Abnormal White Matter Microstructure of Posterior Cerebral Tracts Correlates with Sensory Dysfunction, Impaired Multisensory Integration and Inattention in Children with Sensory Processing Disorders

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Purpose: Sensory processing disorders (SPD) affect 5-16% of school-aged children and cause long-term deficits in intellectual and social development [1,2]. Current theories regarding the underlying basis of SPD implicate primary sensory cortical areas and higher-order multisensory integration cortical regions. To our knowledge, the role of white matter microstructure in SPD has not been previously investigated. We hypothesize that reduced microstructural integrity of white matter fibers in primary sensory tracts and in tracts projecting to multimodal association areas may result in loss of the precise timing necessary for sensory impulse propagation which subserves sensory processing, multisensory integration, motor planning and the ability to suppress distracting stimuli.

Methods: 3 Tesla DTI was acquired from 16 boys with SPD and 24 age-, gender-, handedness- and IQ-matched neurotypical controls (TDC). All subjects were ages 8-11 years, had full-scale IQ > 70, and a stable medication regimen for over 6 weeks. Auditory, tactile, visual, multisensory, and inattention scores for all subjects were collected using the Sensory Profile, a parent questionnaire. DTI was performed at 2.2-mm isotropic voxel resolution with 64 encoding directions at b=2000 s/mm^2. FSL was used to calculate fractional anisotropy (FA), mean diffusivity (MD) and radial diffusivity (RD). Nonparametric permutation testing from tract based spatial statistics [3] was used to detect significant group differences in the white matter of the whole brain and to detect regions where DTI parameters were significantly correlated with behavioral variables at p<0.05, corrected for multiple voxel-wise comparisons with threshold-free cluster enhancement [4].

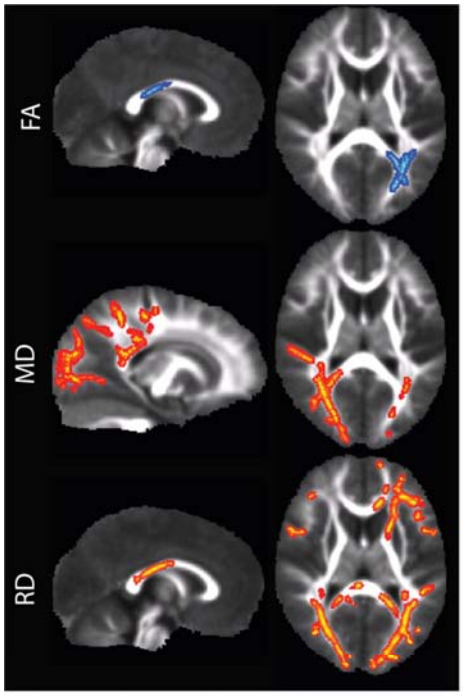

Figure 1: Regions of decreased FA in the SPD group are show in blue and regions of increased MD and RD in the SPD group are shown in red.

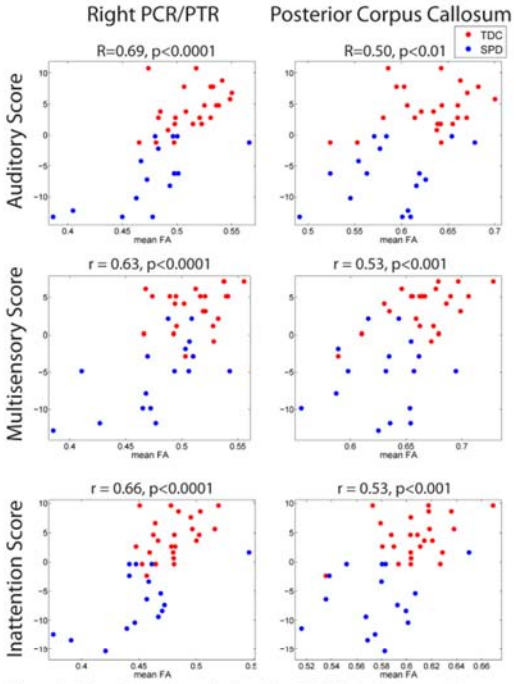

Figure 2: Mean FA in clusters in the right PCR/PTR and the posterior corpus callosum are found to be positively correlated with the auditory, multisensory, and inattention scores.

Results: Significant decreases in FA as well as increases in MD and RD were found in cerebral white matter in the SPD cohort relative to controls, primarily in posterior white matter tracts including the splenium, isthmus and posterior body of the corpus callosum, the bilateral posterior corona radiata and the bilateral posterior thalamic radiations, including the optic radiations. In Figure 1, the regions with significantly decreased FA and significantly increased MD and RD are shown. Significant positive correlations were observed between FA of specific frontal and posterior cerebral tracts and the auditory, multisensory, and inattention scores (r=0.5-0.7; p<0.001). In Figure 2 we plot the correlation between the behavioral scores and the mean FA of the clusters in the right posterior corona radiata (PCR) and the posterior thalamic radiations (PTR) and, separately, the posterior corpus callosum. Conversely, negative correlations were detected between RD in these tracts and the multisensory and inattention scores (r=0.5-0.7; p<0.001).

Discussion and Conclusion: To our knowledge, this is the first study to demonstrate reduced white matter microstructural integrity in SPD patients versus matched controls. We also show that DTI microstructural parameters in posterior cerebral tracts correlate strongly with sensory dysfunction and abnormal multisensory integration, while left frontal tract integrity correlates specifically with a behavioral measure of attention. Hence, like the behavioral scores, the DTI measurements in these tracts lie along a continuum rather than in two widely separated groups, reflecting the spectrum of sensory processing abilities in children. These imaging findings suggest abnormal white matter microstructure as a biological basis for SPD and also help to establish SPD as a distinct disease separate from overlapping clinical conditions such as autism and attention-deficit hyperactivity disorder (ADHD), which, at the level of group analysis, have different spatial patterns of abnormality on DTI [5,6] than the abnormal posterior cerebral white matter microstructure that we show here for SPD. Using brain-behavior correlations, we hope to move towards a more individualized model for understanding and treating children with sensory processing differences.

References: [1] Ahn et al., Am J Occup Ther, 2004; [2] Bundy et al., Am J Occup Ther, 2007; [3] Smith et al., Neuroimage, 2006; [4] Smith & Nichols, Neuroimage, 2009.; [5] Travers et al., Autism Res., 2012; [6] Tamm et al., Psychiatry Res., 2012