White-Matter Tract-Based Atlas of the Chimpanzee Brain

L. Li[1], S. Kramer[1], W. Hopkins[2], T. Preuss[2], J. Rilling[3], G. Nair[1], X. Zhang[2], F. Damen[4], and X. Hu[4]
[1]School of Medicine, Emory University, Atlanta, GA, United States, [2]Division of Neuroscience, Yerkes National Primate Research Center, Atlanta, GA, United States, [3]Division of Psychobiology, Yerkes National Primate Research Center, Atlanta, GA, United States, [4]Department of Biomedical Engineering, Georgia Institute of Technology, Atlanta, GA, United States

Introduction: Diffusion magnetic resonance imaging (MRI) and tractography have been used to generate white-matter tract-based atlases of the human and macaque brain [1,2]. However, no such atlas has been created for our closest living relative, the chimpanzee. This is partially due to the challenges of collecting *in vivo* diffusion MR data from chimpanzees. In this study, we acquired diffusion MR data from nine chimpanzees and virtually dissected the major white-matter tracts via probabilistic tractography. We then generated an atlas of the course, location and extent of these tracts. This white-matter tract-based atlas of the chimpanzee brain will have extensive applications in comparative neurology and provide insights into primate brain evolution.

Method: ***Subjects:*** Nine chimpanzees (2 females, age: 24±6 yrs) were included in this study. ***Image acquisition*****:** MRI images were obtained using a 3T Trio scanner (Siemens Trio, Pennsylvania, US). T1-weighted images were acquired with a 3D MPRAGE sequence with the following parameters: FOV=204×204 mm^2, matrix size: 256×256, 0.8 mm isotropic voxel; Diffusion MR data were acquired with the following parameters: single-shot dual spin-echo diffusion echo-planar imaging sequence, FOV=130×230 mm, matrix size: 72×128, 41 slices covering the whole brain, 1.8 mm isotropic voxels, eight averages with opposite phase encoding directions to remove the susceptibility distortion [3]. ***Probabilistic tractography*****:** First, a two (one for corpus callosum) ROI method, similar to Catani et al. [1], was used to dissect ten white-matter tracts based on the probabilistic tractography algorithm implemented in the FSL package. These tracts include the anterior commissure (AC), arcuate fasciculus (AF), corpus callosum (CC), cingulum (CI), corticospinal tract (CST), fornix (FX), inferior fronto-occipital fasciculus (IFOF), inferior longitudinal fasciculus (ILF), superior longitudinal fasciculus (SLF), and uncinate fasciculus (UF). Second, each tract (in each hemisphere if it is bilateral) was normalized by its total number of "probabilistic streamlines" survived during the tracking (waytotal). Third, the normalized tracts were transformed to a common space via a warping field derived by registering each subject's T1-weighted image to a chimpanzee T1-weighted template [4]. Fourth, the transformed, normalized tracts were thresholded by 0.2% (0.05% for CC as only one ROI was used) and then binarized, so each chimpanzee's tracts in the group were weighted equally. Lastly, the binarized tracts were averaged together to generate a variability map of the given tract: a voxel commonality value of 1 indicated that every individual had a connection identified in this voxel whereas 0 indicated that none of them did. In order to view the ten tracts in a three-dimensional reconstructed image, the variability maps were further thresholded at 60%, meaning that only the part of the tract present in the majority of the population in the study is displayed.

Results & Discussion: Fig.1 shows the variability maps of the ten major white matter tracts of the chimpanzee brain as 2D (Fig.1a) and 3D (Fig.1b) representations. The ten tracts that have been previously identified in humans have all been successfully reconstructed in the chimpanzee brain as well [1]. The AF and CST showed similar course and location as those in the previous reports based on different chimpanzee populations [4, 5]. This study presents the first chimpanzee atlas of the course, location, and extent of major tracts using diffusion probabilistic tractography. The atlas could be used for i) complementing the histological study of chimpanzee's white matter; ii) identifying and evaluating white-matter pathways across species for comparative and evolutionary studies; iii) providing convenient tract-based ROIs in a standard space for comparisons in white-matter metrics (FA, MD) obtained from other studies. More *in vivo* diffusion MR data of chimpanzee are being collected for a more representative white-matter tract-based atlas of the chimpanzee brain.

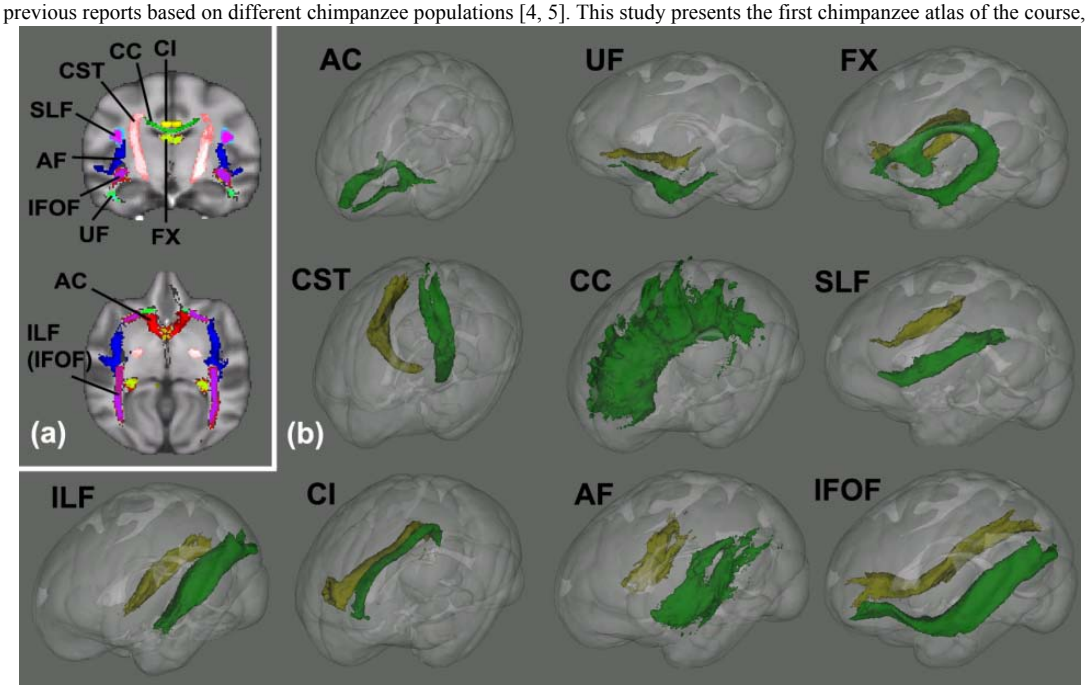

Figure 1. The variability maps of the ten white-matter tracts of the chimpanzee brain derived via diffusion probabilistic tractography. (a): the 2D representation of the white-matter tract-based atlas; each color system represents certain tracts with different variability, which is thresholded at 60%; (b) the 3D representation of the variability maps thresholded at 60%; the yellow color represents the tracts in the right hemisphere and the green color represents the

References: [1]. M., Catani, et al., Cortex, 44(8),2008,1105;[2]. T., Jeon, ISMRM,2010, Stockholm, Sweden; [3]. J.L. , Andersson,et al., NeuroImage, 20,2008, 870; [4]. L., Li, et al., PLoS ONE, 5(9),2010, e12886;[5]. J., Rilling, et. al., Nature Neuroscience, 11, 2008,426.

Acknowledgement: This work was kindly supported by the National Institutes of Health (5P01 AG026423-03, NS-42867 and HD-56232) and Yerkes National Primate Research Center (RR-00165).