7 Tesla fMRI of Mental Maze Solving in the Human Superior Parietal Lobule using Parallel Imaging

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Introduction

The superior parietal lobule (SPL) is a crucial area within the human posterior parietal cortex for visuospatial functions. However, to date no one has reported functional imaging of the parietal cortex at field strengths greater than 4 Tesla. High magnetic fields in functional imaging provide improvements in the spatial accuracy of the BOLD response with respect to the underlying neuronal activity during a cognitive task. In this study, we used a 7 T magnet with a custom-built coil designed for parallel imaging to explore the hypothesis that single voxels in the SPL are “tuned” for the direction of attention.

Methods

The study has been performed on a 7T scanner with varian console. A home-built digital receiver was used for multi-channel acquisition. 7 oblique slices through the SPL were acquired for each subject using parallel imaging with a 15-channel RF coil equipped with an opening for visual stimulation. T1-weighted anatomies were acquired using inversion-recovery TurboFLASH. The fMRI-time series were recorded utilizing T2*-sensitized echo-planar imaging. Parameters and acquisition details were as follows: voxel size: 1.46 x 1.46 mm^2; slice thickness: 2 mm; TR: 1.5 s, TE: 25 ms; SENSE reconstruction (Pruessmann et al., 1999) with a one-dimensional reduction factor of 4; acquired reduced FOV: 18.7 x 4.67 cm; acquired reduced matrix: 128 x 32.

After written consent, four human subjects were imaged as they mentally traversed one of four radially directed paths (up, down, left, right) of a maze while fixating a central point. Mazes were filled with random linear distracters except for the non-branching central path that extended in one of the four directions; half of the radial paths were open-ended (Fig. 1) and exited the maze, and half were closed by a line near the end of the maze. Subjects indicated the exit status with a button press. Each of the four directions was shown four times (16 blocks total; 35 mazes of the same direction per block). The path direction for a given block was varied parametrically in a counterbalanced design such that each direction was preceded and followed by each other direction an equal number of times. Each trial lasted 1.2 s and the maze was displayed for 300 ms at the beginning of a trial.

Fig. 1. Example of a maze.

Data Analysis

Data were detrended to remove low-frequency noise. The first four data points from each block were removed to allow for stabilization of the hemodynamic response. For each subject, the borders of the SPL were used to define the ROIs (Regions of Interest, Fig. 2). Data analysis was performed on single SPL voxels within the ROIs. For each voxel, an ANOVA identified voxels with activity that was significantly altered between blocks of different maze path directions. For significant voxels, a sinusoidal linear regression determined the presence of directional tuning: $A = b_0 + b_x \cos(\theta) + b_y \sin(\theta) + e$, where A is the BOLD activation, θ is the maze path direction, and b_0, b_x, b_y are regression coefficients. If present, the ‘preferred direction’ of a voxel was calculated from the regression coefficients: preferred direction (in radians) = $\arctan(b_y, b_x)$.

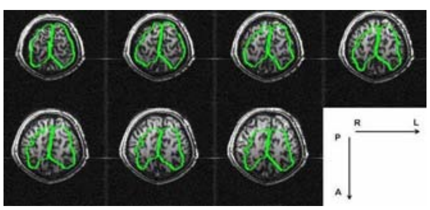

Fig. 2. Example of ROIs.

Results and Discussion

69% of single SPL voxels were directionally tuned, with approximately the same number of tuned voxels in each hemisphere. Preferred directions in the two hemispheres were distributed evenly across the 360-degree continuum (Fig. 3). Such directional tuning suggests that the BOLD signal in single voxels reflects coherent, directionally selective synaptic activity of spatially close neuronal ensembles within the SPL. These results lay the groundwork for more detailed analyses of the functional representation of visuospatial information in the SPL, and they demonstrate the efficacy of imaging highly specific cognitive functions at high magnetic fields.

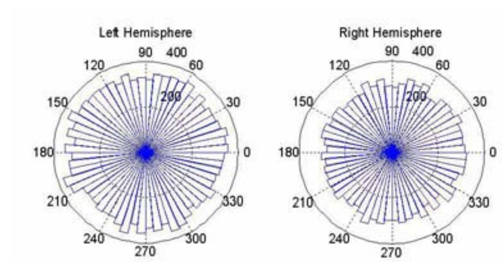

Fig. 3. Distribution of preferred directions in the two hemispheres.

Reference

Pruessmann KP, Weiger M, Scheidegger MB, Boesiger P, SENSE: sensitivity encoding for fast MRI. Magn. Res. Med. 42: 952-62 (1999)

Acknowledgments

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