Gender-Specific Templates of T1, T2 and mcDESPOT Myelin Water Fraction Map Spanning Early Childhood

Target Audience: Developmental neuroscientists.

Introduction: Infancy and early childhood is a dynamic, yet vulnerable, period of brain development. In response to a complex cascade of environmental and genetic influences, the brain structurally and functionally matures through processes that include myelination, dendritic growth, and axonal pruning and others. It is broadly hypothesized that individual differences in these neurodevelopmental processes yield altered brain networks and functional connectivity patterns that, ultimately, result in differing behavioral and cognitive phenotypes\(^1\). In this context, developmental disorders, such as autism spectrum disorders, represent an extreme deviation from normality. To investigate the development origins of behavioral and other intellectual disorders, comprehensive characterization of normal brain maturation is first needed. In this work, we sought to perform quantitative MRI in a large sample of healthy and typically-developing infants, toddlers, and young children, with the aim of acquiring a series of gender-specific T\(_1\), T\(_2\) and myelin water fraction maps in children 2.5 months through 5.5 years of age.

Purpose: To develop a representative set of age and gender-specific parametric (T\(_1\), T\(_2\) and myelin water fraction, VF\(_M\)) maps spanning infant and early childhood brain development, 2.5 months through 5.5 years of age. Using acoustically-modified variants of the mcDESPOT relaxometry approach\(^4\), 424 whole brain T\(_1\), T\(_2\) and VF\(_M\) maps were acquired of typically-developing children. From these data, 14 mean male and female T\(_1\), T\(_2\) and VF\(_M\) maps were created corresponding to 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 42, 48, 54 and 60 months of age.

Methods: MRI Acquisition: 424 mcDESPOT datasets were successfully acquired from 231 healthy and typically-developing children (113 were scanned 2x; 51 3x; 13 4x; and 3 5x) between the ages of 2.5 months and 5.5 years of age broken down by age group as shown in Table 1. Data were acquired on a Siemens Tim Trio scanner during natural non-sedated sleep (children under 4 years) or while watching a movie using previously described customized ‘silent’ pulse sequences\(^5\). Three-pool mcDESPOT post-processing\(^6\), including correction for B\(_0\) and B\(_1\) field inhomogeneity, was used to calculate quantitative T\(_1\), T\(_2\) and VF\(_M\) parameter maps. These maps were subsequently non-linearly aligned to a custom study template in approximate MNI space\(^5\). 14 average male and female T\(_1\), T\(_2\) and VF\(_M\) maps were then calculated by averaging the participants within each age and gender demographic (Table 1). Regional masks corresponding to major white matter areas and pathways were derived from the MNI and John Hopkins white matter atlases, superimposed on each participant’s T\(_1\), T\(_2\) and VF\(_M\) maps, and mean values calculated. Trajectories of these parameters were then plotted to investigate their variation throughout infancy and early childhood.

Results & Discussion: Representative axial slices through the 14 mean male and female template T\(_1\), T\(_2\) and VF\(_M\) maps are shown in Fig. 1. These maps, and the corresponding raw data, are freely available to the research community at babyimaginglab.com/research.htm. Parameter trajectories, corresponding to frontal, occipital, parietal and temporal white matter regions are shown in Fig. 2. As has been shown previously, T\(_1\) and T\(_2\) decrease with age in approximate exponential fashion, whilst VF\(_M\) increases according to a sigmoidal function. The observed changes in T\(_1\), T\(_2\) and VF\(_M\) reflect a wide array of neurodevelopmental processes, including changes in axonal density and structure, water compartmentalization and, perhaps more specifically in the case of VF\(_M\), myelination. These results provide the first consistent set of quantitative parametric maps spanning this dynamic, yet vulnerable, period of neurodevelopment that coincides with the onset of many social, emotional, cognitive, and behavioral functions. The data represents a valuable resource, offering a normative template to which suspected at-risk populations may be compared, or for use in optimizing acquisition protocols for more conventional volumetric studies.