High-field brain structural connectivity at 7T compared to 3T using HARDI

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Introduction:

High-field diffusion imaging can be used to map anatomical connectivity in the living brain, but little is known about how the resulting connectivity maps compare to those obtained at lower fields..The growing interest in brain connectivity makes it important to know how details of the scanning protocol (e.g., field strength) affect recovered patterns of connections and how increasing the field strength and spatial resolution might improve our knowledge of the human connectome. We separately tested how field strength and partial voluming affect the apparent pattern of connectivity. Prior studies examined field strength effects in diffusion imaging [1], but for the first time, we assessed how anatomical connectivity matrices depend on the field strength. The goal of this pilot study was to identify connectivity measures that might be vulnerable to protocol differences in studies of anatomical connectivity.

Methods:

Diffusion-weighted MRI and anatomical MRI at both 7 Tesla and 3 Tesla were collected at the Center for Magnetic Resonance Research (CMRR) in Minnesota, with protocols summarized in **Table 1.** Five young healthy subjects (two male, age: 32.4±14.6 years) were scanned at 3T and with a 7T protocol with 1.5mm isotropic voxels (called "7T-1.5mm" below). To assess field strength effects while keeping voxel size constant, we also scanned 2 of the 5 subjects using a protocol called "7T-2mm" for comparison purposes. All diffusion images were corrected for eddy current distortions and EPI nonuniformities using FSL. ODF-based tractography was performed using TrackVis (http://trackvis.org/dtk). Connectivity matrices were created as in [2].

Table 1.

Protocols	3T	7T-1.5mm	7T-2mm
Scanner	Siemens Tim Trio	Magnex Scientific MRI	
Isotropic Voxel	2mm	1.5mm	2mm
TR/TE (ms)	9000/96	5000/50	5000/50
FOV (mm)	256x256	192x192	192x192
Number of DWI	128	128	128
Number of b0	15	15	15

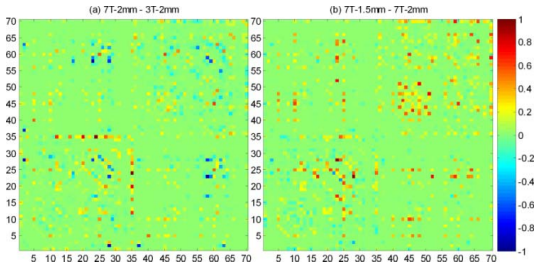

Fig. 1. In each plot, axis labels 1-35 and 36-70 correspond to ROIs in the L and R hemisphere. The connectivity value at each location represents the proportion of all fibers (extracted in the whole brain) that interconnect the 2 ROIs shown on the *x* and *y* axes. Values are renormalized [-1,1] to represent the connectivity difference between two field strengths: (a) 7 vs 3 T) or two resolutions at 7T, (b) 1.5 vs 2.0mm.

Results & Discussion:

Fig 1a shows the differences between the connectivity matrices at two field strengths at the same spatial resolution. For several pairs of regions (such as the insula and the rest of the cortex), a greater proportion of connections was recovered at 7T than 3T. **Fig 1b** shows that at high field strength (7T), the partial volume effect affects the recovered pattern of cortical connectivity –more pairwise connections were detected when using smaller voxels. In general, the directionality of differences is mixed when comparing 7T and 3T scans. When examining higher spatial resolution in the 7T images, we note a general trend towards greater connectivity in most connections. In **Fig 2,** a paired Student's *t* test was used to evaluate whether the 7T-1.5mm protocol picked up a different pattern of brain connections compared to 3T-2mm, and a *P* map is shown. Connections between rostral anterior cingulate and the lateral orbitofrontal, caudal middle frontal and rostral middle frontal cortex in the left hemisphere were more prominent at 7T-1.5mm, and showed the most significant differences by protocol. 7T and 3T scans of the same subjects may lead to different patterns of recovered connections, based on whole-brain tractography. Differences were apparent in some but not all regions, offering a target for more formal studies as the sample size increases. In tests of SNR of the b0 images, 7T DWIs offered greater SNR than 3T, even when some of the available SNR was sacrificed to achieve a smaller voxel size. Smaller voxels allowed more connections to be recovered, particularly shorter ones, and this affected the relative prominence of different connections in the matrices.

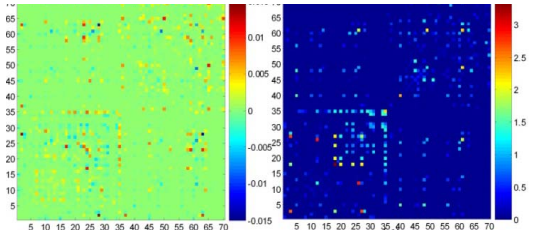

Fig. 2. (a) Differences in brain connectivity at 7T-1.5mm and 3T-2mm; (b) *P* map showing the differences, based on a paired Student's *t* test. (FDR *p*-value, at q=0.05, is 1.03×10^{-4}). The color bar shows *P*-values on a $-\log_{10}(p)$ scale.

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References:

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