Structural Correlates of Fluid Reasoning Development Indexed by Diffusion Tensor imaging and Cortical Thickness Analyses

K. J. Whitaker[1], E. D. O'Hare[1], Z. A. Op de Macks[2], B. D. Johnson[1], E. Ferrer[3], and S. A. Bunge[1,4]

[1]Helen Wills Neuroscience Institute, UC Berkeley, Berkeley, CA, United States, [2]Developmental Psychology, Leiden University, Leiden, Netherlands, [3]Psychology, UC Davis, Davis, CA, United States, [4]Psychology, UC Berkeley, Berkeley, CA, United States

Introduction: The ability to solve novel problems, referred to as fluid reasoning (FR), is integral to theories of human intelligence; it is thought to serve as a scaffold for the development of many other cognitive functions. FR capacity increases very rapidly until late adolescence and early adulthood, and declines thereafter. The goal of this study is to investigate the relationship between structural changes in gray and white matter in the developing brain and behavioural measures of FR ability. Functional brain imaging studies in adults [1,2] and children [3,4] have implicated lateral prefrontal and inferior parietal regions in reasoning and relational integration. To date, no one has used diffusion tensor imaging (DTI) to investigate structural correlates of fluid reasoning ability in a developmental population. We hypothesize that strengthened connections between frontal and parietal cortices are critical the development of higher cognition.

Methods: *Behavioral data*: All subjects have completed performance IQ (block design, matrix reasoning) subtests of the Wechsler Abbreviated Scale of Intelligence (WASI), which serve as measures of fluid reasoning, and the verbal IQ (vocabulary) subtest, which measures crystallized knowledge. All subjects are native English-speakers with no history of neurological or psychiatric disorder.

Cortical thickness data: To date, 18 subjects aged 6.0-18.0 have been scanned at 3T on a Siemens Trio TIM MRI scanner with a high resolution MPRAGE T1-weighted sequence (TR = 2300ms, TE = 2.98ms). Semi-automated methods were used to match cortical geometry across subjects and to measure cortical thickness at every surface vertex using the Freesurfer software package [5]. Statistical maps of the correlation between thickness and cognitive performance at matched anatomical points were created for the whole brain.

Diffusion tensor imaging data: To date, DTI data have been acquired for 24 subjects aged 6.9–18.8. Acquisition parameters were: TR = 7900ms, TE = 102ms, b value = 2000, 64 non-collinear directions. DTI preprocessing was performed using the FMRIB software library [6]. Eddy-corrected fractional anisotropy (FA) maps were then aligned into a common space using the nonlinear registration tool FNIRT. Mean FA was extracted from a region of interest (ROI) surrounding cortex which showed a significant positive correlation (r = 0.70, p = 0.001) between age-corrected WASI matrix reasoning ability and cortical thickness.

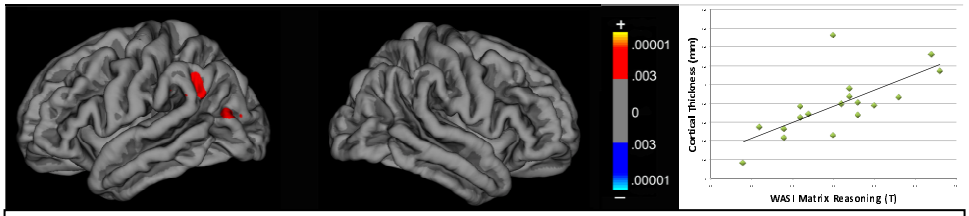

Figure 1: Increased cortical thickness in left BA 40 significantly correlates with age corrected WASI matrix scores (peak vertex: r = 0.70, p = 0.001)

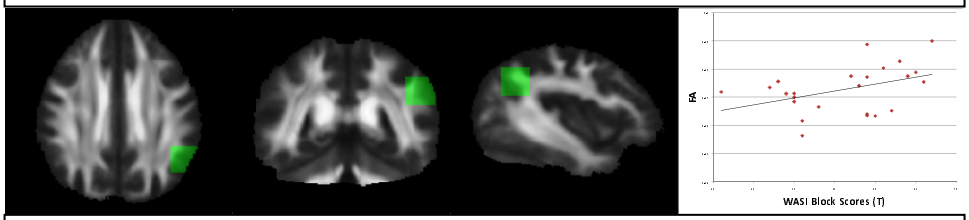

Figure 2: Increased white matter integrity (as indexed by FA) in an ROI surrounding left BA 40 significantly correlates with age corrected WASI block scores (r = 0.41, p = 0.023). Figure shows mean FA maps for the group and the ROI in green.

Results: Increased cortical thickness in left supramarginal gyrus (BA 40) was correlated with better matrix reasoning performance independent of age (figure 1, peak vertex: r = 0.70, p= 0.001). The mean FA of white matter surrounding this ROI (green, figure 2) was correlated with age-corrected scores of WASI block design, another reasoning task (figure 2, r = 0.41, p = 0.023). For all *a priori* regions of interest, we observed age-related increases in FA and concomitant decreases in cortical thickness.

Conclusions: While age related changes are dominant throughout the wide age range investigated in this study, structural changes in parietal cortex are predictive of individual differences in fluid reasoning ability through childhood and adolescence.

References: [1] Gray et al., *Nat. Neuro.*, (2003); [2] Wendelken et al., *J Cog. Neuro.*, (2008); [3] Wright et al., *Front. Hum. Neurosci.*, (2008); [4] Crone et al., *Dev. Sci.,* (2008); [5] http://surfer.nmr.mgh.harvard.edu/ [6] Smith et al., Neuroimage, (2004).