Neocortical Network Damage Assessment by Homotopic Lesion Mapping on Healthy Subjects

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INTRODUCTION Assessing the impact of a lesion from cerebral vascular attack can be a difficult task for a clinician. Often the damage is not only confounded to it is local surroundings but has also global ramifications.
As previous work [1] did not model white matter related connectivity damage, we propose a method which can help visualize the impact of a lesion on the connectivity of the neocortical network by homotopically mapping the lesion on a control population and establishing before and after network conditions.

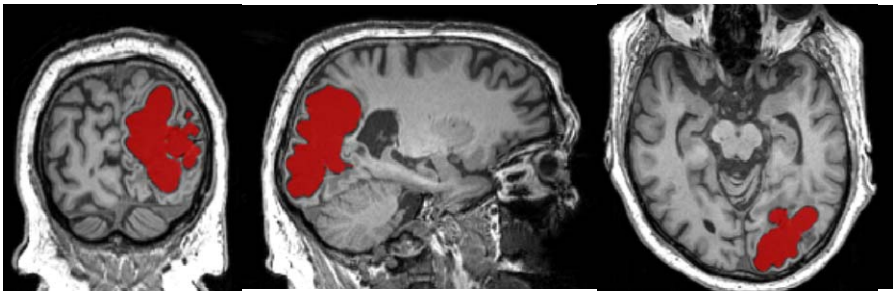

Fig. 1: visualized is an anatomical scan with the ischemic lesion in the right occipital cortex highlighted in red.

DATA 56 healthy subjects (38 females, 28 males 22.04 ± 2.42y) and 1 patient (male), who suffered from a cerebral vascular attack were scanned on a Siemens 3T TIM Trio system with a 32 channel head coil. Approval for the study was given by the local ethics comity. *Anatomical scans* were acquired using a 3D MPRAGE sequence with TE=3.03ms, TR=2300ms, TI=1100ms, a flip angle of 8° with 1mm isotropic voxels for all subjects. *Diffusion weighted imaging* volumes were acquired for the healthy subjects using a single-shot echo-planar imaging (EPI) sequence, with TE=101 ms, TR=13.0s, 2mm isotropic voxels and taken in 256 non-collinear directions at a b-value of 1500 s/mm^2. In addition, 28 volumes were acquired with b=0 s/mm^2.

METHODS All subjects where non-linearly mapped using FNIRT [2] to the MNI standard space. The patient's lesion was manually segmented using MRIcron (see Fig. 1) and transferred via the MNI template brain onto the individual healthy subjects. There, connectomes [3,4] where created using a template free approach [5] with and without integration of the lesion to establish connectivity parameters for the neocortical nodes. The parameters where finally mapped using surface based registration on the freesurfer standard brain where they were averaged across subjects.
We considered a reachability and distance based network measure δ to assess the impact of the lesion on a neocortical network. We defined δ for a particular node *n* to be zero if it is isolated and otherwise as the reciprocal of the average of all shortest distances between *n* and any other node, while we defined the distance between two unconnected nodes to be zero. The difference of $\delta(n)$ before and after adding the lesion, which signifies the increase of shortest path lengths, was investigated for the entire neocortex.

RESULTS δ-based damage scores were highest in the occipital cortex where the lesion was located. However neocortical areas in the contra-lateral hemisphere showed considerable increase of their shortest path length as well, as several shortest links to areas in the right hemisphere may have been severed. Also visible on the surfaces is how cortices in the left and right temporal lobe are affected.

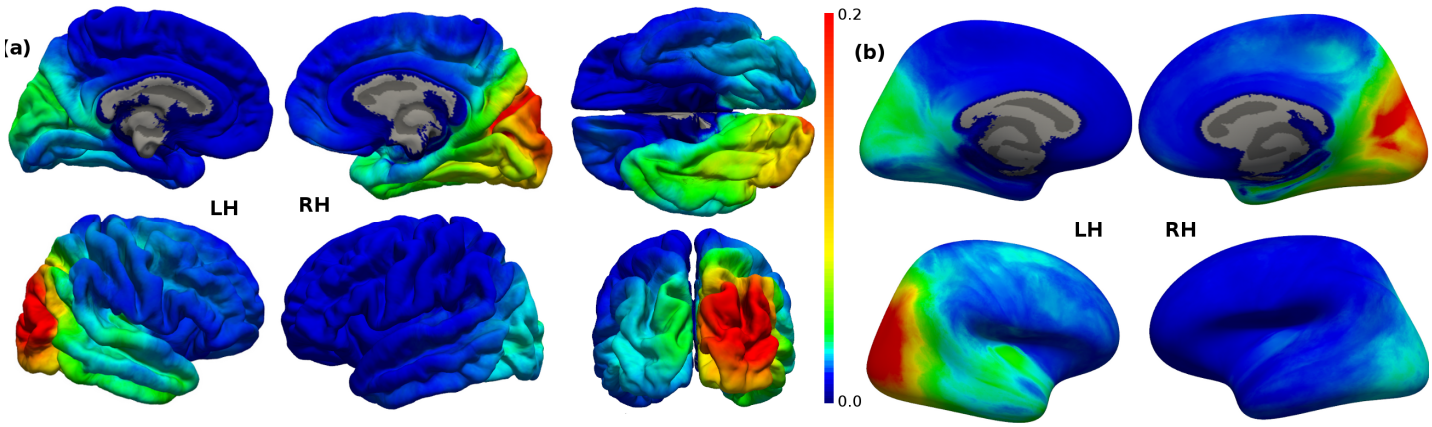

Fig. 2: shows the average damage map on the (a) pial surface and (b) on the inflated surface. Areas with higher (more red) values are considered to be more affected by the impact of the lesion.

DISCUSSION The impact of a lesion is difficult to assess without knowing the network conditions before the damage occurred. The proposed method circumvents this problem by simulating homotopic lesions on a population of healthy controls, such that a damage map can be derived which visualizes the strongest and most likely affected areas. Combined with the chosen reachability and distance based measure we were able to show how a neocortex can be locally and globally affected by a lesion. An important error source of the proposed method lies in the precision of the lesion mapping process, as white matter structures can be imperfectly mapped and therefore incorrect lesions simulated.

REFERENCES **[1]** *J. Alstott et al,* Plos Biol (2009); **[2]** *S. Smith et al,* NeuroImage, 23:208-219 (2004); **[3]** *P. Hagmann et al*, PLoS Biol 6, e159 (2008); **[4]** *O. Sporns et al.*, PLoS Biol 1, e42 (2005); **[5]** *E. Nijhuis et al,* Proc. ISMRM, 676 (2011);