Evaluating Structural Brain Changes in Adolescence with Magnetic Resonance Imaging and Deformation Based Morphometry

W. R. Riddle[1], S. C. DonLevy[2], C. A. Wushensky[1], B. M. Dawant[3], J. M. Fitzpatrick[3], and R. R. Price[1]

[1]Radiology and Radiological Sciences, Vanderbilt University, Nashville, Tennessee, United States, [2]Pediatrics, Vanderbilt University, Nashville, Tennessee, United States, [3]Electrical Engineering and Computer Science, Vanderbilt University, Nashville, Tennessee, United States

Introduction

While it is well known that there are cognitive, behavioral, and emotional differences when children become teenagers, little is known about structural brain changes during this time. The purpose of the study was to use deformation based morphometry and color-coded overlays of the transformation Jacobian to show local volume changes between childhood and adolescence.

Methods

Longitudinal scans were obtained from eight subjects, six to seven years apart. The subjects were 9 to 12 years old on the first scan and 15 to 19 years old on the second scan. Three-dimensional MR volumes were acquired on 1.5 Tesla GE Signa scanners with a 3D T1-weighted sequence (SPGR, 124 sagittal slices, TI=400 ms, TE=3.6 ms, BW=10.4 KHz, matrix=512x224, and flip angle=20°). The first image volumes were acquired with 1.2 mm slice thickness and a FOV of 22 cm. The second volumes were acquired with 1.3 mm slice thickness and a FOV of 24 cm. The MR scans were converted to 1 mm isotropic volumes with trilinear interpolation, the second volume was aligned to the first volume with a rigid transform (3 translation vectors and 3 rotation angles), and an elastic transform between the two aligned volumes was calculated with optical flow deformation. For each subject, the color-coded transformation Jacobian of the elastic deformation field was used as an overlay for each of the MR slices to identify local volume changes. The red-orange-yellows indicate volume increases from 1.5 to over 3.5 times. The purple-blues-greens indicate volume decreases from 1/1.5 to less than 1/3.5 times. Volume changes between 1/1.5 times and 1.5 times were displayed as the gray scale image.

Results

Contractions of 1/1.5 to 1/3.0 times were observed in gray matter (cerebellar, cerebral, cingular gyrus, caudate, putamen, and thalamus). Expansions of 1.5 to over 3.5 times were observed in white matter (cerebellar, corona radiata, genu of corpus callosum, splenium of corpus callosum, frontal lobe, internal capsule, parietal lobe, pons, and temporal lobe. Figure 1 shows a transverse slice through the inferior caudate and putamen from one of the subjects.

Conclusion

Deformation based morphometry with longitudinal scans provides a method to study regional structural changes with brain growth and maturation.

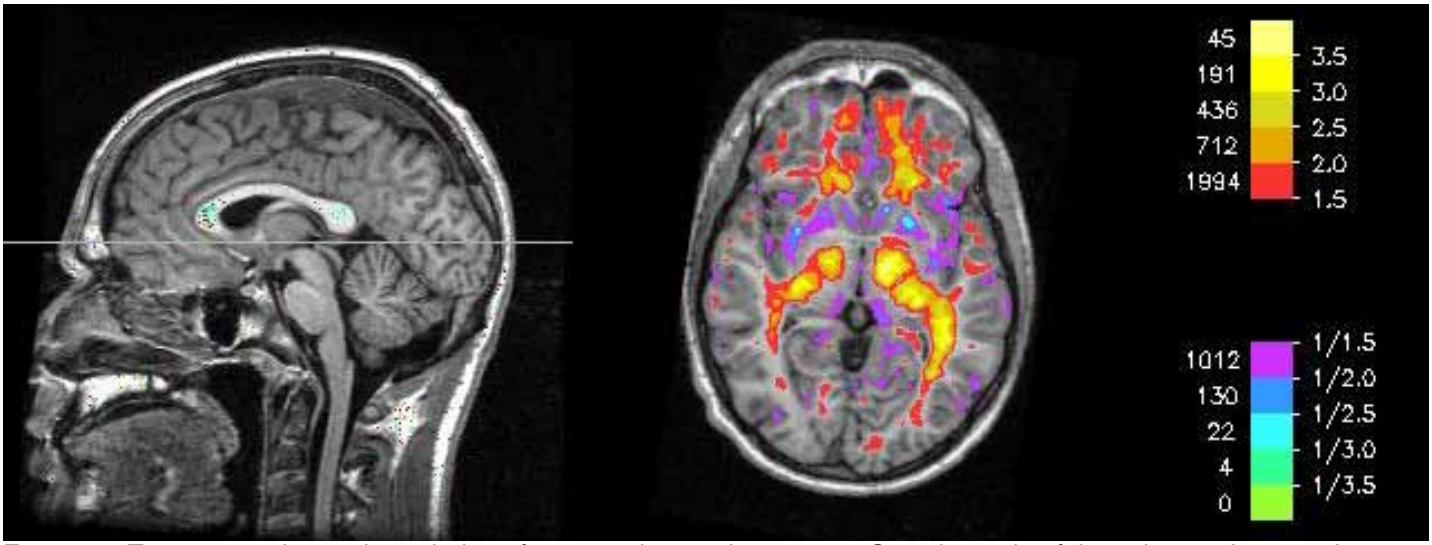

Figure 1—Transverse slice is through the inferior caudate and putamen. On either side of the color patches are the number of pixels containing that color and the range of Jacobian values that the color represents. The color overlays show contractions of 1/1.5 to 1/2.5 in the thalamus; contractions of 1/1.5 to 1/3.0 in the left and right caudates; and contractions of 1/1.5 to 1/3.0 in the left and right putamens. Expansions of 1.5 to greater than 3.5 times are shown in the internal capsule, frontal white matter, temporal white matter, and parietal white matter.