Task-Modulation of Low Frequency Oscillations in the Human Brain Detected by fMRI

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Introduction: Oscillations of neural networks in the brain span five orders of magnitude in frequency. These oscillations are phylogenetically preserved and believed to be functionally relevant (1). fMRI methods with high temporal and spatial resolution make it possible to non-invasively detect such oscillations with spontaneous low frequency in the human brain (2). It is hypothesized that that these oscillations are functionally relevant and the functional synchrony of these oscillations will change upon different neural tasks. In the present study, we have designed three cognitive tasks: the recognition of indoor and outdoor scenes, the determination of sizes of left and right pictures, and resting. We demonstrate that the functional synchronies of these oscillations are significantly different when subjects perform the different tasks.

Method & Materials: Nine cognitively healthy volunteers (5 males and 4 females, age 28±4 years) participated in this study. Informed consents were obtained from all subjects for this IRB-approved study. fMRI data were acquired on a Bruker BioSpec 3.0T scanner using a single-shot gradient-echo EPI sequence (TE = 27.2 ms, TR = 2 s, 64×64 in-plane resolution, FOV = 24 cm, 125 kHz acquisition bandwidth, 4 mm slice thickness, 17 sagittal slices). Two different memory tasks and one resting condition were employed: A) recognition of in- and outdoor scenes for active explicit encoding, B) comparison of left/right sizes of scrambled pictures for suppressing explicit encoding, and C) subject viewing a blue screen with a fixation point. Scans 1, 2, and 3 were acquired. Each lasted for 10 min with the first 6 min continuously performing A, B, or C tasks, and the last 4 min performing task B for 30 seconds and task A for 30 seconds, as shown in the left panel in Fig. 1. A set of high-resolution anatomical images was acquired for image registration.

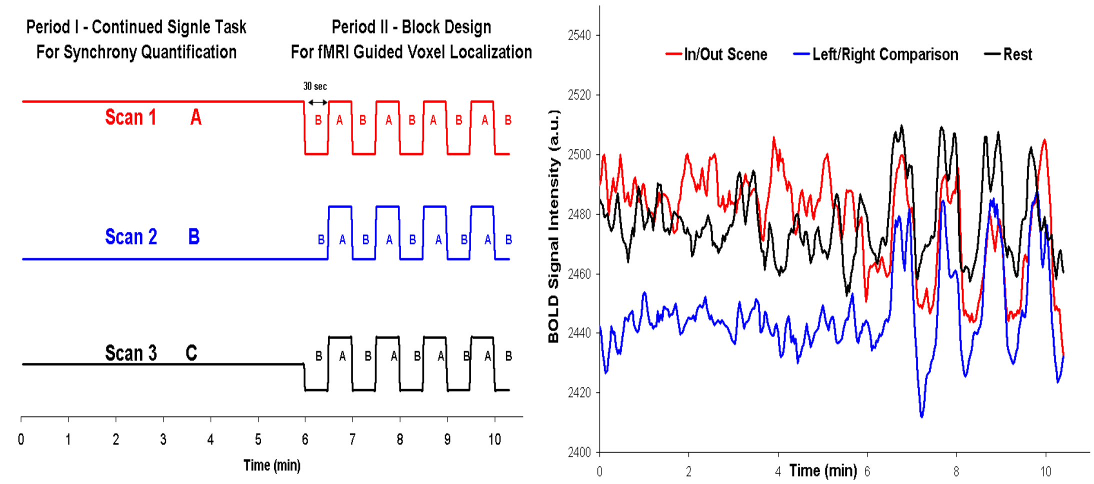

Fig. 1: Experimental paradigms (left) and averaged voxel time courses from activation voxels in PHP region.

Data Analysis: The voxel time courses in each of the last 4-min scans were employed to generate activation maps using the cross-correlation method in a block-design paradigm (p <0.01). The voxel time courses in each of the first 6-min scans were employed to quantify the functional synchrony by using the phase delay index (PDI) method described previously (3). Only those activated voxels in the parahippocampus (PHP) region were selected for the calculation of PDI. To compare the PDI values under different tasks during the 6-min period, only those voxels commonly activated in all three scans during the 4-min tasks were selected.

Results: Figure 1 (right panel) showed that the signal intensities of averaged voxel time courses acquired in the first 6-min period are different. The signal is the lowest when performing task B, highest for task A, and in between for task C. Figure 2 shows the areas of the parahippocampus, posterior cingulate and fusiform gyrus significantly activated bilaterally. The PDI was found to be significantly the lowest when performing task A (33.81±5.04), highest for task B (54.91±7.27), and in between for task C (42.08±8.43).

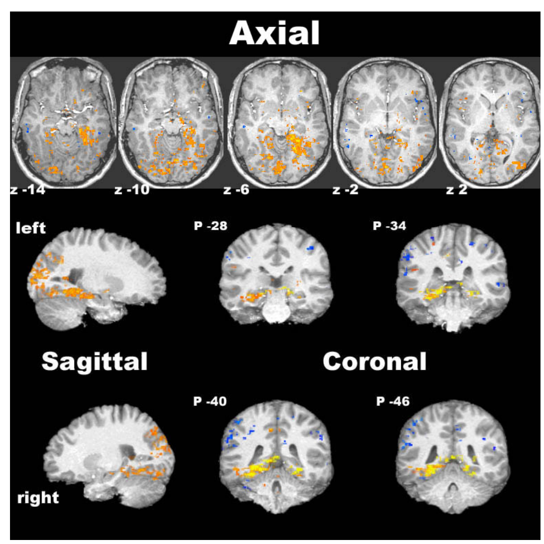

Fig. 2: Activation Map stimulated by tasks A and B.

Discussion and Conclusion: With the fMRI guided voxel selection method, we demonstrated that quantitative assessment of functional synchrony with PDI index revealed that the spontaneous low frequency oscillation can be modulated under different tasks. According to the definition of PDI, the lower the PDI value, the less the phase shifts between the voxel time courses, and the higher the cross-correlation coefficients, the higher functional synchrony between voxel time courses. It is interesting to point out that the PDI values during the resting condition (task C) are lower than the PDI values in the task B condition. This result supports a notion that the default mode of brain (4) may have higher brain activity than that during performance of a particular task (lower brain signal and less synchrony in case C). It is further suggested that the changes in the patterns of the functional synchrony may be a useful indicator for brain disease (5). During active encoding the PPA was getting more synchrony with a smaller PDI value, which was consistent with other neuron oscillation studies (3). fMRI studies usually show task-related brain activities by comparison with a resting condition that is believed to contain a default mode of brain function (4). The resting-state synchrony PDI value lying between active encoding and the control condition of suppressed encoding indicates the appearance of dynamic neuronal activities during the resting condition. The quantitative character of BOLD synchrony measurement makes the PDI suitable for future neuronal cortex exploration or possible application to the prediction of disease, such as Alzheimer's.

References:

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