Global Quantification of the Structural Brain Connectivity

Aina Frau-Pascual¹, Anastasia Yendiki¹, Bruce Fischl¹,², Iman Aganj¹,²
¹ MGH/HST Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Harvard Medical School
² Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology

Abstract

MOTIVATION: Existing literature on the relationship between the brain functional and structural connectivity is not fully consistent: while several studies have shown functional connectivity to be correlated with structural connectivity, strong functional connections have also been commonly observed between regions with no direct structural connection. Some of this variance has been found to be due to the impact of indirect structural connections, usually not considered in modeling.

GOAL: assess the impact of indirect connections in the variance between structural and functional connectivities, by using a global structural connectivity measure that allows us to account for direct brain connections, as well as indirect ones that would not be otherwise accounted for by standard techniques.

Methods: Global structural brain connectivity

We model brain connectivity globally as a circuit. [Chung et al., 2012, Aganj et al. 2014, Chung et al. 2017]

(a) We use a combination of differential Maxwell’s equations and Kirchhoff’s circuit laws, with diffusion tensors computed from dMRI [Tuch et al., 2001]. We solve the partial differential equations for a certain current configuration $\gamma_{i,s}$ between a pair of source $i$ and sink $s$.

We computed connectivity matrices according to various connectivity conventions: plain tract count, tract count normalized by the median length, considering tracts crossing the ROI or ending in the ROI, etc. - rs-fMRI processings: detrend, bandpass-filter at 0.01-0.08Hz, and smooth with a 6mm FWHM kernel. We stacked four sessions and computed the correlation matrix for the ROIs.

Results: structural vs. functional connectivity

We compare our global connectivity with the standard connectivity.

DATA analysis:
- 100 subjects of the WashU-UMN Human Connectome Project data set.
- MR processings: tissue segmentation and cortex parcellation into ROIs using FreeSurfer.
- diffusion MRI processings: reconstruction of the diffusion tensors (DTI) with DSI Studio, streamline (SL) tractography using DTI and generalized q-sampling imaging (GQI).

A two-tailed paired t-test between the two distributions in (b) revealed a statistic of $t = 36.97$ and a significance value of $p = 10^{-33}$ in the DTI case, and $t = 35.24$ and $p = 10^{-35}$ in the GQI case.

Summary

Using the proposed methodology, one can compute structural connectivity measures that are more correlated with functional connectivity than by using more standard approaches. This supports the hypothesis on the role of indirect connections in the relationship between functional and structural connectivity.