Diffusion Tensor Fiber Tractography on a Population Averaged Brain

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Abstract: To date, DT-MRI tractography results have only been reported on an individual subject basis. In this work, we first show how a number of DT-MRI data sets can be spatially normalized to a standard anatomical template to create a population average. We then show that in major fasciculi, meaningful tractography results can be obtained from the population average and we compare our results with those obtained in an individual subject's brain.

Methods: DT-MRI data, with isotropic resolution (2.5 × 2.5 × 2.5mm), were collected from 60 slice locations from 11 healthy male volunteers (age = 33.3 ± 4.7 years). To generate the population average, it was first necessary to co-register the data sets. First, we selected one of the eleven subjects to act solely as the template data set. His T_2-weighted image was affine-matched to the T_2-weighted EPI template included in the 'SPM' software package[1]. The affine transformation matrix thus obtained was applied to the FA map of this 'template' subject to generate a template FA map in standard space. For each of the remaining subject's, the FA map was affine-matched to the template and the transformation matrix, required to match the individual's FA map and template maps, was subsequently applied to the individual's tensor volume data set. In contrast to co-registering scalar data, it was not sufficient to simply translate voxels within each DT-MRI volume according to the transformation matrix. Rotation and shear of the image volume reorients the tensors in each voxel and so the tensor elements must be modified accordingly. We used the 'Preservation of Principal Directions' algorithm[2] for this purpose. The ten spatially-normalized DT-MRI data sets were then combined to generate a population average in standard space. Tractography was then performed in different regions of the brain by first generating a continuous B-spline representation of the tensor field and then tracking using a fourth order Runge-Kutta method[3]. In order to 'dissect' one fasciculus from another where the fasciculi run close to one another, we sometimes defined two regions of interest (ROI) and only those tracts passing between the ROIs were retained for display. Elsewhere[4], we have shown how to quantify inter-subject intra-voxel orientational coherence of principal eigenvectors. We used this approach to identify seedpoints in regions of both high and low inter-subject intra-voxel coherence, in order to determine where tractography results in the average brain would or would not be representative of results in an individual brain. To test this, tractography was also performed in one of the individual brains, using the same seedpoints.

Results and Discussion: On visual inspection, we found that tracking results in the average and individual data sets agreed well in central structures such as the splenium and body of the corpus callosum. (Figure 1). This was expected from the high inter-subject intra-voxel coherence of principal eigenvectors found within these structures[4]. For application of DT-MRI to cognitive and psychiatric disorders in general, however, it would be interesting to focus not only on structures such as the corpus callosum, but also on the association pathways that typically run in the deep white matter of the hemispheres, and which do not have well defined and isolated trajectories. However, one may fear that the anatomical variability in the deep white matter may make meaningful tracking of the association pathways in a population-averaged brain impossible. Contrary to these concerns, we have shown that tractography results obtained from the group-averaged data set correlate well with results from an individual data set in the association pathways, such as the uncinate and inferior occipitofrontal fasciculi (Figure 2)

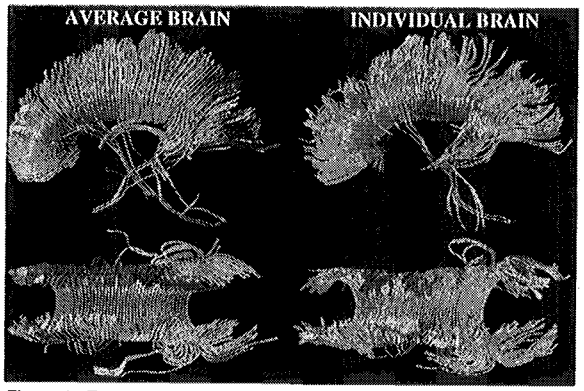


Figure 1: Tractography results in corpus callosum

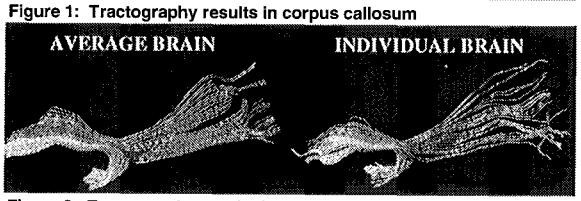
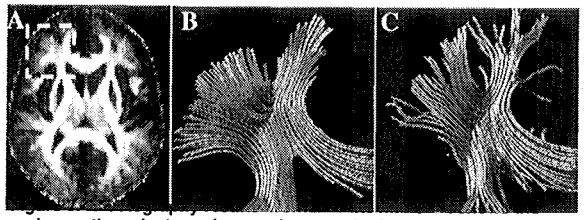


Figure 2: Tractography results in the inferior-occipitofrontal (darker) and uncinate (lighter) fasciculi (lighter).

In other regions of the brain, e.g. loosely defined 'frontal' white matter, where the inter-subject intra-voxel orientational coherence of principal eigenvectors was low, the tracking results obtained in the individual and population averaged brains were quite different (Figure 3). While this situation may be improved through the use of more sophisticated elastic registration techniques, we caution against the use of the population average to study connections in such regions, at least while using an affine approach.



region on the anisotropy image where seedpoints were placed. B shows results in the average brain and C shows results from the individual brain.

Conclusion: We have shown how to generate a population averaged DT-MRI data set in a standard reference space and have shown how, for certain structures, tractography can be performed in a meaningful manner on the average brain and that the results thus obtained are representative of results obtained in individual members of the population. Of particular interest was the ability to correctly summarise fronto-temporal connections by tracking in the averaged brain. This approach should facilitate comparisons of tractography results obtained in different subject populations.

References:

1. Wellcome Department of Cognitive Neurology, London, UK.
2. Alexander A, Gee J, Bajcsy R. *Proc MICCAI* 1999
3. Basser PJ *et al.* Magn Reson Med 2000; 44: 625
4. Jones *et al.* Submitted to ISMRM 2002