Unsupervised Parcellation of Precentral Gyrus using Resting-state fMRI

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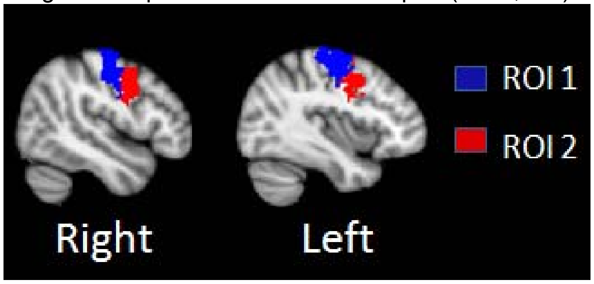
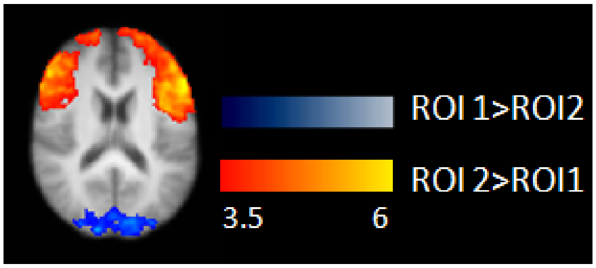
Introduction:
Anatomical landmarks (i.e. sulci and gyri) are commonly used to identify regions of interest (ROIs) for brain imaging studies. However, there is no evidence that such ROI definition reflects functional specialization. In fact, previous studies showed that some of the anatomically defined ROIs can be subdivided into sub-regions based on their anatomical [1,2] or functional [3,4] connectivity patterns. Most of the parcellation approaches use clustering algorithms in which the number of clusters should be known and assigned in advance. This limits their application to cases where we have a reasonable guess about the number of sub regions. We implemented a recently introduced [5] clustering method that automatically estimate the number and size of sub-groups, and tested it to parcellate precentral gyrus of human brain. Our objective is to investigate the ability of the implemented method in dividing human precentral gyrus into sub regions.

Method:
Eighteen healthy male subjects, age 45 ± 5, were scanned with 3T Trio MRI (Siemens Medical Solutions, Erlangen, Germany). 200 volumes of echo planar imaging (EPI) were acquired (TR = 2000 ms, TE = 29, flip angle = 90, 36 slices, matrix = 64x64; FOV = 200x200 mm^2). Post-acquisition processing was performed by means of locally developed software in MATLAB along with the FSL (http://www.fmirb.ox.ac.uk/fsl/) software package. fMRI processing included motion correction, correction for magnetic field inhomogeneity, slice timing correction, spatial smoothing, temporal filtering, and extraction of white matter, CSF, and motion confounds. Two masks were generated over left and right precentral gyrus in the MNI standard space, using the AAL atlas. The masks were then transformed into each subject's functional MRI space. Each ROI was further parcellated using the block diagonalising method [5]. First the cross correlation matrix of time series of all voxels inside each ROI was calculated and then the voxels were reordered to generate a block-diagonilized correlation matrix using a simulated annealing optimization algorithm. The voxels were subsequently clustered using least square fitting to find the optimum number and size of clusters that best fit block-diagonal boxes to the reordered correlation matrix. Each individual cluster was transformed into the MNI standard space. Group consistency was measured with the method proposed in [6]. For each subject a cluster-similarity matrix was generated in which its a_{ij} element was assigned the value 1 if ith and jth signals were grouped into the same cluster and 0 otherwise. Averaging the cluster-similarity matrices across subjects generates a symmetrical matrix whose a_{ij} element shows in how many subjects' voxels ith and jth are in the same cluster. This matrix is then clustered using the same block-diagonalising algorithm discussed above, to generate sub regions that are consistent among subjects. Average consistency of each sub-region is defined as the average number of subjects with a consistent sub-region , divided by the total number of subjects (i.e., 18). Lastly, reference signals were extracted from each sub-region and voxel-wise connectivity analyses were performed to investigate differences in connectivity patterns between identified sub-regions.

Results:
Using block diagonalising method, Precentral gyrus is sub divided in two parts for both left and right hemisphere (top figure): the posterior part (ROI1, blue) has an average consistency of 80% in left and 76% in right hemispheres and the anterior part (ROI2, red) on average has 73% consistency in left and 65% consistency in right hemisphere. Voxel-wise connectivity analysis shows that the posterior part has significantly higher connectivity to the visual cortex, whereas anterior part is more connected to middle frontal gyrus (bottom figure).





Conclusion:
Precentral gyrus is known to be responsible for motor tasks and is generally employed as a single region in brain connectivity studies. Using the block-diagonalising clustering method, we were able to divide it into two parts with significantly different connectivity patterns; the posterior part that encompasses hand area is more connected to the visual cortex whereas the anterior part that encompass face area is more connected to middle frontal gyrus. Identifying distinct functional units of brain is a key step in brain connectivity studies. This study highlights the importance of using a parcellation method that can automatically detect the number of clusters.

References:
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