

# Multiple networks for interhemispheric integration in the visual brain: fMRI BOLD response increases with EEG synchronization.

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**Purpose.** Natural images contain a wide spectrum of spatial information, ranging from extremely low to very high spatial frequencies (SF). To encode complex shapes/objects, local descriptions of the retinal image at multiple spatial scales must be integrated across space and pooled across SF components. Here we summarize our fMRI/EEG studies in humans aimed at mapping neural assemblies involved in the Gestalt-based interhemispheric integration of the bilateral stimuli systematically varying in SF.

**Methods.** In separate EEG and fMRI experiments, 13 subjects viewed bilateral sinusoidal black-and-white gratings drifting with a temporal frequency of 2Hz. The stimuli either obeyed Gestalt grouping rules (iso-oriented collinear gratings, IG) or violated them (orthogonally-oriented (OG) and out-of-phase gratings (DG)) in the range of 0.25-8.0 c.p.d.

During EEG recording session, the stimulus order and exposure were randomized. The high surface sampled EEG (128 channels, EEG/ERP system) was submitted to spectral analysis with an emphasis on interhemispheric coherence (ICoh). During fMRI recording session, the stimulus conditions were alternated with background in a balanced-randomized order 5 times 15 s each. Functional MRI images were acquired with an EPI gradient echo T2\* weighted sequence (FA 90, TE 66, pixel size 3.75 x 3.75mm, acquisition time 1.7s) with a TR = 3s. Preprocessing, single subject analysis and group statistics were conducted on SPM2.

**Results.** Stimulation with bilateral iso-oriented collinear gratings synchronized EEG signals interhemispherically in the beta band (20-31 Hz) band. Principal Component Analysis suggested that several independent sources produced narrow-band interhemispherically coherent signals within this band. The bilateral iso-oriented drifting gratings within the range of spatial frequencies (SF) 0.5-4.0 cpd induced interhemispheric EEG coherence peaking at 22 Hz and 28 Hz. These peaks showed non-correlated behavior across SF and distinct spatial distribution over occipito-parietal brain regions. They differentiated the “good-Gestalt” stimulus (IG) from the “bad-Gestalt” stimulus (OG).

The fMRI experiments revealed maximum BOLD response to the gratings at 0.5-2.0 cpd. Within this SF range the low frequency gratings induced higher activation distributed in the striate and extrastriate areas. The interhemispheric integration (IG vs. OG/DG) increased BOLD in ventral and dorsal extrastriate locations. The BOLD response was partly invariant across SF (ventral clusters, bilaterally in the collateral sulcus, Vp, V4) and partly dependent on SF (lingual gyri ventrally and precuneal region of cingulate sulci medio-dorsally). The SF-conditioned part of the response decreased in ventral and increased in (medio-) dorsal locations with SF.

The fMRI BOLD and EEG coherence responses were linearly coupled in extrastriate locations at both SF. The synchronization at different EEG frequencies (22 vs. 28 Hz) correlated with BOLD response in different areas. In particular, correlation maps for the low-beta ICoh response converged in the ventral stream areas (fig.1A), partly overlapping clusters preferably activated by IG stimulus. The correlation maps at the high-beta frequencies were located in the dorsal stream areas (fig. 1B), partly overlapping the BOLD response at 2 cpd.

**Conclusion.** Visual stimuli of various spatial frequencies induce SF-specific pattern of activation and of interhemispheric synchronization in the beta-gamma band. Both fMRI and EEG data suggest involvement of occipital and parietal neuronal networks in the processing of different spatial frequencies. Linear relation between BOLD and EEG coherence suggests that local activation can be boosted by synchronization.

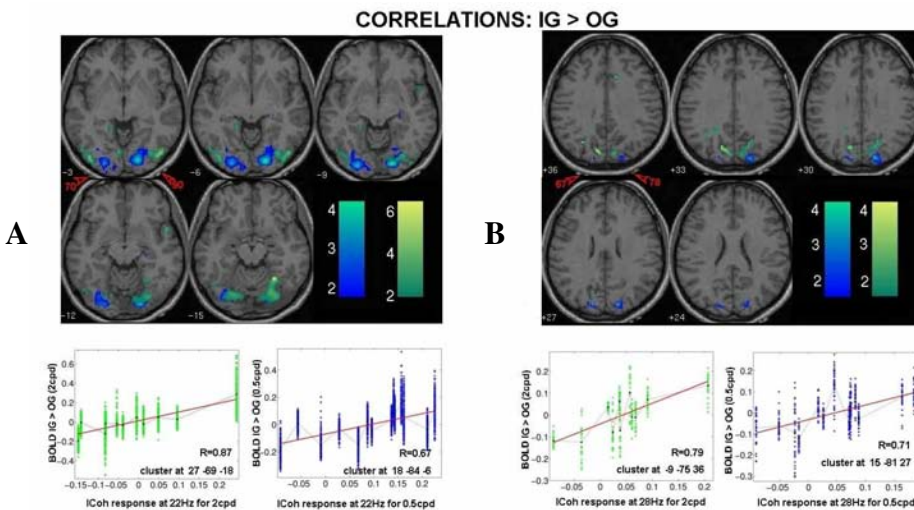


Fig.1: BOLD/EEG coherence correlation maps for the group data. Representative slices (top view) show clusters of voxels with the BOLD response (IG > OG) proportional to the interhemispheric coherence from the 70-90 sensor pair for beta1 frequency (22 Hz, in A), and from the 67-78 sensor pair for beta2 frequency (28 Hz, in B). They are shown using the blue scale for 0.5 c.p.d., and the green scale for 2 c.p.d. condition. The arrows point to the EEG sensor markers.

Scatterplots show individual BOLD responses as a function of ICoh response for all the voxels in 4 clusters representing each statistical correlation map. Blue for 0.5 cpd and green for 2.0 cpd.