Impact of simulated lesions on communicability metrics of the brain structural network

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Purpose: In the present study, communicability related metrics of brain structural networks of 19 healthy subjects were analyzed. Communicability is a wider measure of connectivity based on the idea that potentially any path between two nodes will contribute to the total flow of information ([1], [2]). In previous studies, communicability metrics were found to be useful to detect differences in the network organization of patients versus controls also in peripheral areas distant from the main lesion focus ([2], [3]). This suggests that communicability metrics may be more sensitive to reorganizational changes of the brain network following a lesion. The specific aim of this study was to assess the sensitivity of communicability related metrics by the use of simulated lesions modelled as random and targeted attacks to nodes and single edges respectively.

Methods:

Data acquisition: Diffusion Tensor Imaging (DTI) was performed on a Siemens Trio 3T scanner using a spin echo (SE-) sequence (TR/TE=6800/93ms, matrix size=128×128, FOV 256×256 mm², 50 slices, slice thickness=2 mm, gap thickness=0 mm, pixel bandwidth 1346 Hz/pixel, max b-value 1300 s/mm², 42 non-collinear directions). In addition, T1-weighted anatomical images were acquired with a 12-channel head coil (176 sagittal slices, slice thickness=1.0 mm, FOV 256×256 mm², TR/TE=7.92/2.48 ms, Flip angle=16°, inversion with symmetric timing (inversion time=910 ms), fat saturation).

Network construction: Movement and eddy currents corrections were performed in FSL. After coregistration of diffusion weighted images with T1-weighted images an automated cortical parcellation was performed in FreeSurfer ('Destrieux' cortical atlas). The structures defined then served as ROIs for probabilistic fiber tracking in FSL. A connectivity map for each ROI was created starting from seeds placed in every voxel of the ROI considered (Tracking parameters: 5000 paths from each seed point, step size 0.5 mm, maximum trace length 500 mm and curvature threshold of ±80°degresses). An index of connectivity was assigned to each brain voxel, representing the proportion of generated paths that passed through it. For each subject, the undirected weighted network was created using 154 ROIs as nodes. An undirected edge aij between nodes i and j was established if a nonzero connectivity index was found to exist between the voxels of regions i and j. The edge weight was defined as the 

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Conclusion: Our analysis showed that metrics related to communicability were differently sensitive to lesions. In particular, Cm was found to be a sensitive measure to select targets for attacks. In addition, the high increase of CBC in peripheral nodes and the changes in Cm over the whole network confirmed that communicability metrics are sensitive to lesions also in regions distant from the main lesion focus. Overall, our results confirmed that communicability metrics are an interesting tool to study the effects of lesions and further analyses on single nodes may enable to better understand the mechanisms of reorganization following brain damage.

Figure 1: comparison of strategies for target selection.
Figure 2: sensitivity of the metrics in the case of nodes lesions.