

## Searching for the source of alpha rhythm: EEG-triggered fMRI at 4T

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**Objective:** EEG-triggered fMRI is a technique that allows monitoring of the EEG activity (e.g., alpha rhythms) while subjects undergo functional MRI. EEG alpha rhythm is the mainstay of monitoring vigilance and arousal states. However, the source of the EEG alpha rhythm found predominantly in occipital scalp EEG leads is unclear. Several studies report thalamus or other, cortical structures as its source. The aims of this study were to establish scanning parameters for EEG-triggered fMRI at 4T and to localize alpha rhythm generators in healthy subjects using this technique.

**Material/Methods:** 6 healthy adults (ages 18 to 43) underwent simultaneous EEG and fMRI (4T Varian Unity INOVA MRI system). We collected 64 channels of EEG using MRI-compatible EEG system that was modified for this purpose and Scan 4.3.1 software (both Compumedics Neuroscan) during a simple eyes closed rest. Scan 4.3.1 was used to remove Echo Planar Imaging (EPI) artifacts. Concurrently to EEG, we collected fMRI data using a T2\*-weighted spin-echo EPI pulse sequence (TR/TE = 3000/45ms, FOV = 25.6x25.6cm, matrix 64x64 pixels, slice thickness = 4mm, flip angle = 90°); NR = 400. A reference time course file was generated based on the EEG where alpha background was coded as 1; no alpha background as 0; artifact as -1. We analyzed fMRI data using Cincinnati Children's Hospital Image Processing Software (CCHIPS). Baseline drift correction was performed using a quadratic baseline correlation on a pixel-by-pixel basis. Cross-correlation values were computed on a pixel-by-pixel basis from series data correlated with boxcar reference waveform. BOLD signal changes calculated this way (all  $r \geq 0.3$ ) were superimposed on a structural image ( $T_{MD}=1.1$  s, TR=13 ms, TE=6 ms, FOV=25.6 x 19.2 x 19.2 cm, matrix 256 x 192 x 96 pixels, flip angle=20 degrees).

**Results:** EPI artifact removal was successful in all scanned subjects (Figure 1). Major area of negative correlation with posterior dominant alpha rhythm was noted in the occipital regions (Figure 2 - top). This corresponds to gyrus lingualis and radiation optica (Brodmann areas 17 and 18) with centroid on the left:  $x=8, y=-74, z=-2$ . Major areas of positive correlation with posterior dominant alpha rhythm are noted over posterior nucleus caudatus and anterior thalamus (with centroid on the left:  $x=9, y=1, z=8$ ; Figure 2 - middle), and over precuneus and lobulus parietalis superior (with centroid on the left:  $x=14, y=-31, z=55$ ; Figure 2 - bottom). Small area of activation is also noted over the right frontal convexity – Figure 2, bottom.

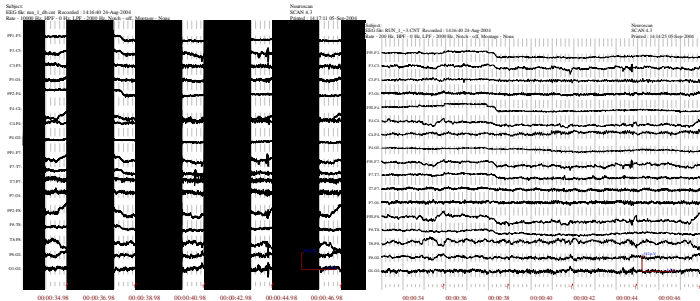


Figure 1. An example of EEG data collected during EEG-fMRI procedure at 4T; 64 channels referential montage was converted to 16 channels standard "double banana" bipolar montage. Left part of the figure shows an uncorrected EEG with fMRI EPI artifact obscuring parts of the EEG activity. On the right, a corrected EEG is shown (EPI artifact removed using Scan 4.3 software) without further processing (BCA was not removed). Alpha background is noted on both pictures (on the left picture between the artifacts related to the EPI pulse).

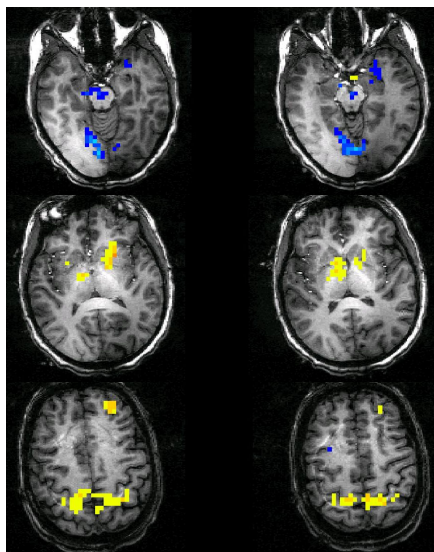


Figure 2. Results of the EEG-fMRI in a single subject (same subject as Figure 1): Activation map showing areas of BOLD signal changes in response to spontaneous alpha pattern changes. All pictures are in neurological convention (left on the picture = left side of the brain).

**Conclusions:** This is a first report describing successful use of the EEG-triggered fMRI technique at 4T. Our findings are in agreement with previous PET and EEG-fMRI studies showing positive and negative alpha rhythm correlations in the cortical and subcortical structures. Positive BOLD signal changes in the basal ganglia with concurrent negative correlations between alpha rhythm and BOLD signal in the occipital head regions suggest that the alpha rhythm generators (oscillators) are localized in the basal ganglia while the neocortical synchronization in the occipital head regions is a result of afferent connections between thalamus and occipital cortex. Correlations in frontal and parietal regions are most likely related to spontaneous fluctuations in attention that are expressed as loss of alpha activity on scalp EEG