The use of simultaenous EEG and fMRI to investigate the correlation of BOLD responses and the P300

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Introduction:

Simultaneous EEG-fMRI provides a powerful tool to study evoked activity due to the high temporal and spatial resolution of the complementary techniques. In this study an oddball paradigm is used to elicit a P300 potential. The P300 is widely believed to be a neural signature of both attention and working memory of task-relevant stimuli [1]. Many factors affect the amplitude and latency of the P300 such as the oddball probability and inter-stimulus-interval (ISI) [2] and the target-to-target interval (TTI) [3, 4]. This study investigates the effect of TTI on fMRI BOLD amplitude and oddball P300, both ERP amplitude/latency and EEG spectral power being analysed, to explore correlations between BOLD amplitude and the P300.

Methods: The paradigm was initially tested on three subjects using EEG outside of the scanner to investigate the effect of the TTI on the ERP P300, and to determine the optimum method of subject response to the oddball (count vs button press). Five healthy volunteers with no known neurological disorders then performed simultaneous EEG and fMRI. All subjects gave written consent.

Paradigm: An auditory oddball paradigm with 91 % non-target stimuli (1979 Hz tones) and 9 % target stimuli (36 tones, 2095Hz) was used. Stimuli were generated using Presentation (http://www.neurobehavioralsystems.com/software/presentation) and delivered to the subject via MR-compatible headphones in a pseudorandom order. Target-to-target interval (TTIs) of 8.8, 15.4, 19.8, 35.2, 39.6, 50.6 s were used and the ISI between tones was 2.2 s. All participants reported they could clearly discriminate the stimuli from background scanner noise. Participants were asked to silently count target tones with their eyes closed as the initial experiments showed this increased the amplitude of the ERP (count ERP amplitude 11.3 μV; button press ERP amplitude 8.8 μV). Prior to the task, each participant performed a practice block of trials.

EEG Recording and Analysis: EEG data were recorded on a MRI compatible 32 Ag/AgCl channel brain vision recorder (Brain Products, Munich, Germany) placed on the scalp according to the 10-20 international system; electrode skin impedance was kept less than 10 KOhms. Data were collected with a sampling rate of 5 KHz and processed using Brain Vision Analyzer software (Brain Amp, Brain Products, Munich, Germany). Cardio-ballistic pulse artefacts in the EEG traces were corrected using the ECG electrode and the vector cardiogram (VCG) from the MRI scanner, and MRI artefacts were detected and corrected with the EEG software. To investigate the correlation between the ERP and TTI data was binned into six groups according to the TTI. To study the effect of TTI, the P300 ERP amplitude and latency was assessed, as well as the ERP spectral power using a Morlet complex (range 1-45 Hz) Wavelet transform (WT). Data from Analyzer was also imported into SPM5 and the evoked response source localised using the fMRI locations as location priors.

fMRI Acquisition and Analysis: Data was acquired on a Philips 3 T Achieva scanner using a SENSE head RF coil. 14 transverse GE-EPI images [64 x 64 matrix size, echo time (TE) of 35 ms, and 3 x 3 x 6 mm voxel size] were acquired every 1 s throughout the fMRI paradigm. Functional MRI data were acquired in six sessions in a 3 hour period, each session took 17 minutes. Cardiac and respiratory data were simultaneously recorded using the VCG monitoring system and respiratory belt. fMRI data was corrected for physiological noise using RETOICOR and then was analysed in SPM5. Data was corrected for slice timing, realigned, normalised to MNI space, and spatially smoothed with 5 mm Gaussian kernel. Statistical parametric maps were then generated by modelling the 'targets' versus the standard 'non-target' stimuli which was used as the baseline condition Activation maps were threshold at $p < 0.001$ uncorrected. Data was analysed per TTI and correlations between BOLD amplitude and TTI investigated.

Results: All subjects showed the expected fMRI and ERP P300 responses. fMRI data for the 'target' versus 'non-target' tones showed activation in anterior cingulate, insula, prefrontal cortex, and parietal cortex. In these areas an increase in BOLD activation in correspondence to TTI was found for all subjects. Figure 1 shows the BOLD response to the 8.8 s and 35.2 s TTI. Figure 2 shows the averaged P300 potentials and spectral analysis for (A)' target' and (B) 'non-target' tones. Delta (1-4 Hz) and theta (4- 8 Hz) bands showed significant increase in power for the 'target' tones (Figure 2A and B).

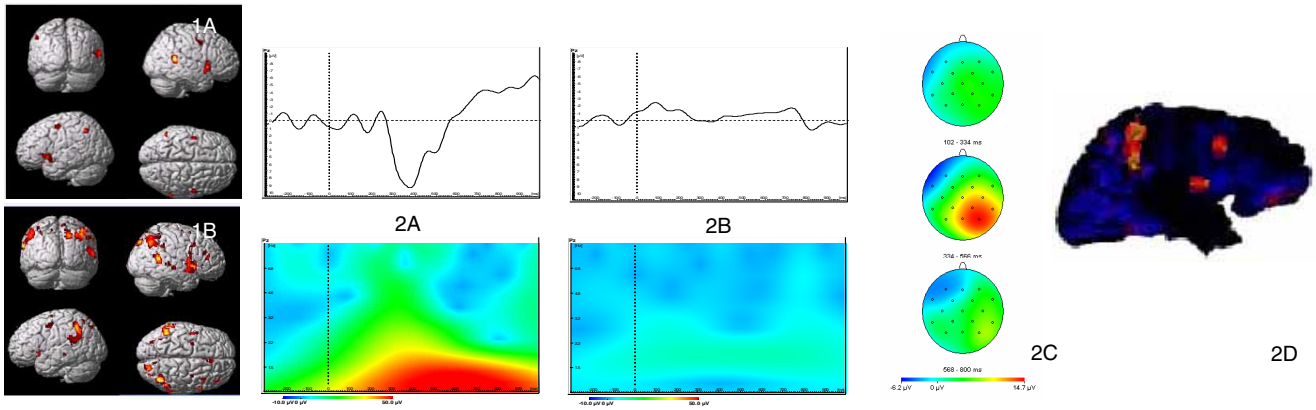

Figure 1: SPM for 'target' versus 'non-target' at TTIs of (A) 8.8 s and (B) 35.2 s. Figure 2: Channel Pz ERP response and corresponding WT analysis (1-10 Hz) for (A) 'targets' and (B) 'non-targets' inside the scanner (C) Scalp topography of 'target' ERP signals (D) Evoked response source localisation.

A trend of increasing ERP amplitude with TTI was found for data collected outside of the scanner. However this effect was not seen in all subjects for simultaneously acquired EEG/fMRI data (5.7 μV at 8.8 s; 10.1 μV at 35.2s) and no clear trend with TTI was observed in the spectral analysis.

Discussion: We have shown reliable P300 data and fMRI results in response to an oddball task using combined EEG and fMRI, and have source localised the evoked response. Increased TTI has been shown to result in increased BOLD amplitude in all subjects. However for the ERP data a trend with TTI was not found across all subjects and was not seen in the power analysis. This may arise due to the additional filtering of the EEG data in the MR scanner resulting in this effect being difficult to detect, together with the small number of trials for each stimulus. Future analysis will involve performing a group analysis of the data to improve power with which to detect TTI effects.

References

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Acknowledgments: This work was funded by an MRC/EPSRC grant.