The fMRI BOLD Response Co-varies Spatially and Temporally with Electrical Oscillatory Change and a Sustained Electrical Response

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Introduction: The fMRI BOLD response is driven by the increased energy demand due to increased neuronal activity. Furthermore, this energy demand is believed to originate largely from postsynaptic events (1). The neuromagnetic fields measured in MEG arise from postsynaptic current flow, thus it may be postulated that the MEG signal should provide insight into the cause of the BOLD effect. Much of the MEG literature is concerned with spatially specific changes in oscillatory power in some given frequency band (2) and in a recent study (3) the spatial location of the reduction in oscillatory power (or desynchronization), identified using Synthetic Aperture Magnetometry, (4) was shown to have a striking similarity with the spatial location of the BOLD response. In this study we investigate similar phenomena for a visual stimulus, and show that the BOLD response is not only a spatiotemporal covariate of oscillatory power change but also of a sustained field response.

Methods: FMRI data were obtained using a 3T MRI scanner, with custom-built gradient coil and a whole head TEM RF coil. MBEST EPI images were collected from 10 continuous coronal slices at the back of the head (TE=40ms, TR=100ms, matrix size 64x64, voxel size 4x4x6mm^3). Images were processed using standard techniques in Spm99 (6); co-registration of the resulting SPM's onto anatomical images was achieved using AIR registration in Medx.

MEG data were recorded using a 151 channel CTF Omega system with a sample rate of 625Hz. In order to spatially map stimulus related oscillatory power changes Synthetic Aperture Magnetometry (4) was applied to the raw data. To map the spatial distribution of a sustained field effect, the MEG beamformer approach (5) was used in conjunction with the general linear model (6) to create volumetric T-statistical images.

In both fMRI and MEG studies, subjects were presented with a full field visual stimulus, (a static checkerboard). Each fMRI experiment comprised 10 trials, each trial consisting of 2s baseline followed by 5s stimulus presentation and 18s rest period. The MEG experiment consisted of 40 trials, each with a 2s baseline, 5s presentation and 7s rest period. A longer rest period was used in fMRI to allow for the haemodynamic response to decay back to a baseline state.

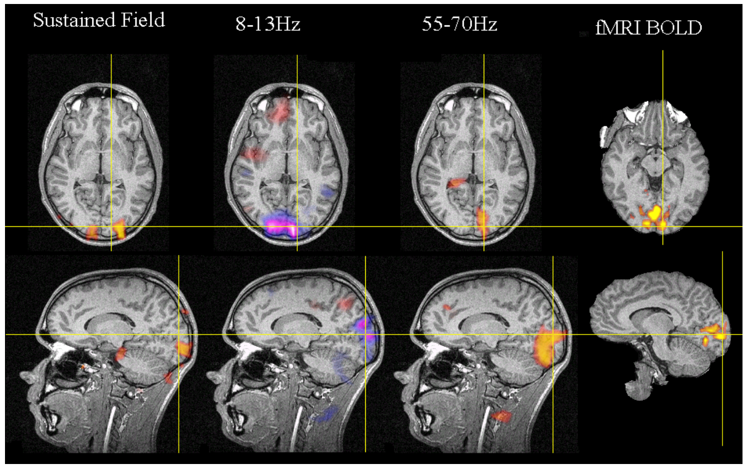

Figure 1:- The spatial distribution of the sustained field, the 8-13Hz desynchronization, the 55-70Hz synchronization, and the BOLD response.

Results and Discussion: Four normal volunteers took part in the study; typical results from a single subject are given here. Figure 1 shows the spatial distribution of the BOLD effect (to a corrected p-value of 0.05), 8-13Hz-desynchronisation (Thresholded at T=3), 55-70Hz-synchronization (Thresholded at T=0.5), and the sustained field (Thresholded at T=3). Figure 2 shows the time course of the sustained field, together with the Hilbert transform of the 8-13Hz desynchronization, and 55-70Hz synchronization. The Hilbert transform gives the instantaneous amplitude of oscillatory activity in the frequency band of interest, thus allowing the envelope of this band passed activity to be plotted against time.

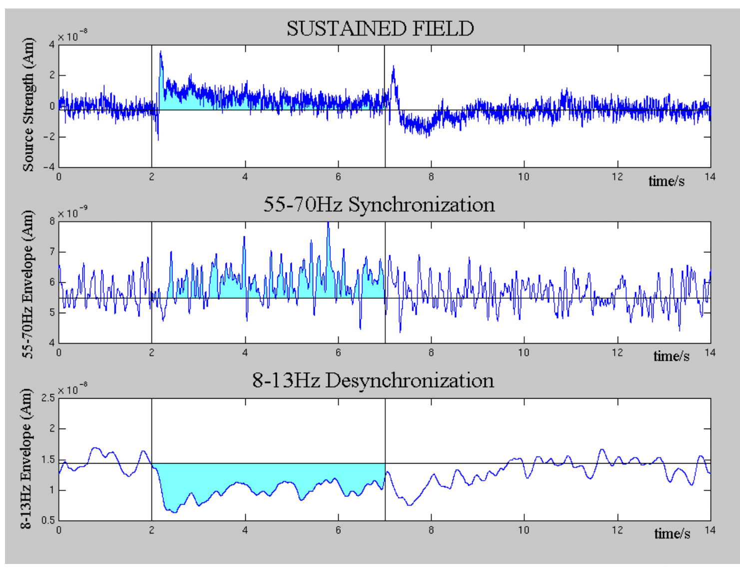

Figure 2:- Time courses showing source amplitude of a virtual electrode. for the sustained field, 55-70Hz synchronization and 8-13Hz desynchronization.

Loss of oscillatory power in a specific frequency band is thought to be a correlate of increased neuronal activity (2), and hence spatiotemporal covariation with the increased metabolic requirement reflected in the BOLD response is expected. (3) Interestingly, our work demonstrates the presence of a visual sustained field in MEG similar to that previously observed in somatosensory (8) and auditory (9) cortex. We show that this visual sustained field is also a spatiotemporal correlate of the BOLD response. Such sustained fields are thought to be caused by either a sustained cortical input, or the summation of asynchronous firing of neural networks. Either explanation is plausible and such sustained fields may make a significant contribution to the increased energy requirement and hence to the BOLD signal. Our results also depict a weak synchronization of 55-70Hz oscillatory activity, which is again in agreement with recent findings (7).

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