Multimodal Connectivity-Based Parcellation of the Brain

HUMAN BRAIN ORGANIZATION SP2

Human Brain Project

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Multimodal connectivity-based parcellation (CBP) delineates distinct sub-regions within a larger region of interest (ROI) based on multiple imaging modalities. First, connectivity between ROI voxels and other parts of the whole brain are computed. These features are then used to identify distinct groups of voxels. These represent functional modules of the brain that provide a priori information for modelling and pathophysiological investigations.

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1. BACKGROUND

Human and non-human brains are not homogeneous and assumed to be organized in distinct modules (Brodmann, 1909). These modules differ from their neighbors in their structure, connectivity, and function (Eickhoff et al., 2015).

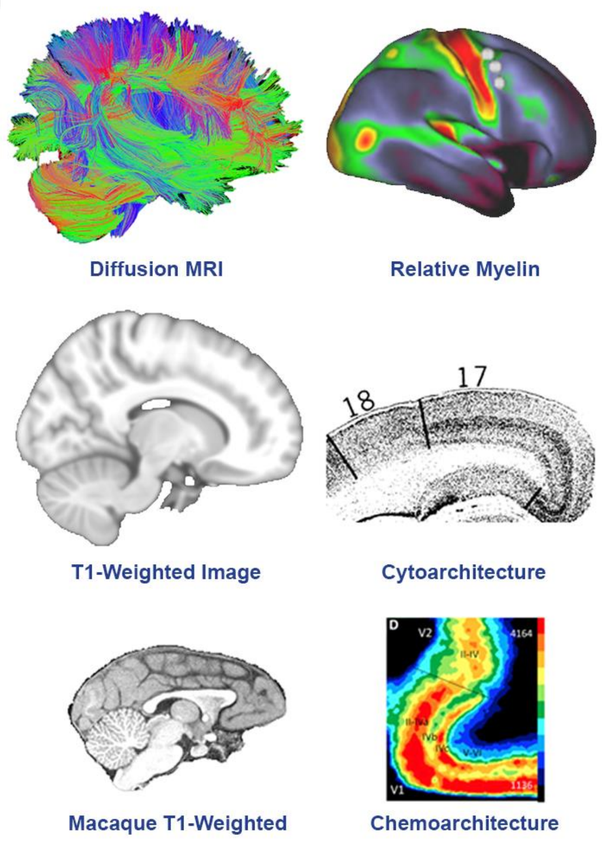

Figure 1. *Examples of different brain data sets that can be used to define brain areas of the human or macaque (bottom left) brain.*

2. MULTIMODALITY

In-vivo brain parcellation uses non-invasive neuroimaging data. In the CBP context modalities refer to different non-invasive imaging measurements, such as resting-state (RSFC) for task-independent functional connectivity, meta-analytic connectivity modelling (MACM) for task-dependent functional connectivity and co-activation patterns, and probabilistic diffusion tractography (PDT) for anatomical fiber-connectivity. Multiple modalities are used in order to gain insight into different aspects of brain organization. *Figure 2* shows three different image modalities (top) used in CBP of the human brain.

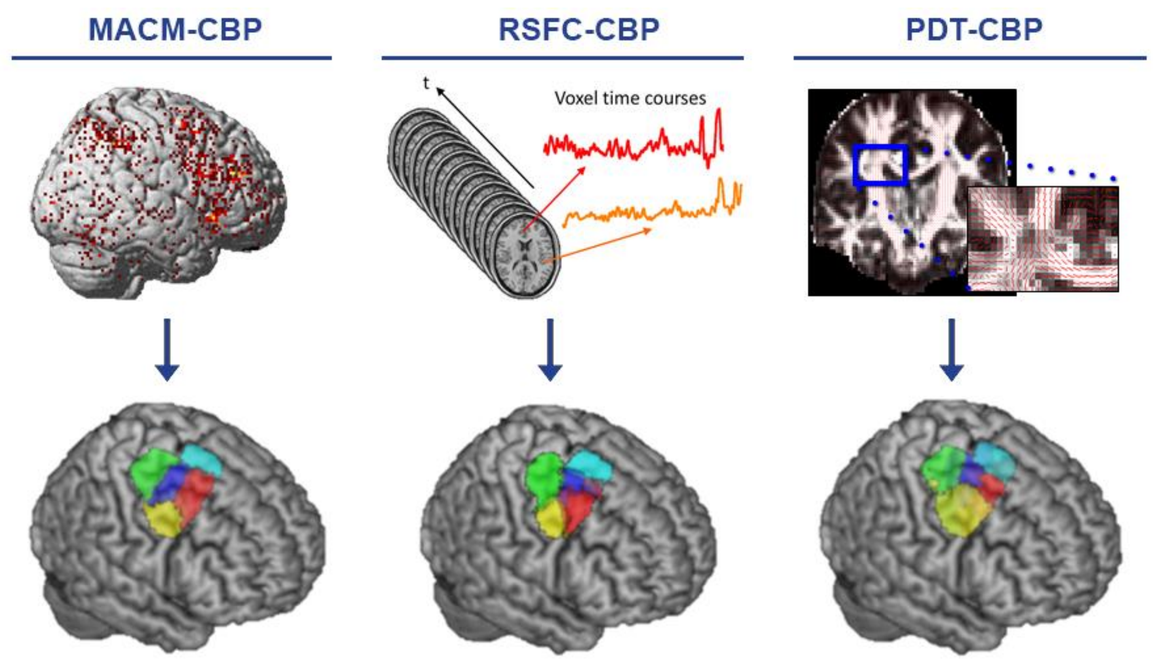

Figure 2. *Connectivity-based parcellation using three different modalities, resulting in three separate cluster solutions.*

3. BRAIN DATA

The first step in CBP is to acquire the data that will be used. This can be measured by yourself, or alternatively (and preferably) taken from existing large databases such as the Human Connectome Project or 1000 brains project for resting-state functional connectivity, structural connectivity, and diffusion MRI data, and the BrainMap task-related functional connectivity.

4. CONNECTIVITY-BASED PARCELLATION

Next, we group voxels into clusters so that voxels within a cluster show similar features, whereas between clusters the features are as different as possible. This reveals the underlying latent structure reflecting the heterogeneity of the region of interest and hence the modules of brain organization. Once defined, the ensuing clusters (i.e., brain areas) can be characterized in detail regarding their structure, function, and connectivity, but moreover also their relation to inter-individual variation of behavior and affection by brain disorders. *Figure 2* shows k-means clustering results performed on three different modalities: MACM-CBP, RSFC-CBP, and PDT-CBP respectively. *Figure 3* outlines the entire process from selecting a region of interest to obtaining the most viable cluster solution.

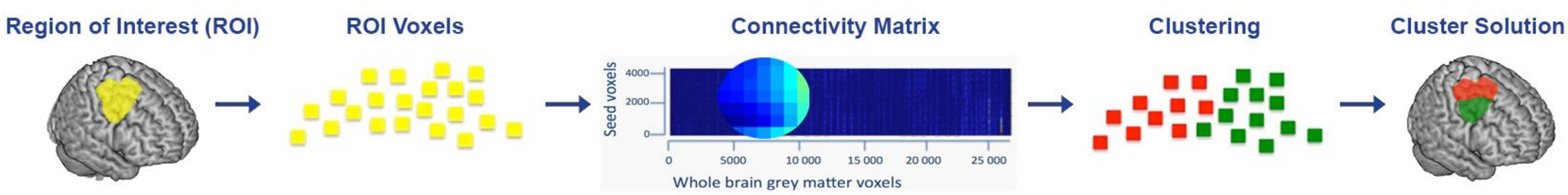

Figure 3. *Connectivity-based parcellation procedure, from ROI to the cluster solution involving computation of the connectivity matrix and clustering.*

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5. INTERPRETATION

What does it mean to divide the brain based on differences in connectivity? CBP aims to identify an optimal clustering solution that best describes the data. This can subsequently be used as a common reference space for brain imaging studies and has different meanings per modality used.

For instance, MACM-CBP reveals clusters that are probably functionally distinct modules, while PDT-CBP derives clusters that most likely reflect connectivity-defined modules. A multimodal approach is used because each modality reveals a different aspect of brain organization.

INSTITUTIONS

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