Connectivity-based segmentation of the precuneus in individual adolescent rhesus macaque DTI data.

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Introduction: The precuneus is an important hub of brain connectivity located in the posterior region of medial parietal cortex. It is functionally implicated in eye movement, consciousness, attention, episodic memory retrieval, and mental representation of "self," among others. Thus it carries functional connections to many other regions of the brain. In this work, we use probabilistic tractography applied to diffusion tensor imaging (DTI) data of individual Rhesus monkeys to segment the precuneus based on its connection probability to key areas of the cortex.[1] We do this on both a population template and in individual DTI scans of adolescent rhesus monkeys. We also examined the relative sizes of connectivity-based parcellations change as a function of age. This may provide insights into the developmental trajectories of brain connections to different parts of the cortex.

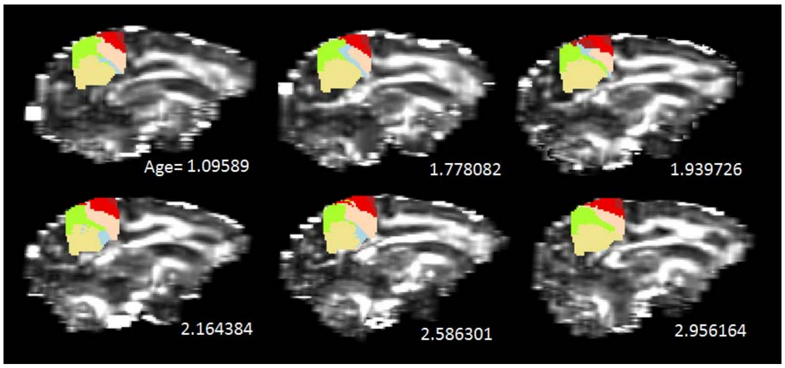

Figure 1: A selection of 6 subjects, shown in a mid-sagittal slice, with overlay of the precuneus segmented by connection probability.

Methods: A rhesus DTI template[2] created from 271 individual DTI scans was registered to a T1-weighted template of cortical parcellation units from the Paxinos atlas,[3,4] to create a parcellation of 13 bilateral cortical regions. Subregions known to be a part of the precuneus were combined and holes were filled in to create a solid continuous region of interest to be our "precuneus ROI." The precuneus ROI was used as a seed region and probabilistic tractography was performed using the "PICo" algorithm in Camino[5] with probability density functions (PDF's) from the Bingham distribution, which allows elliptical probability density contours. Streamlines were generated with 1000 iterations at each voxel. The streamlines were then processed using connectivity based segmentation. Each voxel in the precuneus ROI was assigned an index corresponding one of the 13 cortical regions with which it had the strongest connection probability. The procedure was performed on DTI data from 18 individual rhesus monkeys registered to the DTI template (age range 1.09589 - 3.693151 years) and the T1W population template. The number of precuneus voxels in each segmented region was then counted for statistical analysis.

Results: In both the population template and individual subjects, the precuneus region is dominated by connections to six regions: cingulum, lateral temporal, lateral somatosensory, medial somatosensory, lateral occipital, and medial occipital. An example of the segmented precuneus in six subjects is shown in Fig. 1. The spatial connectivity patterns are similar across the animals. For analysis the number of voxels in the medial and lateral occipital segmented regions were added together to represent "visual" connections, medial and lateral somatosensory for "sensory," and cingulum and lateral temporal for "limbic" connections. The relative volumes of these three precuneous regions are plotted as a function of age in Fig. 2. In general, the greatest fraction of connectivity is to visual areas (~40-50%), then limbic areas (~35-45%), and sensory connections are the smallest fraction (~10-20%). There are some trends with age. The proportion of precuneus voxels connected to the limbic regions appears to decline with age, while the sensory connected areas appear to increase. The regression was performed using robust estimation of the linear models using iteratively reweighted least squares with a bisquare weighting function.[6] Using Fisher r to z transformation, we compute statistical significance of the differences between the correlation coefficients of the age and volume-fractions of the three ROIs. Among the three regions of the precuneus, there was a significant age X region interaction between the limbic and sensory regions, with z=-2.32 and p=0.02 (two-tailed p–value).

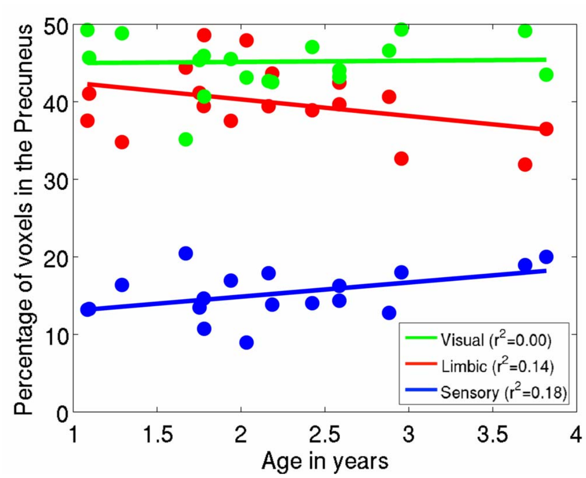

Figure 2: A linear regression analysis using robust estimationof the percentage of precuneus voxels having strongest connections to three major functional regions: visual, limbic, and sensory.

Discussion: This study showed a consistent anatomical pattern of connectivity in the precuneus of the rhesus monkey. Since the age of the monkeys used corresponds to humans of roughly 4-15 years of age, this is an important starting point for creating models of brain connectivity development in children and adolescents.

References: 1. Parker GJM et al. JMRI, 2003; 18:242–254. 2. Adluru et al. Neuroimage, 2012; 59(1): 306-318. 3. Paxinos G et al. (2008) Academic Press. 4. Moirano et al. (under review) NeuroImage. 5. Cook et al.14th ISMRM, 2006; 2759. 6. Holland, PW et al. Commun Stat A-Theor, 1977; 813-827.