Topography of high-order human object areas measured with DTI and fMRI

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Synopsis

Positional invariance is a characteristic of object category selectivity. Given the fact that the central visual fields become progressively overrepresented in higher visual areas, one might assume that a confluence of information from central fields is necessary to generate positional invariance. Alternatively, it seems also reasonable to suppose that a convergence of peripheral inputs is necessary to support positional invariance. In the present study, we use diffusion tensor imaging (DTI) fiber tracking to separately follow the connectivity of central and peripheral fields in the human visual system. Central and peripheral fibers showed different patterns of connectivity with higher visual areas. Areas showing category-specific fMRI responses showed higher connectivity with regions representing central visual field.

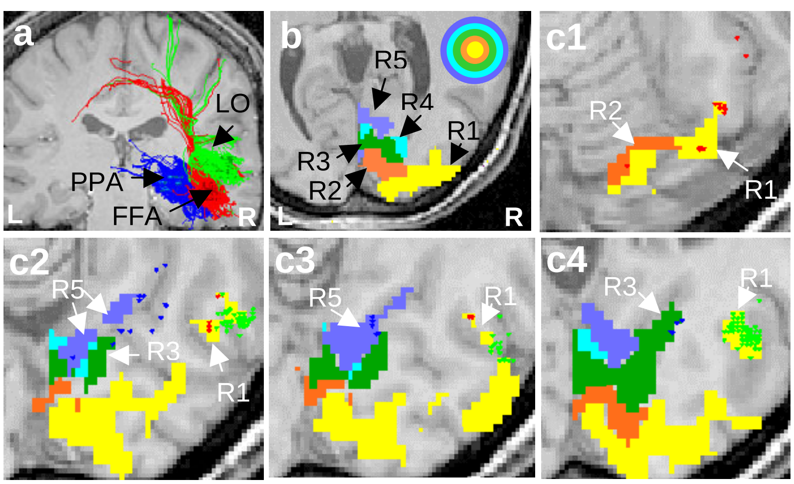
Introduction

In recent years, functional magnetic resonance imaging (fMRI) based on the non-invasive blood oxygenation level dependent (BOLD) T2/T2* contrast has been used to identify multiple visual areas along the human ventral visual stream. These areas are defined on the basis of a specific selectivity to certain *categories* of visual objects. Chief among these areas are fusiform face area (FFA; face-selective), parahippocampal place area (PPA; place-selective), and lateral occipital cortex (LOC; object selective). However, how this object category-selectivity emerges from the fundamentally object category indifferent receptive field properties in the early stages of the visual pathway (retina, lateral geniculate nucleus, V1/V2) remains elusive. We hypothesize that this unique transformation of receptive field properties along the human occipito-ventro-temporal visual stream is founded on a systematic pattern of neuronal connections within this stream. We tested this hypothesis through a tractable progression of experiments combining non-invasive fMRI and diffusion tensor imaging (DTI) techniques.

Methods

The functional areas (FFA, LOC, and PPA) including primary/higher order organization of the both hemispheres of the human visual cortices were obtained using standard stimuli. We used 3T whole body scanner (Intera, Philips). Typical MR parameters for fMRI: gradient-echo Echo-Planar Imaging (GE-EPI); TE=40 ms; TR=3000 ms with ventral stimuli and 2000 ms with retinotopic stimuli; 128×128 in a FOV of 230×230 mm^2, 30 slices, 2 mm of slice thickness, native resolution: 1.8×1.8×2 mm^3/voxel. Parameters for DT-MRI: spin-echo EPI; TE=91 ms; TR=10646 ms; 256×256 in a FOV of 230×230 mm^2, native resolution: 0.9×0.9×1.5 mm^3/voxel with b=1000s/mm^2. Diffusion-weighted images were obtained for 15 gradient encoding directions. FMRI data was analyzed with BrainVoyager (Brain Innovation, Netherlands), and custom-written Matlab (Mathworks) software was used for diagonalization, fiber tracing, and visualization. The areas identified using functional imaging were used as seeding ROIs for DTI based axonal fiber reconstructions. Subsequently, corresponding fMRI and DTI tracing data were superimposed on three-dimensional anatomical images.

Results



The distributions of terminating points (blue/red dots) projecting from high order regions are overlaid on color-coded iso-eccentricity maps. The data as displayed in the panels left suggest that fiber-trajectories to/from from FFA and LO are clustered around central-eccentricity preferences (R1/R2), while those to/from PPA are clustered around peripheral eccentricity bias (R3/R4/R5).

Figure legend: Distribution of terminating points shown over iso-eccentricity maps. *a*: Color-coded fiber-projections from different ROIs (Green: LO, Red: FFA, and Blue: PPA). *b*: Color-coded iso-eccentricity maps (R1 to R5 correspond to central to peripheral, respectively). *c1*: The red dots indicate the termination points for fiber projecting to/from FFA (R1/R2: central bias). *c2-c4*: The blue dots from PPA terminate on R3 and R5 (peripheral bias) while red/green dots from FFA and LO do on R1 (central bias).

Conclusion

The results of our study suggest that central and peripheral visual field areas in the primary visual cortices preferentially connect with the areas FFA, LO and PPA, respectively. This differential pattern of eccentricity-dependent connectivity pattern may form the basis for the distinct positional/object specific processing properties in these higher visual areas.

Acknowledgements

Supported by NIH RR008079, MIND Institute, NIH MH67530, the KECK Foundation, and the Human Frontiers Science Program.