Thalamic and Cortical Substrates of Large-Scale Alpha Oscillations Assessed with Simultaneous EEG-fMRI

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INTRODUCTION

Large scale signal correlations are observable in both BOLD and EEG/MEG measurements of human brain activity. These two forms of **synchrony** reflect the hemodynamic and electrophysiological signatures of underlying neuronal circuitries, respectively. However, their relationship and respective role to brain functions remain to be fully investigated.

The **alpha** (8-12Hz) rhythm is the most dominant and widespread oscillatory activity in the resting brain. The power of alpha rhythm fluctuates spontaneously in absence of any explicit stimulus or task, or can be modulated by opening/closing the eyes. The spatiotemporal characteristics of inter-regional alpha-power correlations resemble those of functional connectivity observed with resting BOLD fluctuations [1].

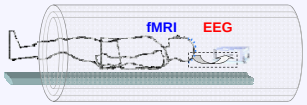
In this study, we conducted **simultaneous EEG-fMRI** recordings to address the following questions.

1) What are the thalamic and cortical regions responsible for the spontaneous and induced power modulations of the alpha-band EEG measured over the visual cortex?

2) Are the BOLD-correlates to the visual-cortex alpha-power modulation confined to the thalamic and cortical components of the visual system?

3) Can we find functional connectivity with resting-state BOLD-fMRI between these thalamic and cortical regions related to alpha-power modulations?

METHODS AND MATERIALS



3T GE Signa System
GRE-EPI (16-coil array, 30 4mm axial slices, rate-2 SENSE, FOV=220x165 mm², matrix=64x48, TR/TE=1.5s/30ms, flip angle=90°)

BrainAmp MR Plus
32 Channels (<10 kΩ impedance, 5kHz sampling synchronized with MRI master clock, referenced to FCz, filtered from 0.5 to 70Hz)

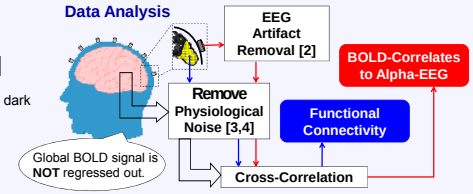
Experimental Paradigm

1) **STIM**: Visual Stimulation with Fixation Task

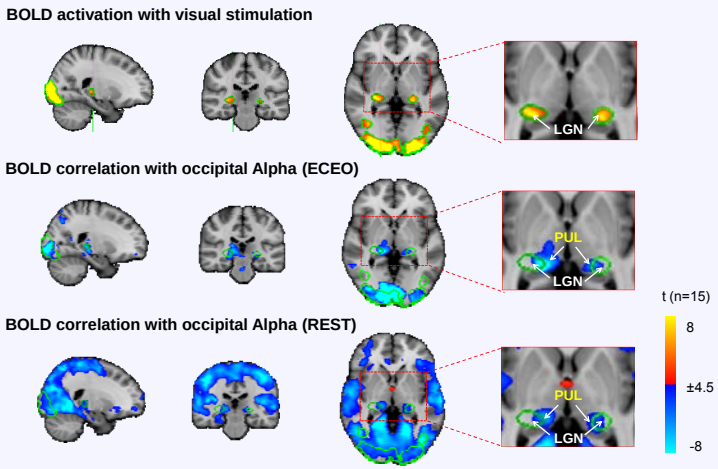
2) **ECEO**: Voluntary Eyes-Closed-Eyes-Open in dark

3) **REST**: Continuous Rest with Eyes Closed

Data Analysis



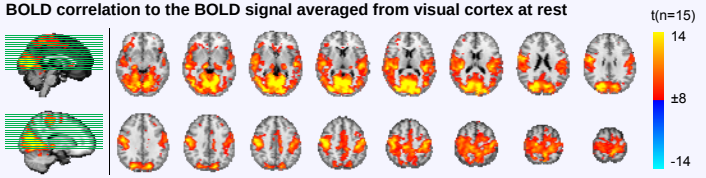
Negative Correlation between BOLD signals at Pulvinar and Alpha Power from Visual Cortex



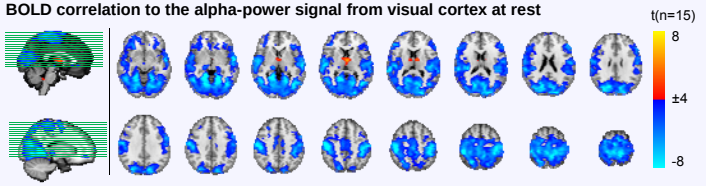
(Group analysis based on data from 15 subjects)

Negative BOLD-Alpha Correlation Coincides with Positive BOLD-BOLD Correlation

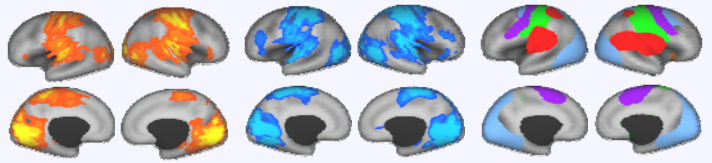
BOLD correlation to the BOLD signal averaged from visual cortex at rest



BOLD correlation to the alpha-power signal from visual cortex at rest



BOLD-BOLD **BOLD-ALPHA** **Locations of Sensory Modalities**



(Group analysis based on data from 15 subjects) Visual Auditory Motor Somatosensory

Discussion

❖ **Inferior thalamic nuclei in pulvinar are recruited for alpha-power modulation over the visual cortex [5]**

- o Negative thalamic BOLD-alpha correlations occur more medial and inferior relative to LGNs, which relay retinal inputs to visual cortex and are activated by visual stimulation.
- o These negative thalamic BOLD-alpha correlations are more likely at the inferior pulvinar, which also connects to visual cortex and may regulate visual processing.

❖ **Intra-laminar thalamic nuclei are recruited for global alpha-power modulation [6]**

- o At rest, positive BOLD-alpha correlations occur at intra-laminar thalamic nuclei, which are the thalamic components of ascending reticular activating system [6] and have non-specific connections to the entire cortex.

❖ **Resting-state BOLD correlations to alpha-power modulation and BOLD-BOLD correlations reveal consistent cortical locations, but with opposite polarity in correlation coefficient**

- o Without global signal regression, the BOLD signals from all sensory cortices (including visual, motor, somatosensory and auditory systems) are correlated positively with the BOLD signal from the visual cortex, but negatively with the alpha power from the visual cortex.

Conclusion

The power modulation of alpha rhythm arises from both specific and non-specific thalamic and cortical substrates. Pulvinar-cortical connections contribute to the alpha modulation within the visual system. Non-specific intralaminar thalamocortical connections contribute to global alpha modulation occurring through all sensory systems. Such specific and non-specific alpha modulations partly account for functional connectivity observed with resting BOLD-fMRI.

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6. Steriade, Science, 1996; 272: 225-226.

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