Left temporal white matter integrity predicts verbal memory in older children

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Introduction and Purpose: Despite evidence that white matter plays a critical role in physiological mechanisms of brain maturation and neural signalling, evaluation of relations between white matter and cognitive function in children has only recently received attention. Diffusion Tensor Imaging (DTI) indices of white matter integrity in various brain regions predict intelligence, reading, cognitive control, and processing speed in children. Maturation of white matter, particularly in the temporal lobes, is likely important in memory development, as increased efficiency of axonal and dendritic signal conduction may play a role in consolidating relevant neural networks. The neural basis of memory has been elucidated largely through the study of children and adults who have undergone surgery for intractable epilepsy. Little is known about the relationship between white matter and memory in normal development. To test these relations we acquired DTI indices of white matter and measures of memory in typically developing children.

Subjects and Methods: Participants were 17 children and adolescents ranging in age from 9 to 15 years (mean = 12.48 S.D. = 1.53) with a mean FSIQ of 117 (S.D. = 9.68). Imaging data were acquired with a GE LX 1.5T MRI scanner using a single shot spin echo DTI sequence with an EPI readout (25 directions, TE/TR=79/8300 ms, 28 contiguous axial slices, 3 mm thick, 128x128 matrix, FOV=26 cm, rbw = 125 kHz). Mean fractional anisotropy (FA) was calculated for 12 regions of hemispheric white matter defined on an anatomical T1 scan and registered with the DTI scan (see Figure 1) including left and right occipital (LO, RO), parietal-occipital (LPO, RPO), temporal (LT, RT), frontal-parietal (LFP, RFP), inferior frontal (LIF, RIF) and frontal (LF, RF) regions. Behavioural measures included tests of verbal (story recall, verbal associative learning, and verbal list learning) and visually mediated (recall of a complex design, recall of picture locations) memory. Correlations were used to examine the relations between age, FA, and memory.

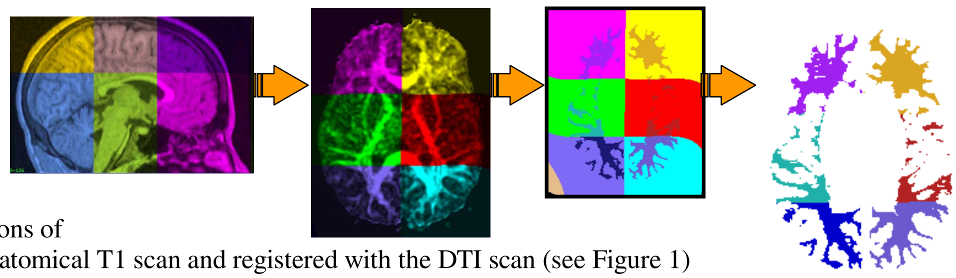

Figure 1: Registration of T1 regional template with FA map and white matter mask to define regions.

Results: The strongest increases in FA as a function of age were for areas of frontal white matter, including right frontal, left inferior frontal, and bilateral frontal-parietal regions ($r < .63$, $p < .05$). Age related increases were also evident for left frontal, right inferior frontal, right temporal and bilateral-occipital regions ($r < .56$, $p < .05$). Relations between FA and memory measures were examined controlling for FSIQ. All measures of verbal list learning were related to left temporal FA (see Table). Initial free recall was also related to right occipital FA, and delayed free recall was related to bilateral occipital and right frontal-parietal regions. In terms of visual-spatial material, copying of a complex design (Rey-O copy) was related to bilateral occipital FA, and delayed recall of this design was related to bilateral frontal-parietal FA (approaching significance for the right side, $p = .06$). Hemispheric white matter integrity did not predict story recall, verbal associative learning, or recall of picture locations.

Table 1

	LO	RO	LPO	RPO	LT	RT	LFP	RFP	LIF	RIF	LF	RF
Verbal Learning Initial Free Recall	.42	.51**	.32	.39	.59**	.42	.32	.34	.16	-.05	.19	.11
Verbal Learning Initial Cued Recall	.27	.31	.37	.41	.61*	.43	.48	.46	.29	-.03	.46	.15
Verbal Learning Delayed Free Recall	.62*	.68*	.40	.28	.57**	.46	.39	.48	.17	-.01	.13	.33
Verbal Learning Delayed Cued Recall	.41	.44	.43	.28	.62*	.48	.39	.50**	.34	.07	.45	.32
Copy of a Complex Design	.53**	.57**	-.01	-.04	.15	-.02	.20	.11	-.13	-.44	-.33	.08
Recall of a Complex Design	.42	.46	.38	.42	.42	.34	.49**	.48***	.38	.18	.17	.24

* $p < .01$, ** $p < .05$, *** $p = .06$

Conclusions: Three findings are notable. First, consistent with prior volumetric studies, white matter maturation as indexed by DTI appears greatest in frontal regions for older children and adolescents. Second, we found that left temporal white matter integrity is related to proficiency in verbal list learning in typically developing children and adolescents. In clinical populations, tasks that measure verbal learning appear most sensitive to memory networks sub-served by the temporal lobes. Our results are the first to identify the important role white matter integrity plays in these networks, particularly for a functional network that appears relatively stable by older childhood and adolescence. Finally, encoding and recall of complex visual information is related to white matter integrity in the occipital and frontal parietal regions. White matter connections appear important in supporting the neural mechanisms of memory representation.