Human Brain Mapping 2008

Print

Abstract Number: 1026
Submitted By: Caroline Brun
Last Modified: January 6 2008

VOLUMETRIC DIFFERENCES IN BRAIN STRUCTURE IN IDENTICAL AND FRATERNAL TWINS COMPUTED USING RIEMANNIAN TENSOR-BASED MORPHOMETRY

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Introduction: Twin studies can disentangle the genetic and environmental influences on brain morphology, creating maps of their relative contribution to anatomical variance in a population. Here, we used Tensor-Based Morphometry (TBM) to study how genes influence normal brain structure, based on MRI scans of 10 monozygotic (MZ) twin pairs and 10 same-sex healthy dizygotic (DZ) twin pairs. Although TBM is increasingly used to study brain disease, this is one of its first applications to a genetic study.

Methods: 3D T1-weighted MRI scans of all 40 twins were skull-stripped and aligned, via 9-parameter transformation, to the Colin27 standard space. Preprocessed images were then fluidly registered to a common template, consisting of a typical DZ subject. For registration, we modified a previously developed elastic matching algorithm that regularizes the full deformation tensor S using a Log-Euclidean metric [1]. Our new fluid registration method [2] regularizes a Riemannian energy functional based on the rate-of-strain tensors ∇v (where the template velocity v is the time-derivative of u) instead of ∇u in [1]; this formally guarantees that the resulting mappings are one-to-one and invertible, but can still recover arbitrarily large deformations. From the registration, the displacement field (u) and deformation tensors S were derived (with $S = \sqrt{J^T J}$; J is the Jacobian matrix; $J = \nabla u^T \nabla u$). The average of the absolute difference in regional volume was computed from the determinant of S (one value per voxel), to measure relative volume expansion or shrinkage. Furthermore, the difference in the tangent of the geodesic anisotropy ($tGA(S) = tanh((trace((logm(S) – trace(logm(S)/3)*I)^2))^{1/2}$), a measure of the anisotropy in local shape changes, was also computed for both groups.

Results: Mean absolute differences in regional brain structure in MZ twins (Figure 1, left) and DZ twins (Figure 1, right) are shown as well as images of *tGA* in MZs (Figure 2, left) and DZs (Figure 2, right). Red colors indicate regions with large differences between twins; in regions colored blue, the difference is close to 0%. These preliminary results show that intra-pair differences in regional structure volumes were smaller between MZ twins than between DZ twins, especially in deep white matter structures. To a lesser extent, DZs were also shown to have greater differences in *tGA* than MZs, suggesting that this parameter may be under lesser genetic control.

Conclusions: This work will serve as the basis for mapping heritable aspects of brain structure, automatically computing maps of genetic parameters from a large twin database, and using full (matrix Lie group) multivariate statistics in the computation and analysis of the deformation mappings.

References: 1. Pennec X et al., Riemannian elasticity: A statistical regularization framework for non-linear registration, MICCAI (2005).
2. Brun C et al., Comparison of Standard and Riemannian fluid registration for Tensor-Based Morphometry in HIV/AIDS, MICCAI (2007).