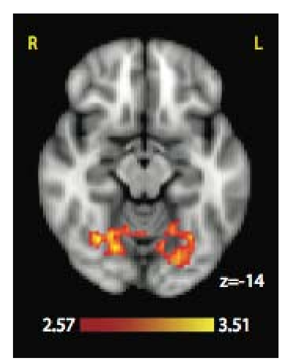

Figure 2 (right): Significant group mean single-trial variability negative BOLD correlations (p<0.01) for the 150 ms response-locked EEG window.

Conclusion

We have demonstrated the feasibility of our previous EEG-fMRI STV analysis methods in the more challenging environment of the higher-field 3T scanner. We were able to discriminate the EEG with greater accuracy than our previous results, despite the decreased SNR of the EEG signal. The increased fMRI SNR improved BOLD correlations, resulting in larger clusters with higher peak z-scores.

References
(1) Goldman et al. (2009) *Neuroimage*, **27**:136-147. (2) Parra et al. (2005) *Neuroimage*, **28**:326-341. (3) deBettencourt et al. (2011) *Frontiers in Psychology*, **2**:91. (4) Stevens et al. (2000) *Magnetic Resonance Imaging*, **18**:495-502.