fMRI BOLD response corralets with interhemispheric EEG synchronization

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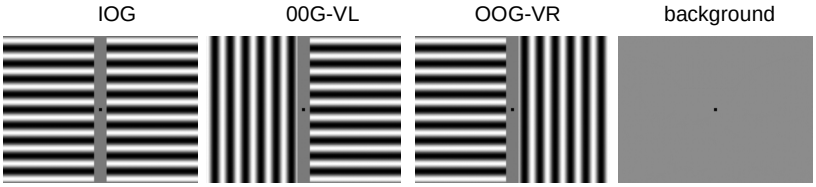
Background

Recent studies showed that the EEG beta-gamma band synchronization (BGS) between distributed cortical sites relates to their anatomo-functional interactions. Currently, only general features of BGS topography are understood due to limitations of the EEG spatial resolution. The relation between BGS and local brain activation measured with BOLD is not known. In this study, we search for fMRI correlates of the callosally mediated synchronization of EEG activity measured with interhemispheric coherence (ICoh).

Methods

Fourteen normal adults participate in the study.Stimuli: in both sets of experiments we presented bilateral sinusoidal iso-oriented (IOG) and orthogonally-oriented (OOG) gratings with vertical grating in the right (VR) or left (VL) visual hemifield. Gratings were centered on the fixation point and had a spatial frequency of 0.5 cpd. They drifted with a temporal frequency of 2 Hz and had a contrast of 70%. A uniform gray screen of the same space-averaged luminance (32 cd/sqm) served as background



During **EEG** recording session, both condition order and exposure (2.2–2.6 s) were randomized. The common average referenced EEG (128 channels, EEG/ERP system) was submitted to spectral analysis (epoch of analysis 1 s, number of presentations not less than 50) with an emphasis on interhemispheric coherence functions (ICoh) as an index of interhemispheric phase synchronization.
According to **fMRI** protocol, the stimulus conditions were alternated with background in a balanced-randomized order 4 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 3.75 mm, acquisition time 1.7 s) with a TR = 3s. Preprocessing, single subject analysis, and group statistics were conducted with SPM99. Maps show voxels which survived at $p<0.01$ and extended threshold of 30 in a paired-T test between contrasts of interest set to perform statistical inference from the group. In several subjects the EEG electrode markers were co-registered with fMRI response followed by 3D reconstruction of MRI morphological images of the head.

Results

With high resolution EEG we confirmed our previous findings (Knyazeva et al. 1999, Kiper et al. 1999, Knyazeva, Innocenti 2001) that, as expected from Gestalt principles and “binding through synchronization” hypothesis, iso-oriented gratings presented to the two hemispheres increase ICoh compared to orthogonally-oriented gratings and gray screen (background condition). The most pronounced responses originated from occipital and parietal sensors and were restricted to the EEG beta-gamma frequencies. In particular, we showed the low frequency peak (21-23 Hz), observable in occipital derivations, and high frequency peaks (27-29 and 33-36 Hz) apparent in parietal sensors. The EEG power changes between IOG and OOG conditions were not significant.
To reveal whether ICoh increase is accompanied with greater activations and/or specific patterns of activation, we performed fMRI experiment similar to those above on the same subjects. All the stimuli compared to background appeared to extensively activate striate and extrastriate areas. The 3D reconstruction of the electrode positions confirmed that the reactive EEG sensors (IOG vs. background) are located over the area of BOLD response.
A contrast between IOG and OOG, clearly showed higher bilateral activation in extrastriate areas (*near the collateral sulcus)* associated with IOG gratings (Fig. 2). Further 3D reconstruction of the IOG-vs-OOG differential activation relative to EEG sensors' positions resolved s*patial aspect of EEG/fMRI coupling*. The EEG sensors from which IOG increased ICoh vs. OOG (I1-I2 =70-90) were located over the sites of differential BOLD activation (Fig. 2, 3).

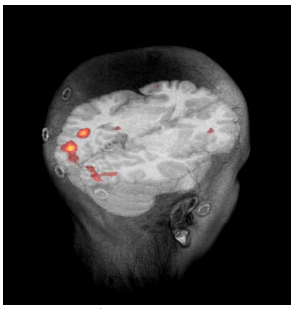


Fig 2

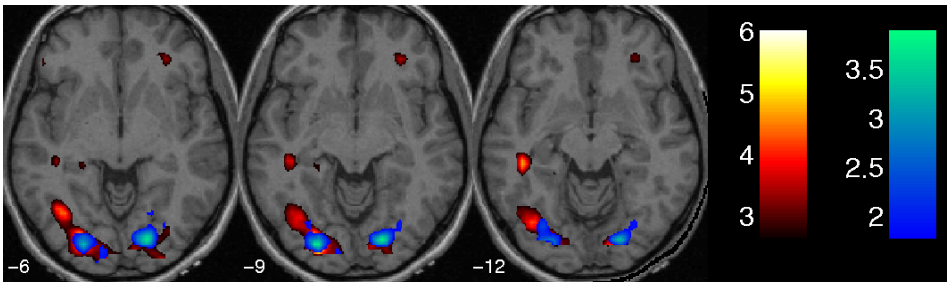


Fig 3

Linear regression analysis of ICoh vs. BOLD activation (performed on voxel-by-voxel basis) within the region significantly activated by IOG vs. background confirmed the spatial pairing of EEG/fMRI responses and revealed an *intensity aspect of EEG/fMRI coupling.* The peak ICoh response amplitude strongly predicted BOLD response in both hemispheres only within the extrastriate areas differentially activated by IOG vs OOG (Fig. 3). These included the collateral sulcus surrounding area in both hemispheres**.**

Conclusion

We show that BOLD responses are both co-localized and proportional to EEG synchronization between distant cortical sites. Current knowledge of functional visual cortical anatomy suggests that both are mediated by cortico-cortical connectivity, specifically by callosal axons.

References

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Knyazeva MG, Innocenti GM, Brain Res Rev. 2001 36(2-3): 119-28.