White Matter Tractography Analysis of the Connectivity Patterns of the Visual Cortical Areas

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Introduction: Vision is an integral part of the human interaction with the outside world and is achieved through a vast neural network that includes several cortical regions and extends across several cerebral lobes. Knowledge of the white matter connections that facilitate communication between these different cortical regions is essential in understanding both normal visual processing and abnormalities that arise in diseases such as autism and schizophrenia (1, 2). In this study we examined the anatomical connectivity patterns of several areas involved in visual processing situated in the occipital (Brodmann's areas 17, 18, 19), parietal (Brodmann's area 39), and temporal (Brodmann's area 37) lobes. Probabilistic connectivity maps of these Brodmann's areas (BAs) were constructed across 16 subjects using white matter tractography (WMT). A template of the BAs was employed to define regions of interest, which were then used to select the corresponding white matter connections. Patterns of connectivity characteristic to each region were found. These patterns appear to be consistent across subjects.

Methods: Diffusion Tensor Imaging: DTI images were obtained on a 3T MRI scanner using a cardiac-gated single-shot spin-echo EPI pulse sequence for 16 healthy subjects (for 12 uniformly distributed encoding directions). The original voxel size was 0.94x0.94x3 mm^3 and was interpolated to isotropic dimensions. Image misregistration from motion and eddy current distortion was corrected using a 2D affine registration in AIR (3). Field map correction was subsequently applied to correct for EPI distortions resulting from B0 inhomogeneities. Brodmann's Areas Templates: BAs templates for each subject were obtained by co-registering the template provided with MRIcro software to the subject FA map using a method previously described in (4). WMT: Fiber trajectories were estimated using the streamline algorithm (5). To investigate hemispheric differences fiber tracking was performed for each cerebral hemisphere separately. Trajectories were generated from each brain voxel with a FA>0.3 and propagated in both forward and backward field directions until they reach regions with FA<0.15 or the hemispheres' borders. Subsequently, the subject BAs templates were used to segment the trajectories that connect to areas of interest. For each subject and hemisphere, binary mask of the connectivity patterns of each BA were obtained by labeling the brain regions intersected by the corresponding connecting trajectories. Probabilistic connectivity maps: Probability maps of the connectivity pattern of each BA were obtained by registering the individual masks to a normalized coordinate space and averaging them. To account for any misregistration, the individual binary masks were dilated using a boxcar filter with a width of 2.8 mm before averaging.

Results: Probabilistic maps of the anatomical connectivity patterns of the visual BA are shown in Figure 1. Connectivity patterns with probability greater than 25% are displayed overlaid onto anatomical images. Regions of high probability (with maximum probability describing voxels that are connected to a BA in all subjects) are displayed in red. Strong connectivity patterns with the lateral geniculate and pulvinar nuclei (via the optic radiations) are observed for areas 17, 18, and 19. All areas investigated here appear to be connected to the pre-frontal cortex and lateral frontal cortex via the external capsule (e.g., through inferior occipital-frontal fasciculus), with areas 17 and 18 connecting mostly to medial cortical regions, and with areas 19, 37, and 39 connecting with both medial and lateral prefrontal cortex. Both areas 37 and 39 are connected with medial frontal cortex via pathways of superior longitudinal fasciculus. All regions connect to the temporal pole through pathways of inferior longitudinal fasciculus or posterior segment of superior longitudinal fasciculus, with areas 19, 37, and 39 showing the strongest connectivity. Areas 17, 18, 19, and 37 also connect with the anterior part of the temporal lobe via the parahippocampal gyrus. Connectivity with the superior temporal sulcus is apparent for areas 19, 37, and 39. Areas 37 and 39 appear to be strongly interconnected through the posterior segment of the superior longitudinal fasciculus. All areas appear to connect interhemispherically through corpus callosum, with areas 18 and 19 showing the highest probability, and area 39 showing rather low probability of connection. Overall, area 17 (primary visual area) appears to have more limited connectivity patterns compared to the other regions investigated here, which is in agreement with classical anatomy findings.

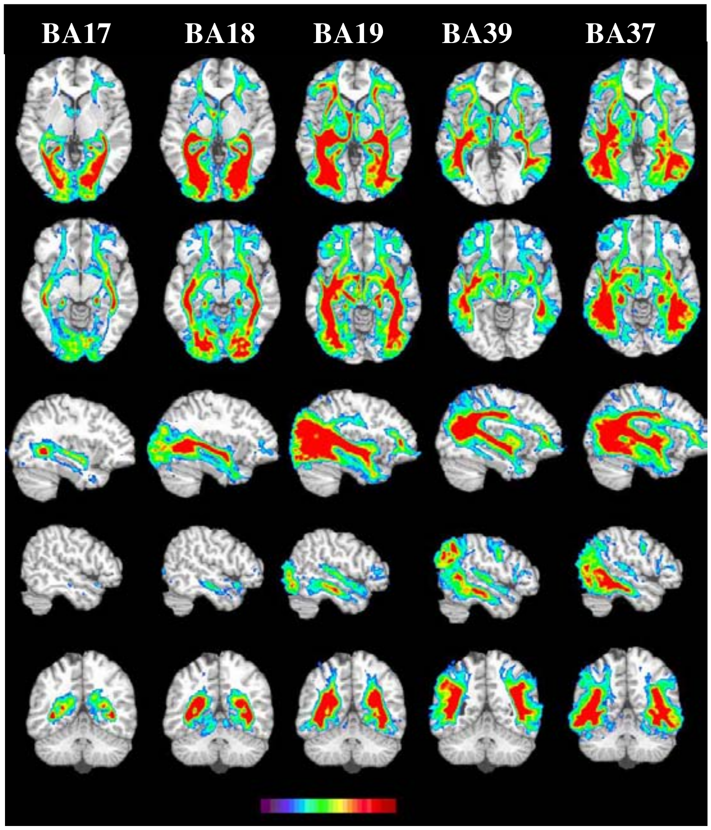

Figure 1: Anatomical connectivity patterns for BA 17, 18, 19, 39, and 37 shown in several axial, sagittal, and coronal cross-sections (top to bottom).

Discussion: We demonstrated anatomical connectivity patterns of several cortical regions involved in visual processing. For example, the probabilistic maps make apparent the connectivity patterns of the dorsal (occipital-parietal) and ventral (occipital-temporal) visual processing streams. WMT allows the non-invasive labeling of these pathways. The white matter connectivity patterns of the investigated areas appear to be consistent across subjects. Anatomical connectivity maps of the visual cortices may be useful in understanding abnormal visual processing (e.g., face processing) in disorders such as autism and schizophrenia.

References: **1.** Pellicano et al. Neuropsych. 2005;43:1044. **2.** Bustillo et al. Am J Psych. 1997 154:647. **3.** Woods et al. 1998. **4.** Thottakara et al., Neuroimage 2005, in press. **5.** Basser et al. MRM. 2000 44:625.