Cortical parcellation of Broca's region based on functional connectivity glyphs

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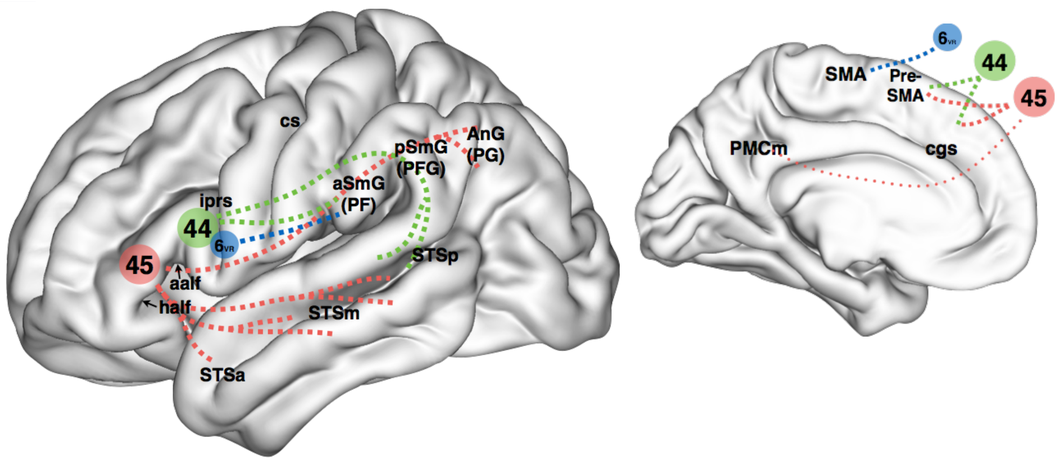
Aim

- To employ prior anatomical knowledge and resting-state functional connectivity, together with a novel visualization method, to manually parcellate the cortex of human brain in vivo.
- The manual parcellations provide training datasets for the development of automated parcellation algorithms with comparable precision at the individual level.

Introduction

1 Distinct connectivity patterns of ventrolateral frontal cortical areas



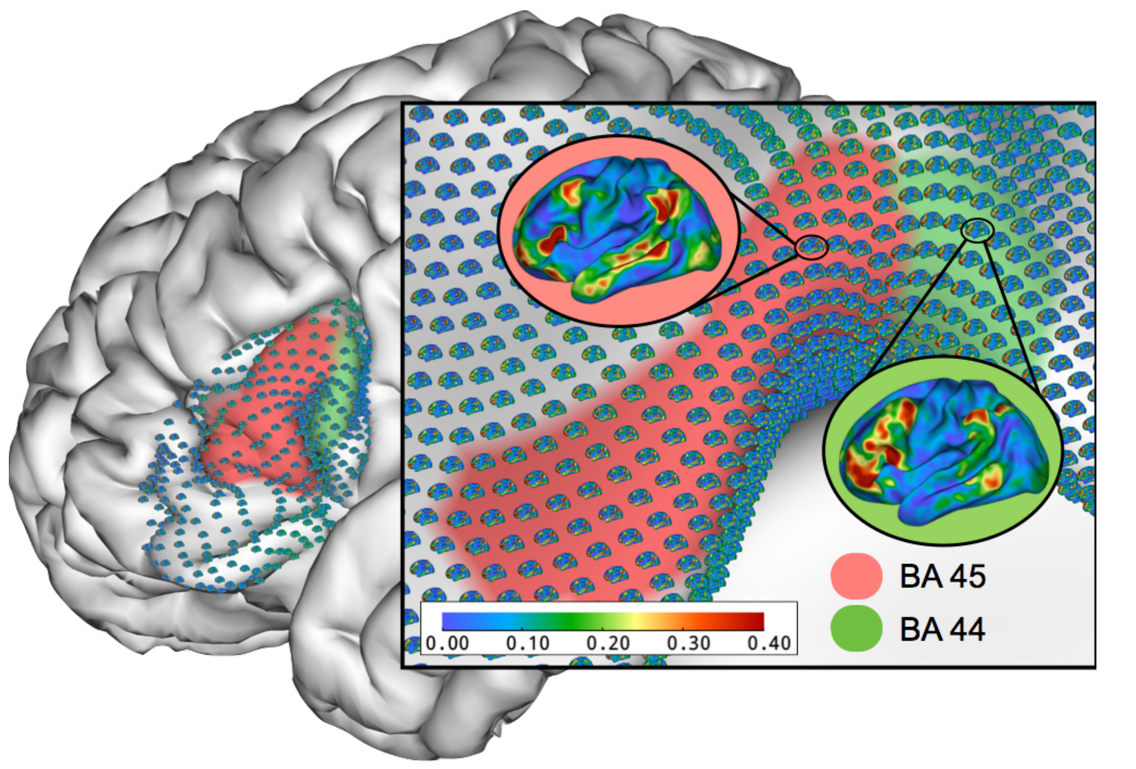
Schematic representation of the distinct connectivity profiles of Brodmann areas 45 and 44, and neighboring area 6VR, based on: [1,2,3]

Data

65 ICA-FIX denoised resting-state fMRI datasets from the Human Connectome Project[4]. Additional processing steps: (1) Time-series data of the left hemisphere extracted (2) 2mm surface smoothing applied (3) Node-wise Pearson correlation matrix computed and Fisher's r-to-z transformed (4) Correlation matrices averaged over four rfMRI runs for each participant (5) Resulting data visualized in brainGL[5].

Methods

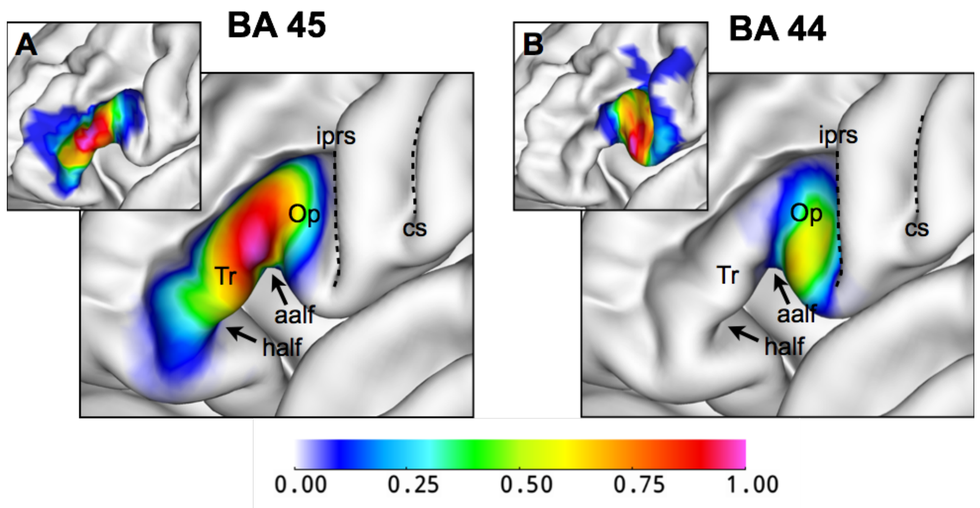
2 Functional connectivity glyph visualization for manual cortical labeling



Manually labeled areas 45 and 44 for one individual subject on the pial and inflated surfaces with functional connectivity glyphs in the ventrolateral frontal cortex. Each glyph represents the full functional connectivity profile from that node to the rest of the cortical surface. Glyph color indicates correlation value. Connectivity of areas 44 and 45 can be distinguished in the anterior temporal and inferior parietal regions.

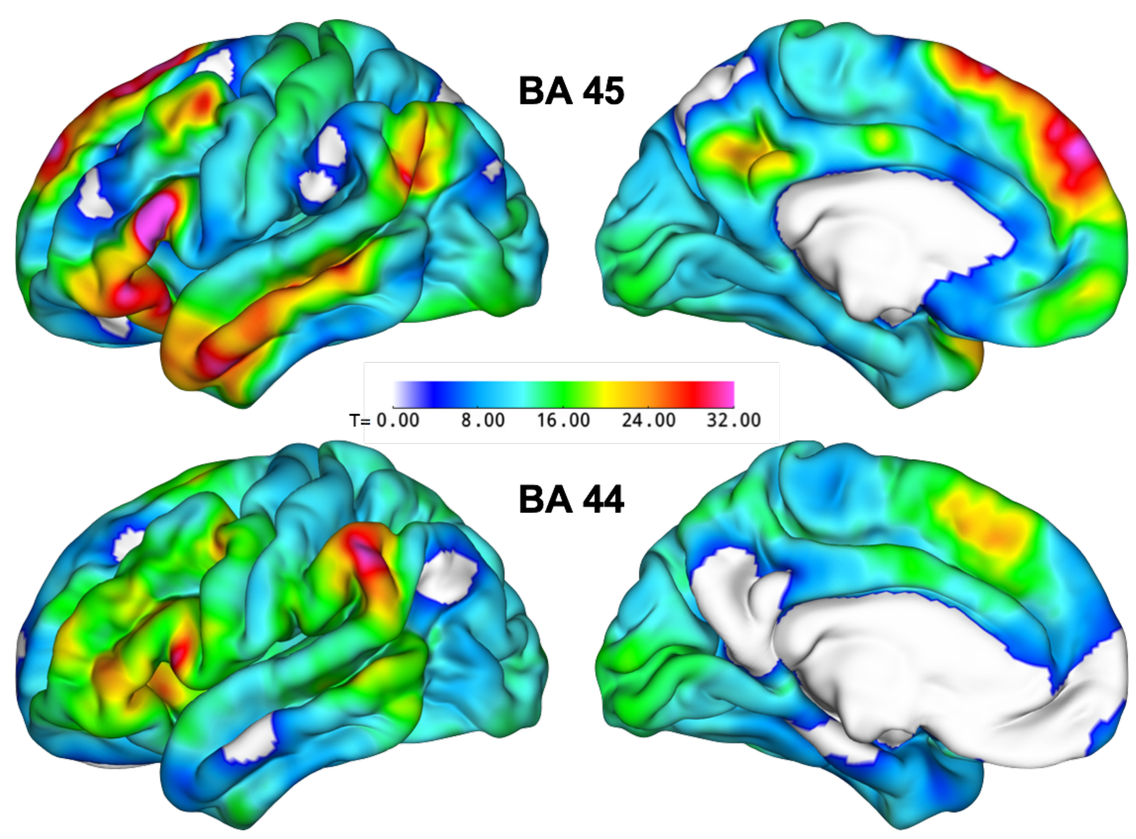
Results

3 Functional connectivity-based probabilistic area maps



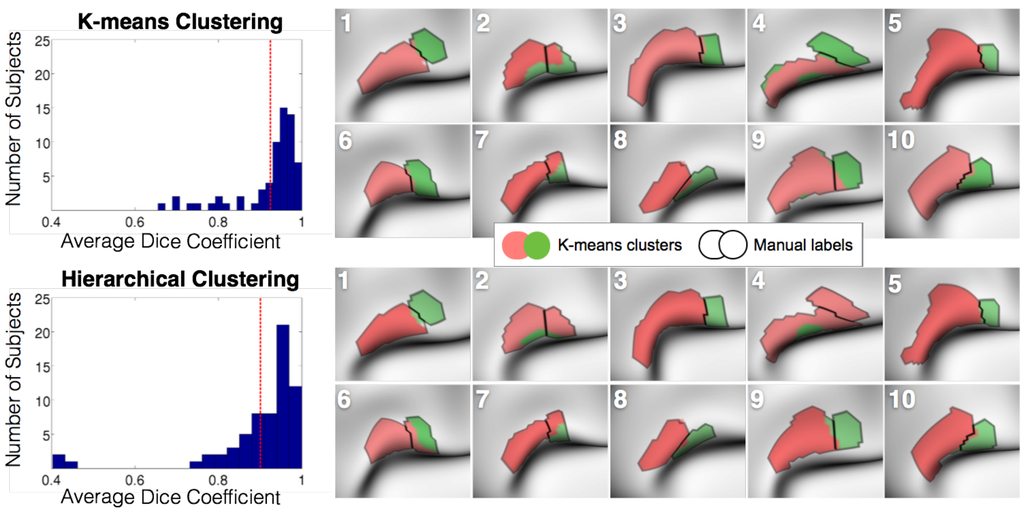
Group-average masks of each area. Color indicates probability of mask overlap across all 65 subjects. (A) and (B) show cytoarchitectonic probability maps from the Juelich Brain Model[6] on the fsaverage5 surface.

4 Average functional connectivity across subjects



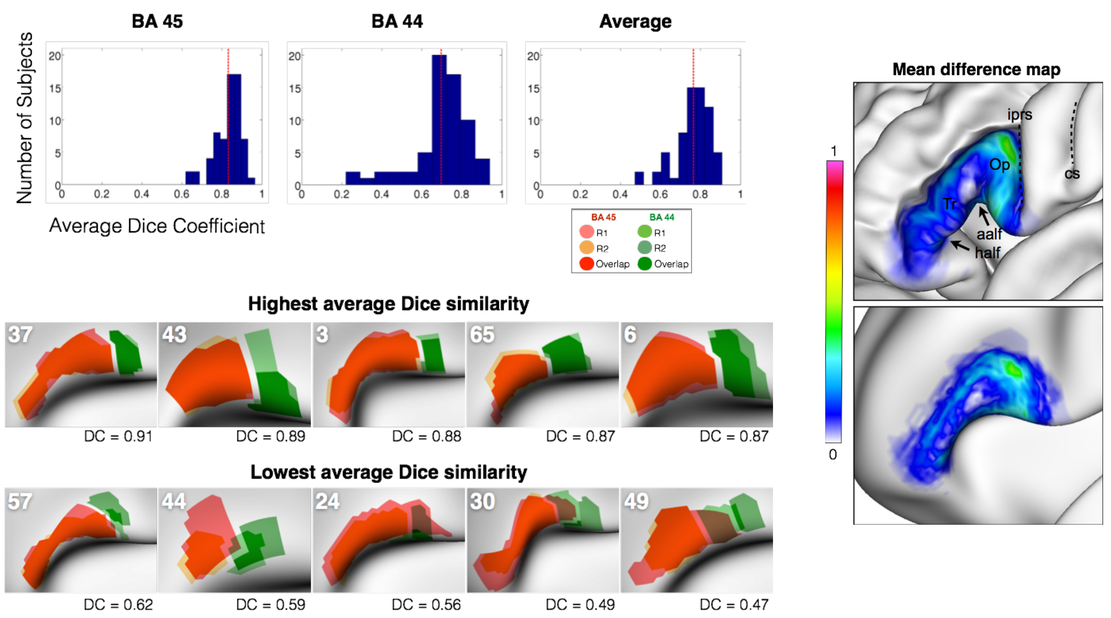
Group-level T-maps for each area showing the functional connectivity for the manual labels across all 65 subjects, with a voxel-wise threshold of p<0.001.

5 Comparison of manual labeling to automatic clustering techniques



K-means and hierarchical clustering were run for a region of interest defined by each individual's combined areas 45 and 44 manual labels.
Left: Distribution of Dice similarity values of automatically and manually labeled areas. Right: Clustering results and manual labels superimposed on the inflated surface for the first 10 subjects.

6 Inter-rater reliability of manual labeling using functional connectivity glyphs



Top: Distribution of Dice similarity values, which describe spatial overlap, between two independent raters for each area. Bottom: Both raters' area 44 and 45 labels shown on the inflated surface from the five subjects with the highest and lowest Dice similarity. Right: Mean difference map between raters on the pial and inflated surfaces, as shown by the group -averaged mask of the labeled nodes differing between raters.

Conclusions

- BA 44 and 45 could be clearly distinguished from each other and neighboring regions in all 65 subjects.
- Results are consistent with previous studies showing unique connectivity patterns of BA 44 and 45.
- Validates the usefulness of glyph visualization for manual cortical segmentation based on connectivity information.
- Group-average masks demonstrate areas of consistency and variability across individuals and highlight the importance of individual-level analysis.
- Future research will apply the same methods to further cortical areas, with the aim of developing a functional connectivity-based probabilistic atlas of the prefrontal cortex.
- The manually delineated datasets serve in the development of automated parcellation methods that aim for comparable precision at the individual-level.

Abbreviations

aalf: anterior ascending ramus of the lateral fissure
AnG: angular gyrus
aSmG and pSmG: anterior and posterior supramarginal gyrus
cgs: cingulate sulcus
cs: central sulcus
half: horizontal ascending ramus of the lateral fissure
iprs: inferior precentral sulcus
PMCm: middle posteriomedial cortex
Pre-SMA and SMA: pre-supplementary and supplementary motor cortex
STSa, STSm, and STSp: anterior, middle, and posterior superior temporal sulcus

http://code.google.com/p/braingl

1 Kelly, C. et al. (2010), Eur J of Neurosci 32(3).
2 Margulies, D.S. and Petrides, M. (2013), J Neurosci 33(42).
3 Petrides, M. and Pandya, D.N. (2009), PLoS Biol 7(8).
4 Smith, S.M. et al. (2013), NeuroImage 80.
5 Böttger, J. et al. (2014), Frontiers in Neuroscience 8 (15).
6 Amunts et al. (1999), J Comp Neurol 412.

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