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Intellectual Ability is Correlated with Regional Brain Volumes in Normally Developing Children

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Introduction:

Background: Several prior studies have scanned children with magnetic resonance imaging (MRI) as their brains develop, to estimate growth trajectories for different structures. In general, there is a traveling wave of cortical gray matter growth and then loss during adolescence (Gogtay et al., 2004); trajectories peak earlier in children with higher IQ (Shaw et al., 2006). By contrast with studies that focus on the cortex, tensor-based morphometry (TBM) can map tissue growth rates throughout the brain, identifying regions where growth is slowed in disorders such as childhood-onset schizophrenia (Gogtay et al., 2008) and autism. Here we set out to determine whether growth rates and/or regional brain volumes are related to IQ, in normally developing children, after adjusting for sex differences. Based on prior work, we expected that measures of intellectual ability – specifically performance-related IQ - might correlate with temporal and frontal white matter volumes (Lange et al., 2010). To test this, we used tensor-based morphometry (TBM) to relate patterns of growth rates and brain volumes to various IQ-related measures in a group of 57 healthy children.

Methods:

MRI scans were acquired from 57 healthy adolescents (mean age: 15.8±5.2 years; 28 girls and 29 boys). Each subject received two high-resolution three-dimensional MRI scans with an average inter-scan interval of 2.3 ± 0.6 years. A high-resolution average brain template was created to represent common anatomical features of the study population. All individual brains were non-linearly aligned to the brain template, using an inverse-consistent elastic intensity-based registration algorithm (Leow et al., 2005). These mappings were used to quantify 3D patterns of growth (longitudinal change) and volume deficit or excess relative to the brain template (cross-sectional measures). At each voxel in the brain, multiple regression was used to assess associations between regional brain volumes and (1) age, (2) sex, and (3) the following IQ measures and subscales: full-scale IQ (FSIQ), vocabulary, block design, verbal IQ (VIQ), performance IQ (PIQ), simulation and matrix reasoning (MR). Multiple regression was used to assess associations between growth rates and the measures mentioned as well.

Results:

Normal growth patterns were shown with widespread white matter growth and some gray matter loss (see Fig. 1), but growth rates did not show detectable correlations with any of the IQ measures. Regional brain volumes, however, related to IQ and sex. There were sex differences in overall cerebral volume with boys having larger brains than girls of the same age (FDR q=0.05, critical P=0.04). This is consistent with past results (Lenroot et al., 2007). After controlling for sex differences, a higher FSIQ was associated with greater regional volumes in the temporal lobe white matter (FDR q=0.05, critical P=0.005). A higher matrix reasoning score - a performance-related measure - was associated with larger brain volumes in all white matter regions (FDR q=0.05, critical P=0.02). All other IQ measures showed no detectable associations with regional brain volumes, after controlling for sex differences.

Conclusions:

Conclusion: TBM analysis of brain MRI scans provides a noninvasive measure of brain volume and growth rates. Although brain growth rates had no detectable correlation with IQ in this sample, cerebral white matter volumes showed sex differences. After controlling for sex differences, temporal lobe volumes were correlated with two IQ measures, including matrix reasoning scores. These results are consistent with prior reports. They suggest a link between brain morphometry and cognition in studies of children and adolescents.

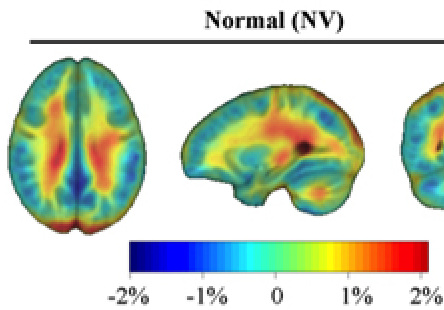

Figure 1. Group average map showing mean growth rates in this cohort of healthy adolescents. Growth rates are fastest in the deep subcortical white matter. Tissue growth rates are as high as 2% per year (*red colors*), with some gray matter reduction in the cortex (*blue colors*).

Figure 2. Sex differences in regional brain volumes showing percentage of volume difference in males v. females. The negative values suggest that brain volume is greater in males.

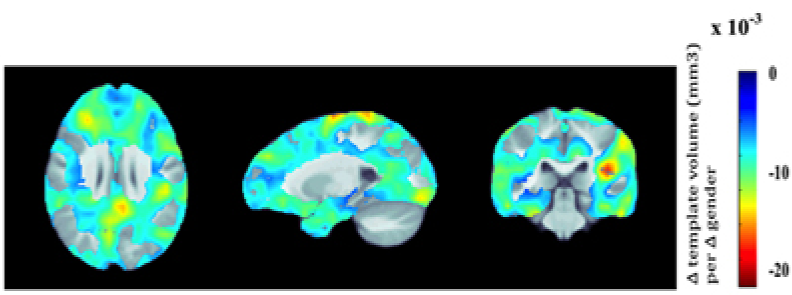

Figure 2. In brain regions where gender is significantly associated with volume, the regression coefficients are shown at each voxel. These values represent the estimated degree of tissue deficit or excess at each voxel (in cubic millimeters relative to the template) that is associated with gender.

Figure 3. Correlations between matrix reasoning scores and regional brain volumes are shown, in this cohort of normally developing adolescents. The positive values suggest that brain volume increases with MR IQ.

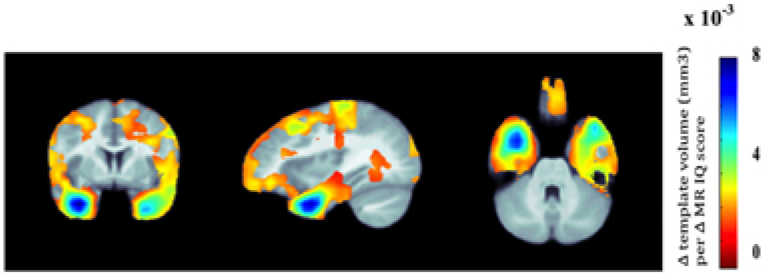

Figure 3. In brain regions where matrix reasoning score is significantly associated with volume, the regression coefficients are shown at each voxel. These values represent the estimated degree of tissue deficit or excess at each voxel (in cubic millimeters relative to the template) that is associated with MR IQ.

Lifespan Development

Normal Brain Development

Abstract Information

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