Neural Correlates of the Longitudinal Development of Phonological Processing in Early Childhood

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Target Audience: Pediatric Clinicians, Researchers, Neuropsychologists

Introduction: Abnormal white matter development is believed to be associated with the emergence of many neurodevelopmental disorders[1]. Dyslexia is a language-based learning disability characterized by deficits in phonological processing, a set of skills considered essential for reading acquisition[2] through word decoding. Phonological processing skills include awareness of and access to the sound structure of oral language[3], and include the ability to blend sounds together, isolate sounds, remove sounds, and match sounds. Children with dyslexia are also at heightened risk for other behavioral and emotional disorders[4]. Though believed to be neurobiological in origin, to our knowledge, no study has yet investigated the relationship between myelin maturation beginning in toddlerhood and later phonological awareness skills. Improved understanding of healthy white matter (WM) maturation during early childhood is central to provide insight into the processes underlying typical and atypical development[5], especially in the application of appropriate early intervention.

Purpose: In this work, we present longitudinal developmental trajectories using MWF and plotting myelin content in two brain regions of interest for typically developing children beginning in toddlerhood based upon their later phonological awareness skills measured at 4-6 years of age.

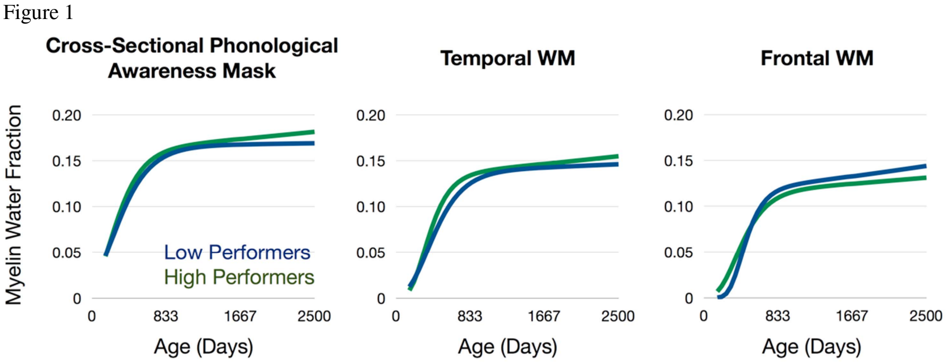
Materials/Methods: *MRI Acquisition:* All data was successfully acquired using a Siemens Tim Trio scanner from typically developing children during non-sedated sleep or while watching a movie. *Phonological Awareness (PA):* Once of age, the Comprehensive Test of Phonological Processing – 2nd Edition (CTOPP-2[3]) was administered to each participant as a measure of PA skills. The CTOPP-2 provides three subscales (Elision, Blending Words, and Sound Matching) that combine into a composite measure of overall PA ability. Participants were then grouped by their level of performance on the PA composite into low (n=7; PA standard score=84(10.8); mean age 1867 (247) days; 19 total scans;) and high (n=5; PA standard score=115(7.9); mean age=1740 (245) days; 23 total scans) performers. *Statistical Analysis:* Using non-linear mixed-effects regression[6-7], we calculated mean Gompertz curves for each group for whole brain WM, as well as frontal, temporal, occipital, parietal, and cerebellar WM, and the body, genu, and splenium of the corpus callosum. For each region, growth models were calculated independently for each ability group, and a single model was fit to the combined data. An F-Test was used to confirm the data supported 2 independent models. For confirmed areas, we then compared the curve parameters of the growth model between each group using an analysis of variance.

Results: Using cross-sectional data reported elsewhere (see Miele et al., ISMRM 2015 submission 6163), a mask was created showing significant separation between high and low CTOPP-2 PA performers. Longitudinal trajectories (see Figure 1) revealed sigmoidal Gompertz curves of increasing MWF by age. Each of the four parameters defining the growth curves was significant in each region. In the temporal lobe, high PA performers had greater myelin content ($p<.05$) compared to low PA performers; however, this pattern was reversed in the frontal lobe, with high PA performers having less myelin content ($p<.05$) than low PA performers.

Discussion: Significant differences between myelin and PA scores suggest a prominent role for white matter maturation in the development of phonological processing skills. Increased temporal myelin content seems to be particularly essential for the emergence of these skills at age appropriate levels, which is consistent with extant knowledge supporting the role of several temporal lobe gyri (e.g., angular gyrus, supramarginal gyrus, insula) in language processing and reading. At the same time, increased frontal WM in low compared to high PA performers may reflect a dynamic change in recruitment of frontal WM structures in less proficient decoders.

Conclusions: In this work we have sought to characterize the longitudinal trajectories of phonological awareness scores using MWF in a cohort of typically developing children. We have demonstrated that appreciable differences in phonological processing ability are significantly related to differing myelin content trajectories in the frontal and temporal lobes, suggesting a relationship between emerging structural and functional networks important for later reading acquisition. This work is important for clinicians to inform early intervention in decoding and other PA skills, and through increasing understanding of regional WM trajectories important for PA, provides support for the observed comorbidities of dyslexia with different behavioral and emotional disorders.

Figure 1



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