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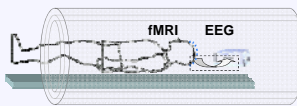
Introduction

Presentation of a visual stimulus may lead to two distinct changes in neural activity, one reflecting processing of information specific to the stimulus, the other reflecting changes in spontaneous activity. These changes, referred to as **evoked response** and **induced response** respectively, do not necessarily involve the same neuronal populations. In conventional BOLD-fMRI studies, the combined effect of both evoked and induced responses is revealed as **activation**, whereas their individual contribution is very difficult to assess with fMRI alone.

We aimed to separate evoked and induced neural and vascular responses to visual stimulation by using EEG-fMRI

We simultaneously acquired EEG and fMRI data while visual stimuli were presented at a very specific temporal frequency. Such frequency specificity allowed us to effectively tag the evoked neural response with the stimulus frequency (SF) so that the change of EEG power at SF could be used to extract the time course of the evoked response. We extracted the time course of spontaneous brain activity as the power fluctuation in the **alpha** band (8-12 Hz), which is the dominant frequency feature of spontaneous EEG. By fitting the BOLD signal change with both time courses, we set out to investigate the spatial locations of the evoked and induced responses in the entire brain.

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

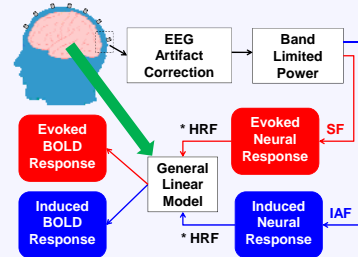


For determining individual alpha frequency (IAF)

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

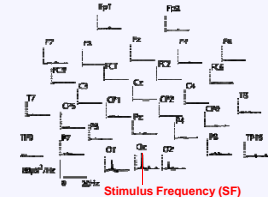


Temporal frequency = 5.95 Hz

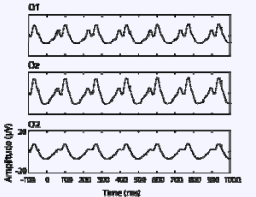


Frequency tagging: providing a frequency marker for evoked neuronal response

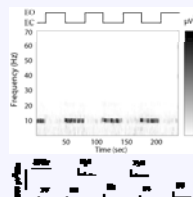
Power Spectral Density (STIM - CTRL)



Steady-State Visual Evoked Potential



Individual alpha frequency

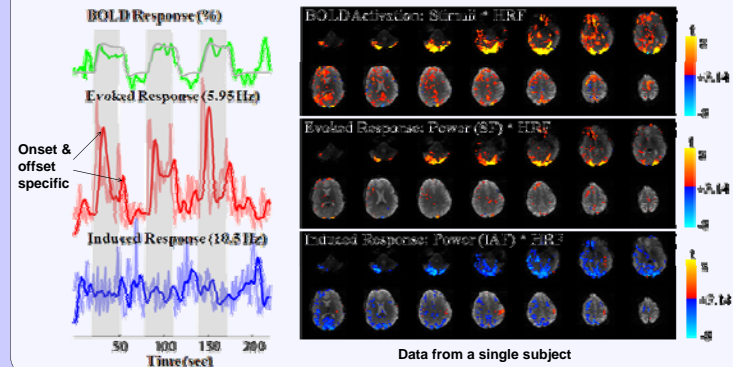


Evoked neural activity has a specific temporal frequency (SF) identical to the repetition frequency of the visual stimulus

The dominant alpha-component of spontaneous neural activity is marked with the IAF determined from the ECEO task

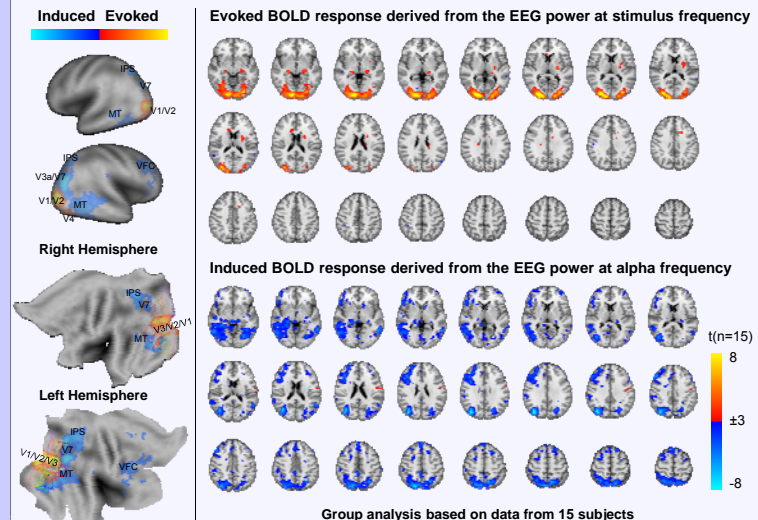


BOLD Activation = Evoked BOLD Response + Induced BOLD Response



Evoked BOLD response is confined to retinotopic regions

Induced BOLD response is located in higher-level visual areas



Conclusion

- The BOLD response to visual stimulation arises from a combination of evoked and induced neural activity
- Simultaneous EEG-fMRI and frequency-tagging techniques can be used to separate the BOLD components corresponding to the evoked and induced neural response
- The time course of the evoked response has a very specific change in relation to stimulus onset and offset, whereas the induced response is less specific
- Spatially, the evoked response is confined to lower-level retinotopic areas, whereas the induced response tends to occur at higher-level visual areas, such as those along the dorsal visual pathway and visual attention network