

Simultaneous EEG & fMRI: Positive Correlations to Frontal Theta Power

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Introduction: Electroencephalographic (EEG) oscillations in the theta band (3-8Hz) along the frontal midline have been found to scale with cognitive demand in working memory tasks in humans [1], typically being attributed to either anterior cingulate cortex or other medial frontal sources. Studies of EEG theta power measured simultaneously with fMRI acquisitions have found negative correlations between BOLD signals in default mode regions and frontal midline theta power in the resting state and during performance of the Sternberg working memory task [2]. However the location and functional significance of positive BOLD correlates of theta power remain unclear. In particular the relationship between hippocampal BOLD signals and frontal theta power remains unresolved. The purpose of this study is to use fMRI to further investigate BOLD signals positively correlated with frontal theta power measured simultaneously with surface EEG.

Methods: [Image Acquisition] Data were gathered on five subjects during performance of a blocked designed verbal identity N-back task, alternating between 0 back and 2 back conditions (30s/block, 4 blocks/run). BOLD sensitive images were acquired on a Philips Acheva 3T MRI scanner with an eight channel receive coil (TR/TE/sense factor = 2s/35ms/1.8, 2.5x2.5x3.5mm voxels, full cerebrum coverage). [EEG acquisition] Data were gathered simultaneously with image acquisition using a 64 channel Neuroscan MagLink cap in combination with Synamps2 signal amplifiers. Signals were acquired at 10kHz sampling. All EEG signals were corrected for gradient and balisto-cardiogram artifacts. [Analysis] A time course representing theta power was created by separating each electrode's signal into segments coinciding with each image volume. The average time course from all frontal electrodes was calculated, and the average power within the theta band was measured for each epoch, yielding a time course of theta power that was then convolved with a canonical hemodynamic response function for use in a general linear model analysis of the imaging data. All fMRI data were analyzed by correction for slice timing and motion artifacts, normalization to the MNI template, and spatial smoothing using an 8mm Gaussian kernel. The six estimated motion parameters, the global fMRI time course across the entire brain, and the average theta power across all frontal electrodes were entered into each individual subject's model, yielding maps of activation related to each subject's own theta power time course. These maps were then entered into a second level analysis for group effects of changes in theta power, the results of which are summarized in Figure 1.

Results: Significant positive correlations between frontal theta power and BOLD signals were found in several regions across the brain, including the left hippocampus, and bilaterally on the central sulci.

Discussion: These results identify positive correlates across the brain to theta power measured in a working memory task. Furthermore, these results suggest a direct relationship between frontal theta power and hippocampal activity in the context of the verbal identity N back task, though it remains to be seen whether this relationship is related to the working memory intensive portion of the task (2 back condition), the memory recall portion of the task (0 back condition), or to the switching between the two. Secondly, these results provide supporting evidence that there may be multiple, distributed regions potentially contributing to the production of frontal theta power measured on the scalp, complicating accurate dipole source modeling. Consistent reports of dipole locations in anterior cingulate cortex may have their underlying assumptions violated when there are widespread generators (like bilateral motor cortex) combining their contributions to produce a superficial field, a point alluded to by [3].

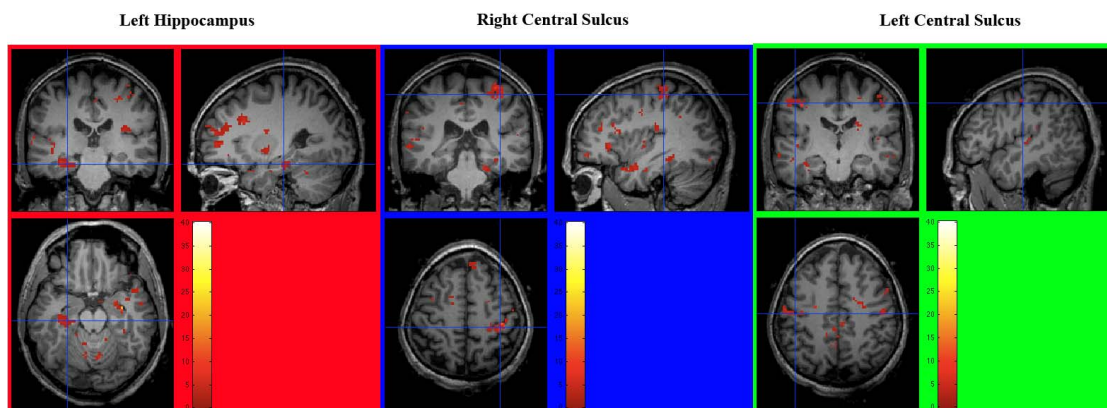


Figure 1: Group maps of activation related to changes in theta power. Significant correlations ($p < 0.05$ uncorrected, min. cluster size = 20vox) were found in the left hippocampus, and along bilateral central sulci.

References: [1] Gevins et al. 1997. Cereb Cortex 7(4):374-85. [2] Scheeringa et al., 2008. Neuroimage doi 10.1016/j.neuroimage.2008.08.041 [3] Mitchell et al., 2008. Progress in Neurobiology, doi 10.1016/j.pneurobio.2008.09.005

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