Spatial and Temporal Characteristics of Evoked and Induced Neural and Vascular Responses Assessed with Simultaneous EEG-fMRI

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Introduction

Presentation of a visual stimulus may lead to two distinct changes in neural activity, one reflecting evoked response and the other induced response. 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

2T GE Signa System
GRE-EPI (16 coil array, 30-mm axial slices, rate-2 SENSE, FOV=220x165 mm, matrix=64x48, TR/TE=1.5/30ms, flip angle=90°)
BrainAmp MR Plus
32 Channels (<10 kΩ impedance, 5kHz sampling synchronized with MRI master clock references 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

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

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

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