Neural Correlates of Phonological Processing in 4-6 year olds

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Target Audience: Pediatric Clinicians, Researchers, Neuropsychologists

Introduction: Phonological processing skill development is considered essential for reading acquisition[1]. Phonological processing skills include awareness of and access to the sound structure of oral language[2], and include the ability to remove sounds from words (elision), blend sounds together to form words, isolate sounds in words, and match sounds between words. Deficient phonological awareness is considered a core feature of the specific learning disability, dyslexia. Despite being understood as neurobiological in origin, the underlying mechanisms that lead to deficits in phonological processing and dyslexia remain elusive. Although numerous cortical areas [4-5] and white matter structures[6] and network hubs[7] have been implicated in dyslexia in adults, far fewer studies have investigated the neural mechanisms that may underlie these phonological processing deficits in children. Three studies in older children (ages 8-17) have reported decreased activity in the temporoparietal area[8-10], but to our knowledge, no study has investigated the neural correlates of phonological processing in young children.

Purpose: In this work, we report, to the first of our knowledge, the relationship between myelin content and performance on a measure of phonological awareness in young children.

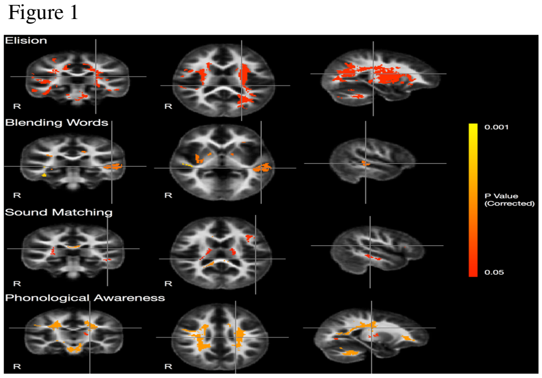
Materials/Methods: *MRI Acquisition:* Using a Siemens Tim Trio scanner, mcDESPOT data was successfully acquired from 25 typically developing children between 4 and 6 years of age (average age=1880(288) days, 60% male; 68% non-Hispanic) during non-sedated sleep or while watching a movie. Following MWF map calculation, each child's map was non-linearly co-registered to a common standardized space. Using the high flip angle T_1-weighted SPGR image acquired as part of mcDESPOT, the MWF maps were non-linearly co-registered to an age-specific template using the ANTS package[11]. A final (precomputed) transformation from each age template to MNI space was then applied[12]. Once all MWF maps were transformed to standard space, they were smoothed with a 4mm full-width-at-half-maximum 3D Gaussian kernel applied within a white and gray matter mask. *Phonological Awareness (PA):* The Comprehensive Test of Phonological Processing – 2[nd] Edition (CTOPP-2[2]) was administered to each participant within 7 days of scan (average age=1884(287) days) as a measure of PA skills. The CTOPP provides three subscales (Elision, Blending Words, and Sound Matching) that combine into a composite measure of overall PA ability. *Statistical Analysis*: Non-parametric correlations, corrected for multiple comparisons, were examined between myelin measures throughout the brain and the four CTOPP-2 indices using a single general linear model with each measure as a covariate for the others and including age as an additional covariate.

Results: Cross-sectional data revealed (see Figure 1) overall PA positively related at ($p<.05$) to myelin quantity in bilateral internal capsule, posterior cingulum, orbitofrontal region, and cerebellum. For individual subscales, elision was significantly related to the most diffuse myelin content of the three subscales in the cerebellum as well as frontal, parietal, and occipital lobes, and lateralized left hemisphere greater than right along the internal capsule. Blending Words ability was significantly related to myelin content in the temporal lobe including the left Heschl's gyrus. Lastly, Sound Matching significantly isolated to increased myelin content in the splenium, posterior limb of the internal capsule, superior temporal gyrus, and inferior frontal gyrus.

Discussion: The positive relationship between myelin content and all three subscales and overall composite of phonological awareness suggests that for certain areas, increased myelin is associated with more advanced phonological processing abilities. The diffuse area of myelin content implicated in higher elision abilities reflects the sensitivity of this index to impairment in single word decoding and similar processes impaired in dyslexia. The discrete left temporal relationship of myelin content with the ability to blend sounds together likely reflects the high load on auditory processing centers, while the involvement of myelin content in the splenium and internal capsule for the capacity to match sounds between words suggests increased need for cross-hemisphere and inter-hemispheric communication.

Conclusions: In this work we have sought to characterize the neural correlates of phonological processing skills in a cohort of typically developing young children. We have shown that underlying aspects of phonological awareness are significantly related to distinct WM correlates not only in the frontal subcortical system but also in the temporal lobe suggesting involvement of areas important for auditory and visual processing as well. This presented work provides an important step in understanding the areas of myelin content in young children that appear critical for processing of phonological information, and also highlights the diffuse WM architecture important to the emergence of this set of skills.

Figure 1



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