EEG-fMRI integration for the study of physiological response to Intermittent Photic Stimulation

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Target Audience: Researchers and clinicians interested in multimodal neuroimaging and visual cortex.

Purpose: The present contribution investigates the physiological response to Intermittent Photic Stimulation through simultaneous EEG-fMRI analysis. Preliminary fMRI studies[1] showed that IPS elicits a complex pattern of positive and negative BOLD changes involving striate and extra-striate visual cortex. While positive BOLD responses (PBRs) are interpreted as activations, the origin of negative BOLD responses (NBRs) is less clear and is matter of discussion in the literature[2,3]. The information on neuronal activity provided by the EEG technique can be the key element in increasing our understanding of the complex fMRI response to IPS and especially of the mechanisms underlying NBRs. In this study, the analysis of fMRI response to IPS is followed by an integrated analysis that investigates the BOLD correlates to EEG power changes at the IPS frequencies.

Methods: Twentyone healthy subjects (9 males, mean age 27.6 ± 2.15 years) took part to the study. The visual stimulation consisted of blocks of IPS alternated with blocks of rest, each lasting seven fMRI scans, where the subjects kept the eyes open. IPS was created by reversing black and white screens at 6, 8, 10 and 12 Hz. Each frequency block was repeated five times, resulting in twenty IPS blocks. The MRI acquisition was performed in a 3T scanner (Philips Achieva, Best, The Netherlands) with a 32 channels head coil. fMRI data were acquired with a T2*-weighted GE planar sequence (TR=2 s, TE=35 ms, flip angle=85°, 30 axial slices no gap, FOV=240x105x240 mm^3, voxel 1.875x1.875x3.5 mm^3). A structural MR image (T1-weighted 3D TFE sequence, voxel 1 mm isotropic, FOV=240x240x175 mm3, TR=8.19 ms, TE=3.74 ms, flip angle=8°) provided a morphological reference for fMRI data. EEG data were recorded simultaneously with fMRI using an MR-compatible EEG system (BrainAmp MR plus, Brain Products, Gilching, Germany) and a 64-channels EEG cap (BrainCap MR, EasyCap GmbH, Breitbrunn, Germany). The fMRI data processing was performed using the SPM software (http://www.fil.ion.ucl.ac.uk/spm/). First, the regions with significant response to IPS in the group were extracted using a 2nd level random-effects analysis (contrast: IPS>/<rest). An EEG-informed fMRI analysis was then performed to study the BOLD correlates to EEG rhythms at the IPS frequencies. After EEG pre-processing, the mean occipital continuous wavelet transforms (Morlet family) at 6, 8, 10 and 12 Hz IPS were convolved with the canonical HRF and used as regressors of interest in a fixed-effects GLM analysis with a unique design matrix for all subjects.

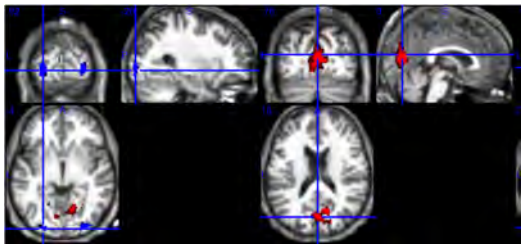

Figure 1. *Regions with significant positive (red) and negative (blue) BOLD response to IPS (p<0.05, FWE)*

Results: The regions with significant fMRI response to IPS (p<0.05, FWE corrected) are shown in Fig.1: the PBR included Lingual Gyrus, Intracalcarine Cortex, Supracalcarine Cortex, Cuneal Cortex and Occipital Pole, while the NBRs were located in inferior Lateral Occipital Cortex, Occipital Fusiform Gyrus and Occipital Pole. The regions with significant fMRI response to EEG power changes at the IPS frequencies (p<0.001) are shown in the left panel of Fig.2. The ROIs responding to 6, 8 and 10 Hz power variations showed no evident coupling with the ones responding to IPS. The increase of EEG power at 12 Hz, concomitant to IPS, elicited the negative response of two regions that largely overlap to the ROIs exhibiting NBR to IPS. The mean BOLD signals of these ROIs in one exemplar subject are plotted in the right panel of Fig.2 together with the 12 Hz power fMRI regressor.

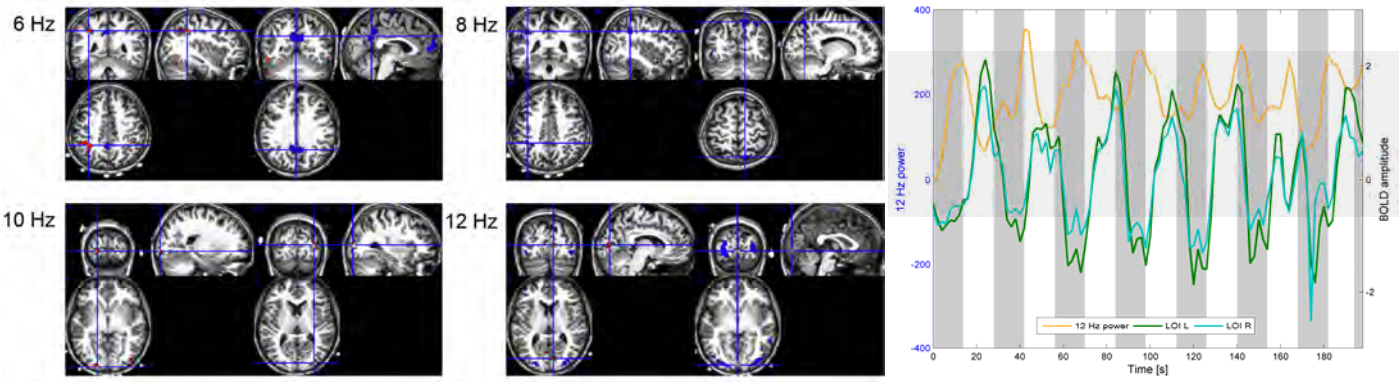

Figure 2. *Left: Regions with significant BOLD response (p<0.001, uncorrected) to EEG power at the four IPS frequencies (positive response: red, negative response: blue). Right: plot of 12 Hz power regressor (orange) and BOLD signal in lateral occipital cortex (left hemisphere in green, right hemisphere in blue) of one exemplar subject. The grey bars indicate IPS blocks.*

Discussion and conclusions: In this work, the integration of EEG and fMRI information has helped in understanding the mechanisms underlying negative BOLD response to IPS. Indeed, the regions with NBR to IPS largely overlapped with the ones responding negatively to EEG power variations at 12 Hz. The increase of 12 Hz power was induced by the visual stimulation and could be the result of a forced adaptation from the basal rhythm to a novel "driven" rhythm. Although these findings need careful interpretation, they pave the way for further studies on neurovascular coupling associated to NBRs.

References:

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