Associations of White Matter Integrity with Discrepancies between Verbal and Performance IQ

Amy Margolis[1], Ravi Bansal[2] , Bradley S. Peterson[2]

1. The Division of Child and Adolescent Psychiatry, Columbia University and The New York State Psychiatric Institute, New York, NY.
2. The Institute for the Developing Mind, Children's Hospital of Los Angeles, and the University of Southern California.

OBJECTIVE

To assess the association of white matter integrity with the Verbal-Performance IQ (VIQ-PIQ) discrepancy in healthy individuals.

BACKGROUND

- The VIQ-PIQ discrepancy is common across childhood developmental disorders
- PIQ is typically greater than VIQ (PIQ>VIQ) in Autism[1,2], Dyslexia[3], and Language Disorder[4].
- VIQ>PIQ in children with Non-Verbal Learning Disability[5].
- Our previous studies demonstrate in healthy individuals the VIQ-PIQ discrepancy is associated with significant cortical thinning (VIQ>PIQ) or thickening (PIQ>VIQ) in posterior cortices and in frontal portions of frontostriatal circuits (inferior frontal gyrus and anterior cingulate cortex)[6].
- We have also demonstrated reduced activation of frontal cortices during the engagement of cognitive control as the magnitude of the VIQ-PIQ discrepancy increases[7].

METHODS

Participants

Diffusion Tensor Imaging MRI were acquired from 166 healthy control participants, age 6 to 79 years (Table 1).

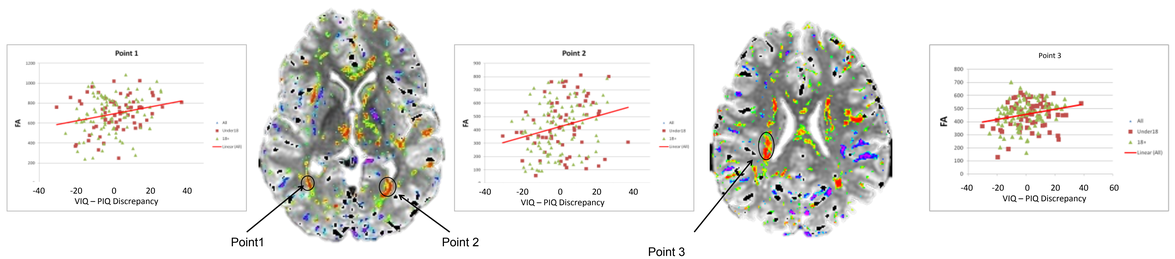
Table 1. Demographic data for the sample.

Characteristic	Total Sample			Children			Adults (over 18)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Number of Subjects	93	73	166	29	36	65	64	37	101
Percent	.56	.44	1.0	.17	.21	.39	.39	.22	.61
Mean Age	25.8	19.4	22.9	12.8	12.9	12.9	31.6	25.7	29.4
Youngest	7	6.0	6.0	7.0	6.0	6.0	18.0	18.0	18.0
Oldest	79	45.0	79.0	17.00	17.48	17.48	79.0	45.0	79.0
Max VIQ	139	139	139	139	139	139	137	137	137
Min VIQ	78	82	78	78	82	78	83	88	83
Mean VIQ	115	114	115	114	113	114	116	114	115
Max PIQ	137	146	146	132	146	146	137	144	144
Min PIQ	75	77	75	75	77	75	92	92	92
Mean PIQ	112	111	111	107	109	108	114	112	113
Max FSIQ	140	150	150	140	149	149	138	144	150
Min FSIQ	80	77	77	80	77	77	88	92	88
Mean FSIQ	115	115	115	112	115	114	117	116	116

VIQ-PIQ discrepancy score. The VIQ-PIQ discrepancy score was calculated with each participant's VIQ and PIQ score obtained from the WASI (Wechsler, 1999). To create the VIQ-regressed-on-PIQ score, we regressed the VIQ score onto the PIQ score, setting the intercept to zero, and saved the residual. These VIQ-regressed-on-PIQ residual scores were normally distributed.
Image preprocessing. For each subject, we computed for each DTI volume the resultant displacement relative to the first unweighted (B0) volume using the three translation parameters from mcflirt in FSL. For each subject we extracted the maximum resultant displacement throughout all DTI acquisitions. The DTI acquisitions were averaged and Fractional Anisotropy (FA) images were generated. Each subject's B0 images were coregistered to their own T2-weighted structural images using linear and nonlinear coregistration algorithms in FSL. T2 images of controls were coregistered to the "most representative" control image and then averaged to create a mean T2. All T2s were coregistered to this mean T2 image.
Analyses. Multivariate linear regression at each point on the reference surface examined associations of the VIQ-PIQ discrepancy score with FA. False Discovery Rate was used to account for the multiple correlations computed across the cortical surface. The *p*-value of the correlation between FA and VIQ-PIQ discrepancy score was evaluated using a Student's *t*-test.

RESULTS

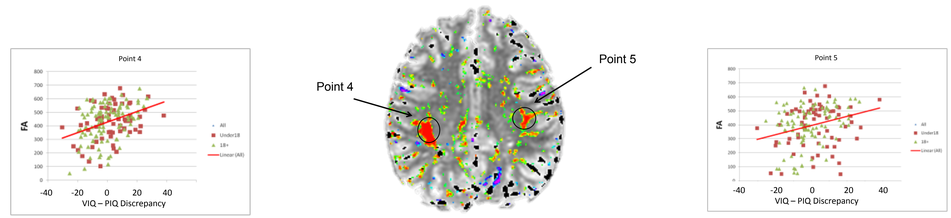
A. Corticobulbar and Corticospinal Tract



Posterior Corona Radiata

Posterior Internal Capsule

B. Superior Occipitofrontal Fasiclus



Parietal Lobe White Matter

C. Cingulum

D. External Capsule

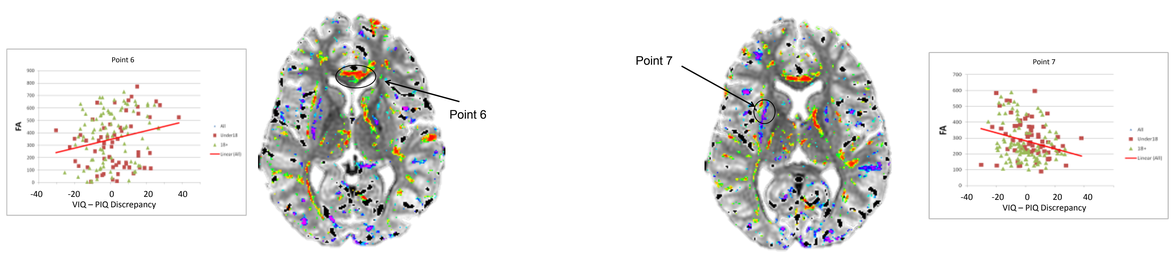


Figure 1. The VIQ-PIQ discrepancy score associated positively with FA in structures composing: A. corticobulbar and corticospinal tract (bilateral posterior corona radiata, posterior internal capsule); B. the superior occipitofrontal fasiclus (bilateral parietal lobe white matter); C. the cingulum; and D. the VIQ-PIQ discrepancy score associated inversely with FA in the right external capsule.

CONCLUSIONS

Voxelwise analysis demonstrated:

- positive associations of the VIQ-PIQ discrepancy score and FA in structures that compose the corticobulbar, corticospinal, superior occipitofrontal fasiculus and cingulum;
- inverse associations of the VIQ-PIQ discrepancy score and FA in the corticocortical association fibers of the right external capsule.

Possibly the VIQ-PIQ discrepancy derives from differences in tissue organization in discrete white matter fiber tracts that support independent information processing capacities.

- In regions/fiber tracts with positive associations between FA and the VIQ-PIQ discrepancy, perhaps increased tissue organization, fiber integrity, or fascicle coherence produces enhanced performance on verbal tasks and higher VIQ scores.
- In fiber tracts with inverse associations between FA and the VIQ-PIQ discrepancy, decreased organization and greater diffusivity produces poorer performance on spatial tasks and lower PIQ scores.

Alternatively, the discrepancy between performance on verbal and spatial information processing tasks may derive from alterations in white matter microstructures in a singular anatomical feature that underlies the discrepancy.

- In this case enhanced FA could occur in areas supporting verbal performance, resulting in higher VIQ scores, while in other areas of this putative anatomical feature decreased FA could produce simultaneously lower PIQ.

Our previous work identified variation in cortical anatomy associated with the VIQ-PIQ discrepancy score in regions that appear to underlie dysfunction in information processing that would specifically affect performance on IQ tasks.

Taken together these findings suggest a distributed network that explains one aspect of variability in normal intelligence and that is likely relevant to the genesis of many childhood developmental disorders.

REFERENCES

1.Charman T, Pickles A, Simonoff E, Chandler S, Loucas T, Baird G. IQ in children with autism spectrum disorders: data from the Special Needs and Autism Project (SNAP). *Psychological medicine*. Mar 2011;41(3):619-627.
2.Mayes SD, Calhoun SL. Ability profiles in children with autism: influence of age and IQ. *Autism : the international journal of research and practice*. Mar 2003;7(1):65-80.
3.Dietz NA, Jones KM, Gareau L, Zeffiro TA, Eden GF. Phonological decoding involves left posterior fusiform gyrus. *Human brain mapping*. Oct 2005;26(2):81-93.
4.Rice ML, Warren SF, Betz SK. Language symptoms of developmental language disorders: An overview of autism, Down syndrome, fragile X, specific language impairment, and Williams syndrome. [References]. (1):7-27.
5.Grodzinsky GM, Forbes PW, Bernstein JH. A practice-based approach to group identification in nonverbal learning disorders. *Child neuropsychology : a journal on normal and abnormal development in childhood and adolescence*. 2010;16(5):433-460.
6.Margolis A, Bansal R, Hao X, et al. Using IQ Discrepancy Scores To Examine the Neural Correlates of Specific Cognitive Abilities. *J Neurosci*. Aug 28 2013;33(35):14135-14145.
7.Margolis A, Pao, L., Tau, G. Zhao, G., Wang, Z., Peterson, B.S., Marsh, R. Associations of IQ Discrepancies with Brain Activation During Conflict Resolution Paper presented at: Society of Biological Psychiatry; May 14-16, 2015; Toronto Canada.

CONTACT

For more information please contact

Amy Margolis, PhD
Assistant Professor of Medical Psychology (in Psychiatry)
Division of Child and Adolescent Psychiatry
1051 Riverside Drive

margola@nyspi.columbia.edu

The authors report no conflicts of interest.