Estimation of Brain Connectivity using Diffusion Tensor Imaging and Resting Temporal Correlations

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Introduction: Both Diffusion Tensor Imaging (DTI) and temporal correlations in the resting state fMRI offer the potential to investigate the neuronal connectivity of the working human brain. Currently neither technique provides a well established method to quantify the strength of connections. While both measure different aspects of neuronal connectivity much can be learned by comparing how well they agree and where and why they differ.

DTI is widely used to investigate the connectivity of white matter fibers and thus the anatomical structure of distant brain connections. While local anisotropy measures are successfully used quantitatively, fiber tracking is mostly used in a qualitative, descriptive way. Here we propose a technique to quantify the strength of connection between predefined Regions of Interest (ROI). After standard DTI based fiber tracking, we integrate all possible geometric paths connecting those regions that can be made using one or more (up to six) contiguous fibers.

Resting connectivity is already developed as a “standard” procedure to quantify the strength of correlation, yet little is understood about why and how those correlations represent the actual strength of neuronal connectivity between any given regions. While the presence of connecting neuronal fibers (anatomical connectivity) is necessary for regions to interact, the strength of functional connectivity can presumably be modulated in various mental states and does not have to be directly related to anatomical strength of fiber bundles that can be observed via DTI.

Imaging : 27 normal subjects were scanned on 3T Siemens scanner. Resting correlations were evaluated in one 5 minute run of 210 images at TR=1500ms, DTI was performed using a sequence of 12 gradient directions and 8 averages.

Data Analysis :

Independent Component Analysis (ICA) was performed on the resting data using GIFT [1] toolbox to identify main brain systems. In 11 subjects, one component delineating motor system were identified and two (right and left) clusters selected as ROI’s. In 12 subjects the default network component was identified and two clusters (frontal in lingual gyrus and posterior in cingulate gyrus) were defined. Resting and DTI based connectivity was evaluated for those pair of ROIs.

DTI analysis was performed using the DTIstudio [2] software package. Fiber tracking was performed using the fiber assignment by continuous tracking (FACT) algorithm using FA threshold of 0.4 allowing bending angle of up to 70 degrees.

The resting time course was calculated for predefined ROIs, filtered with low pass filter with threshold of 0.1 Hz. The correlation between pairs of regions was calculated using partial coefficient, eliminating the contribution from the mean time course of whole brain.

Results :

Two measures of estimated connectivity in motor cortex were correlated (across subjects) with a significance of $p<0.02$. In the default mode network, the between-method correlation was weakly significant at $p<0.05$. In a control analysis using all ROIs defined blindly from all ICA components, no correlation between DTI and resting correlation connectivity measures was found. The measure of DTI connectivity was higher between ROIs defined in the motor and default networks than between other ICA-defined ROI pairs.

Conclusion : DTI and resting correlation techniques can be combined to quantify the strength of neuronal connectivity using both structural and functional informations and they show a high degree of similarity. The correlation between those measures was found in known brain systems and NOT in other regions of the brain. Convergence of these techniques may provide additional tool for interpreting those individual measures.

References:

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