Comparison of Functional Synchrony Measured at 3.0 and 1.5 Tesla Scanners during Cognitive Tasks

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Introduction: The spontaneous low frequency fluctuations (SLFs) (0.015~0.1 Hz) in voxel time courses measured by functional MRI method are cross-correlated in spatially separated brain regions [1] and the mean of these cross-correlation coefficients between the SLFs in the voxel time courses was defined as a quantitative measurement of functional synchrony. It was found that the functional synchrony was significantly lower in the region of hippocampus with Alzheimer's disease than that of cognitive healthy controls [2]. However, it is not clear whether SLFs in the voxel time courses are magnetic field dependent, whether the different magnetic field strengths would affect the quantitative measurement of functional synchrony, or if different tasks could modulate the functional synchrony. In the present study, we conducted experiments at 1.5T and 3T scanners to address these questions.

Materials and Methods: Two sets of identical experiments were conducted at a Bruker 3.0T and a GE 1.5T scanner using a single-shot gradient-echo EPI sequence. Informed consents were obtained from all subjects for this IRB-approved study. Nine young subjects at 3T and seven subjects at 1.5T participated in the experiments. Imaging parameters were set as follows: TR=2 s, FOV of 24 cm, 64×64 matrix, 125 kHz acquisition bandwidth, 4 mm slice thickness, 17 sagittal slices, TE=27.2 ms for 3T and 40 ms for 1.5T. Three kinds of tasks were employed: **Task A**, the identification of indoor and outdoor scenes; **Task B**, the comparison of sizes of the left and right scrambled pictures; and **Task C**, watching a black screen (resting state). A single block design with continuous 6-min task paradigm was employed for each task. For calculating functional synchrony, locations of the activated voxels within the parahippocampus area were determined by an fMRI-guided, block paradigm I which was 30 s on (task A) and 30 s off (task B) for 4 cycles, i.e., each run was composed of a task . The voxels inside the parahippocampus area within the activation map ($p<0.01$) determined from paradigm I, were used. A high-resolution anatomical scan was conducted for image registration to locate the parahippocampus area.

Data analysis: In this study, functional synchrony was quantified with the phase delay index (PDI) as described previously [3]. In brief, phase delay is defined as the ratio of original and maximum-shifted cross-correlation coefficients of SLFs from a pair (i^{th} and j^{th}) of voxel time courses (VTC) of steady state:

$$\theta = \arccos\left(E\left(SLF_i(t)\cdot SLF_j(t)\right) \Big/ \max_{0\le\tau\le T} E\left(SLF_i(t+\tau)\cdot SLF_j(t)\right)\right) \qquad (1)$$

where $E()$ is the expectation function, and T is the maximum-shifted time points determined by frequency lower limit and TR. Then the PDI, θ_G , is defined as the mean of the phase delays across all the pairs of the voxels in the intersection region. Analogous to a sine wave and a cosine wave, the maximum phase shift of 90° is obtained when the two waves achieve maximum synchrony. Obviously, the larger the PDI, the less synchrony between the voxel time courses. During the steady-state condition when performing each of the three tasks, the voxel time courses can be modeled as signal $\boldsymbol{s}$ (the SLF) and noise $\boldsymbol{n}$, which are mutually independent of each other. In this case, signal-to-noise ratio (SNR) is defined as the ratio of the fluctuation intensity of the signal $\boldsymbol{s}$ to noise $\boldsymbol{n}$:

$$\eta = \sqrt{Var(s(t))/Var(n(t))} \qquad (2)$$

where the Var () is the variance function.

Results and Discussion: The SNR and PDI data are shown in Figure 1. The SNRs for the three tasks A, B, and C at 1.5T are ***A,*** 1.209; ***B,*** 1.090; and ***C,*** 1.941, which are relatively lower than that at 3T (***A,*** 1.719; ***B,*** 2.143; ***C,*** 1.748). The PDIs for the three tasks at 1.5T (***A,*** 52.04°±10.23°, ***B,*** 62.85°±13.61°, ***C,*** 51.97°±9.99°) are higher compared with those at 3T (***A,*** 46.94°±7.99°, ***B,*** 54.29°±6.52°, ***C,*** 60.91°±5.23°). The different PDIs obtained during the three tasks at 1.5T have less statistical discriminative power between the three tasks than those obtained at the 3T scanner. For example with the two-tailed *t*-test, the *p*-values at 1.5T (0.0176 for ***A*** vs. ***B;*** 0.9905 for ***A*** vs. ***C;*** 0.0970 for ***B*** vs. ***C***) are higher than at 3T (0.0006 for ***A*** vs. ***B;*** 0.0434 for ***A*** vs. ***C;*** 0.0494 for ***B*** vs. ***C***). These results suggested that different tasks induced different, field-dependent SLFs. Active tasks such as task A and higher magnetic field strength such as that at 3T produced higher SLFs, and higher signal-to-noise ratios of η. For the study of functional synchrony, it is better to perform experiments at 3T than at 1.5T because the PDIs measured at 3T have a stronger and statistically more significant discriminative power than those at 1.5T.

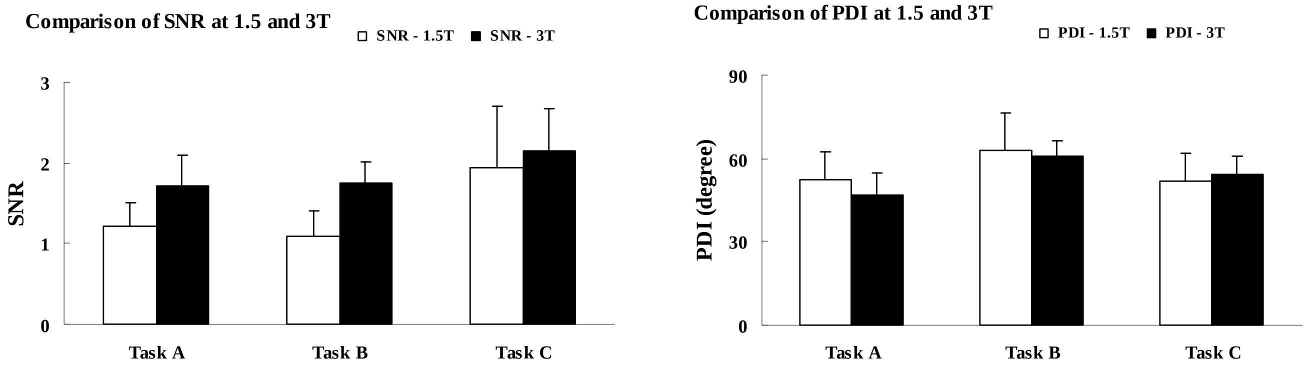

Figure 1: Comparisons of SNR and PDI for three separate tasks at 1.5T and 3T.

References: 1. Biswal, et al. *MRM*, 34:537-541, 1995. 2. Li S-J, et al. *Radiology*, 254:253–259, 2002. 3. Yin Xu *et al*, ISMRM, 12:498, 2003.

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