Retinotopic Connectivity Revealed by DTI

C. K. Jones[1,2], J. T. Serences[3], S. Yantis[3], S. Mori[1,2], J. J. Pekar[1,2], P. C. van Zijl[1,2]

[1]F.M. Kirby Center, Kennedy Krieger Institute, Baltimore, MD, United States, [2]Department of Radiology, Johns Hopkins University, Baltimore, MD, United States, [3]Department of Psychological and Brain Sciences, Johns Hopkins University, Baltimore, MD, United States

Introduction

Functional MRI is frequently used to explore the role that retinotopically organized regions of visual cortex play in supporting our rich spatial representation of visual scenes. Several previous studies have analyzed connectivity in monkey[1], however, human studies have analyzed only the white matter tract connectivity into the visual cortex. We acquired high resolution human fMRI data to functionally define the lateral geniculate nucleus (LGN), early cortical visual areas V1 – V4, and motion-selective area MT+; we also acquired high resolution diffusion tensor images (DTI) to assess the connectivity between these functionally defined regions.

Methods

High resolution fMRI (2mm isotropic voxels) and three stimulation paradigms were used to define retinotopically organized regions of visual cortex and the LGN. Regions V1, V2, V3 and V4 were defined using a rotating checkerboard wedge stimulus[2]; MT+ was defined using a flow field stimulus. LGN was defined based on anatomy and a unilateral checkerboard stimulus alternately stimulating the left and right visual fields. Six DTI acquisitions were acquired each with 30 gradient directions, b = 700 s/mm^2, 60 slices and 2.2 mm isotropic acquired acquisition. A 1mm isotropic MPRAGE was acquired for anatomical localization. The functional regions of interest were defined on a flattened cortical sheet using Brain Voyager software and then projected back into normal brain space with resolution 1x1x1mm. Each of the six DTI acquisitions was registered to the 1mm isotropic MPRAGE and then averaged. Fractional anisotropy, eigenvectors and fiber tracks were calculated using DTIStudio (JHU). All fiber tracking analysis was based on the functionally defined regions of interest.

Results and Discussion

The visual regions were defined on a flattened retinotopic map as shown in Figure 1. The functionally defined regions were overlaid on an MPRAGE image: LGN (blue), V1 (red), V2 (yellow), V3 (purple), V4 (light blue) and MT (green). Fiber connections were found between V1 (left) and regions within the visual cortex and to LGN (Figure 2) as well as a strong bilateral connectivity of the left and right V1. Other fiber connections were found within the visual cortex, for example fibers connecting ventral V2 to dorsal V2 and to dorsal V3.
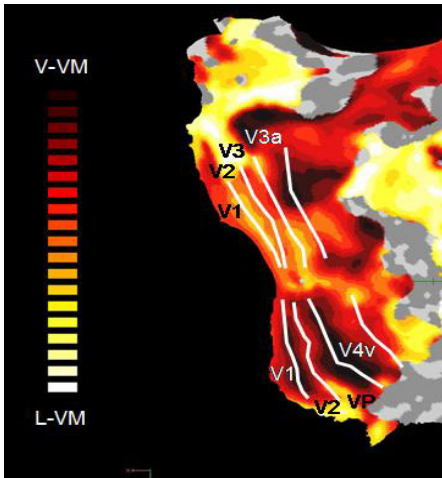

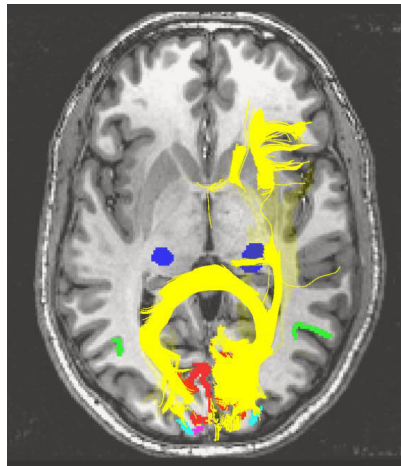Figure 1: Flattened retinotopic map showing V1-V4 defined.

Figure 2: Retinotopic regions defined on MPRAGE: V1 (red), V2 (yellow), V3 (light purple), V4 (light blue) and V5 (green). Yellow fiber projections from V1 (pt left).
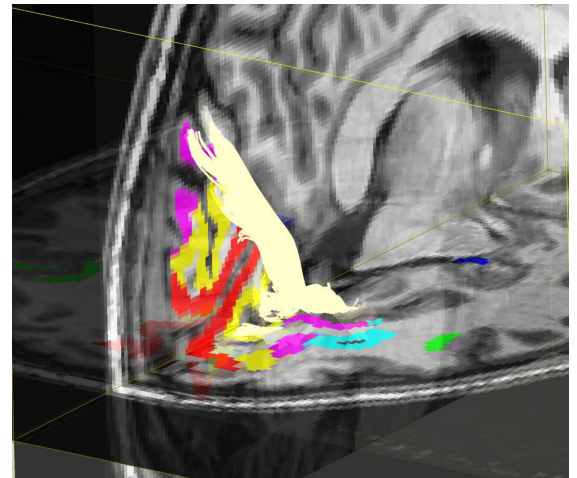

Figure 3: Fiber projections from ventral V2 (light yellow fibers beginning on axial plane) and terminating in V2 (yellow) and V3 (light purple) on the superior side of V1 (red).

Conclusions

We believe this is the first high resolution human *in vivo* connectivity analysis of functionally defined regions *within* the visual cortex. Functionally defined regions of the visual cortex and LGN were used to seed the fiber tracking to assess connectivity. Connections were found between LGN and V1 and within the visual area (V1, V2, V3, and V4). Fiber tracking analysis of the functionally defined retinotopic map will further understanding of the normal human visual cortex in vivo and impairment in diseased regions.

References: (1) Felleman et al., Cereb Cortex. 1991 Jan-Feb;1(1):1-47 (2) Slotnick et al., Hum Brain Mapp. 2003 Jan;18(1):22-9