

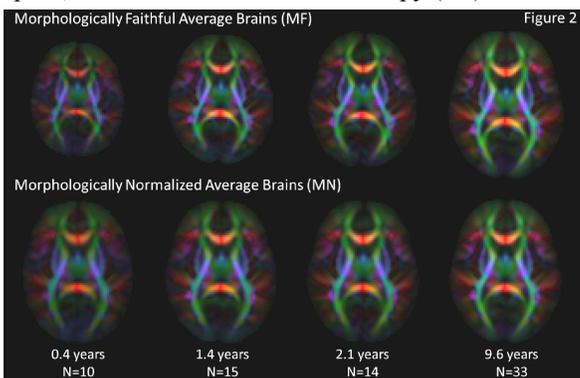
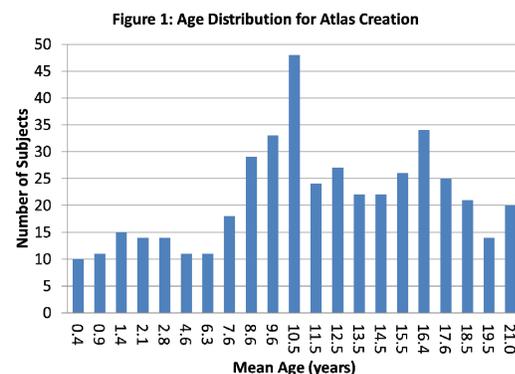
Age Specific DTI Average Brain Atlases from the NIH MRI Study of Normal Brain Development (PedsDTI)

Carlo Pierpaoli¹, Lindsay Walker^{1,2}, Amritha Nayak^{1,2}, Lin-Ching Chang³, William Ball⁴, Kelly Botteron⁵, James McCracken⁶, Robert McKinstry⁵, Michael Rivkin⁷, and the Brain Development Cooperative Group⁸

¹NICHD, NIH, Bethesda, MD, United States, ²CNRM, USUHS, ³CUA, ⁴Children's Hospital Cincinnati, ⁵Washington University St. Louis, ⁶UCLA, ⁷Children's Hospital, Boston, ⁸www.NIH-pediatricMRI.org

Introduction: We present a first analysis of data from the diffusion tensor imaging (DTI) component of the NIH MRI study of Normal Brain Development (PedsDTI). Although DTI studies of brain development are available in the literature¹⁻⁵, PedsDTI represents the largest prospective study on brain development performed to date in healthy children covering the entire age range of 0 to 22 years. DTI data from 498 scans in 274 unique subjects can be downloaded from the public data repository (NIH-pediatricMRI.org). Subjects were prospectively enrolled for the study in 5 centers across the US. All scanning was done without sedation, during natural sleep for the youngest children. An extensive set of neuropsychological data is also available in the data repository, allowing researchers to test hypotheses on structure/function relationships. In this report we present the construction of age specific brain atlases that will also be included in the data repository, and we study the feasibility of extracting developmental trends for DTI metrics in various brain regions directly from the age specific brain averages.

Methods: The data acquisition protocol and the methodological details of the project are available at NIH-pediatricMRI.org. Briefly, PedsDTI consisted of two sets of data with different resolution and acquisition parameters. The results presented here pertain to the 3x3x3mm native resolution DTI data that are currently available for download. A rigorous processing pipeline was specifically developed for this study, which resulted in the creation of the TORTOISE⁶ software package. Artifact remediation and quality control procedures⁷ were used to reject datasets with severe artifacts from inclusion, or to score remaining minor or regionally specific artifacts. Atlases were created from a subset of 449 scans, including all 274 unique subjects. Scans were grouped according to age with a minimum of 10 subjects per age group (Fig 1). DTITK⁸ was used to perform fully deformable diffeomorphic tensor based registration for each group and then again to register each group to a common space for the population. Thus, we produce two types of DTI atlases: 1) morphologically faithful average brains (MF) in which each computed average tensor map has the average morphology for the group of subjects included in that age range, and 2) morphologically normalized (MN) in which each age group has the same morphology which is representative of the population (Fig 2). In addition, atlases normalized into MNI space will also be available in the data repository, but are not presented here. To investigate the developmental trends, ROIs were created on the MN space, and median fractional anisotropy (FA) values were extracted from each ROI and plotted against mean age of the group (Fig 3).



Results and Discussion: Figure 2 shows the DEC map of the MF and MN average brains for four representative age groups. In both atlases, we see an increase in the value of anisotropy, and an increasing complexity of white matter across ages, while the fundamental white matter architectural paradigm is maintained. In addition, consistent patterns are noticeable in peripheral white matter regions across age points, despite the intrinsic biological inter-individual variability in this region. This indicates that the number of subjects included in each group is sufficient to describe the average morphology of the population. These two factors enable the creation of the MN atlas, suitable for voxel wise analyses

of tensor metrics. Figure 3 reports an example of this type of analysis of FA in a selection of brain structures. In general, there is a smooth trajectory over age, providing different trends for different brain structures. In particular, we notice the difference between the trajectories of the motor fibers of the cerebral peduncles (CP) and the sensory fibers of medial lemniscus (ML). We have good stability for low anisotropy structures, such as the putamen (put), and generally good consistency between left and right for all structures. In conclusion, these atlases provide a robust representation of the diffusion features in normal brain development, and promise to be an invaluable tool for DTI studies in pediatric research.

References: [1] P.Mukherjee et al., 2001 Radiology, [2] V. Schmithorst et al., Radiology. 2002 [3] L.Snook: NeuroImage 2005, [4] L. Hermoye et al., NeuroImage 2006 [5] C. Lebel et al., NeuroImage 2008 [6] www.tortoisediti.org [7] A.Nayak et al., ISMRM 2011 #2342 [8] Zhang, H., et al, IEEE Trans on Med Img 2007

