Contribution ID: **4** Type: **Poster**

Sulcal-based alignment of postmortem human brains used to build the Jülich cytoarchitectonic atlas

Wednesday 26 October 2022 16:00 (1 hour)

Cytoarchitecture, which is a basic principle of brain microstructure used to define parcellations, may be related to the development of the cerebral cortex. In primary areas, the primary sulci predict the architectonic subdivisions [1], but the link is much less clear in associative areas. In this context, we first contribute a dedicated alignment method using DISCO+DARTEL [2] to register the 14 first Jülich postmortem human brains. To account for variations of the cytoarchitectonic parcellation between individual brains, a 3D probabilistic atlas called the Jülich-Brain has been built from 23 postmortem brains [3]. In our study, we also build a 3D probabilistic atlas based on the aligned areal data sets (Version 2.9) of the 14 postmortem brains, which may be of interest to compare with the Jülich-Brain.

This study is performed on the 14 grey/white maps inferred from histological sections in Forschungszentrum Jülich. To perform the DISCO registration, sulci are extracted from the brains using the "Morphologist 2021" pipeline [4] of BrainVISA [5]. Due to artefacts in histology-based simulated grey/white maps, a dedicated cleaning procedure based on mathematical morphology and semi-automatic drawing is tuned for each brain before using Morphologist.

DISCO is embedded in a toolbox of BrainVISA. We adjust the value of the DISCO regularizing parameter "coef_sigV" from 20 to 30 in order to impose more regularity on results and use other default parameters. Sulci chosen to drive the DISCO registration are selected throughout the whole brain to achieve a reasonable spatial sampling of constraints (cf. Figure 1-A). DARTEL [6] is performed from the standalone version of SPM12 software, and the regularization parameters of all iterations are set to four times the default values to make the deformations smooth enough. Grey and white matter binary data, which are aligned using the DISCO process, are considered as inputs for this algorithm.

We superimpose on the MNI-ICBM152 template all sulci constraining the DISCO registration before DISCO, after DISCO and DISCO+DARTEL deformation in Figure 1-B. As expected, the DISCO registration greatly minimizes the sulcal dispersion. Compared with the DISCO registration alone, the combination of DISCO and DARTEL registration seems to be more effective in minimizing the sulcal dispersion, especially for the posterior lateral and the collateral fissures. We also show here the sulci of first 10 brains (L/R hemispheres) in colin27 space with the cytoarchitectonic maps in Brodmann areas 44 and 45 in Figure 1-C.

To build the 3D probabilistic atlas of the cytoarchitectonic maps of all subjects, we first transform all the maps of areal volumes of each subject in MNI-ICBM152 space using DISCO+DARTEL. Next, we iterate over all the areas, and for each take the average of the aligned maps, then apply a Gaussian smoothing with a 5 mm smoothing strength. Finally, we choose the maximum probability for each voxel and keep only those voxels that the area accounts for more than 8% of the voxel itself, then give them the corresponding labels. We project this atlas on the FreeSurfer mesh of the MNI-ICBM152 template at "fsaverage" resolution in Figure 1-D.

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Session Classification: Poster Session