New Evaluation criterion for functional brain parcellation methods using a multi-domain task battery

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#1091

Introduction

Brain parcellation is important for:
- understanding the brain in terms different modules working together
- defining regions-of-interest for subsequent analyses

Aims of the current project
1) Develop a new evaluation criterion to determine the quality of parcellations
2) Deploy it on a multi-task data set to identify functional boundaries
3) Compare common brain parcellations for cortex

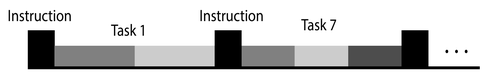
Dataset: Multi-Domain Task Battery

Multi-Domain Task Battery (MDTB)

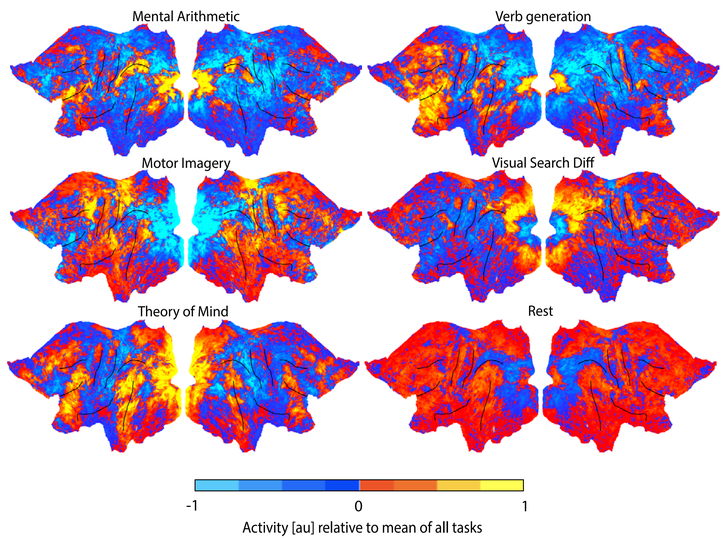
Set A (29 Task Conditions)	Set B (32 Task Conditions)	
No-Go	Theory of Mind	Nature Movie
Go	Action Observation	Landscape Movie
Math	Video Knots	Animated Movie
Digit Judgment	Finger Simple	Spatial Map – easy
Unpleasant Scenes	Finger Sequence	Spatial Map – med.
Pleasant Scenes	Object 0-Back	Spatial Map – hard
Objects	Object 2-Back	Mental Rotation – easy
Sad Faces	Visual Search – easy	Mental Rotation – med.
Happy Faces	Visual Search – med.	Mental Rotation – hard
Interval Timing	Visual Search – hard	Response Alt. – easy
Motor Imagery	Spatial Imagery	Response Alt. – med.
Stroop Incongruent	Verb Generation	Response Alt. – hard
Stroop Congruent	Word Reading	Biological Motion
Verbal 0-Back	Rest	Scrambled Motion
Verbal 2-Back		Permuted Rules
		True Prediction
		Violated Prediction
		Scrambled Prediction

- 47 unique task conditions
- Acquired in the same run with common baseline
- 24 Participants
- 4 Sessions (6 hrs) of data for each participant
- 2 Sessions for each task set
- Whole brain coverage

MDTB is available at Open Neuro
https://openneuro.org/datasets/ds002105/versions/1.1.0



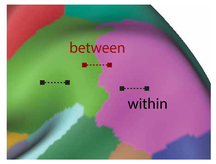
Example activity maps



Distance controlled boundary coefficient (DCBC)

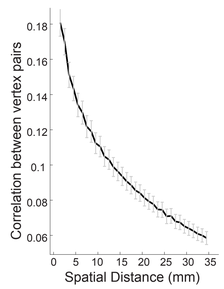
Comparing correlations of within-region to across-region pairs

A good parcellation should result in
- high correlations between vertex pairs within region
- low correlations between regions



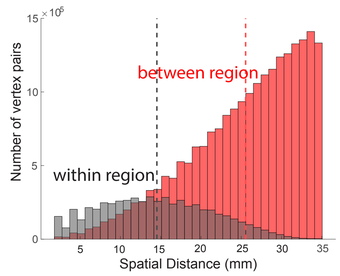
The problem: This evaluation leads to positive bias

Correlation of task activity profiles as a function of spatial distance on cortical surface



The correlations falls off with spatial distance (functional gradient)

Histogram of within- and between-region vertex pairs of the Icosahedron 162 parcellation



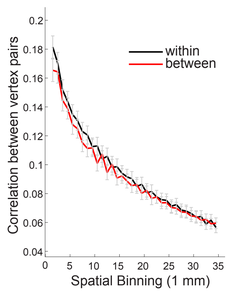
Average distance of within-pairs is significantly smaller than between pairs (14.5 < 25.5 mm).

Even on random parcellations, the average within-pair correlation is higher than the average between-pair correlation (0.0932 > 0.0684) **-> Positive bias**

We propose to evaluate the within and between difference for each spatial distance separately

The solution: DCBC evaluation (unbiased)

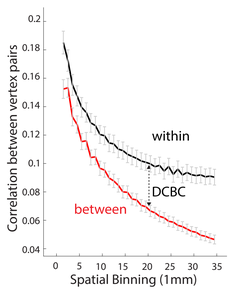
Within and between correlations binned in 1 mm categories for random parcellation



If we choose the bins small enough, the difference between within and between regions correlations disappears. (DCBC=0.0035)

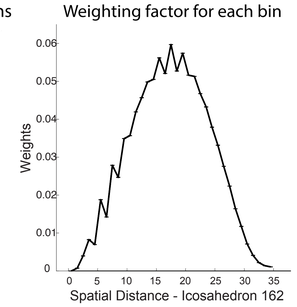
-> DCBC is unbiased

Within and between correlations binned in 1 mm categories for Yeo_17 parcellation



Positive DCBC for resting-state parcellation reveals real functional boundaries, not just smooth functional gradients. (DCBC=0.0312)

Weighting factor for each bin



To integrate across spatial bins, we use weighting proportional to the precision of the estimate.

$$weight_i = \frac{w_i * b_i}{(w_i + b_i) * \sum_{i=1}^{n} weight_i}$$

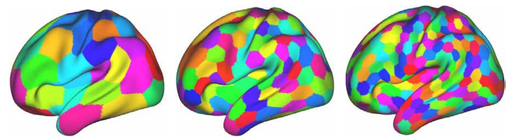
weight of bin i

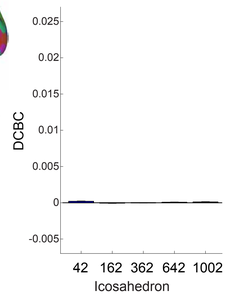
the number of within pairs of bin i

the number of between pairs of bin i

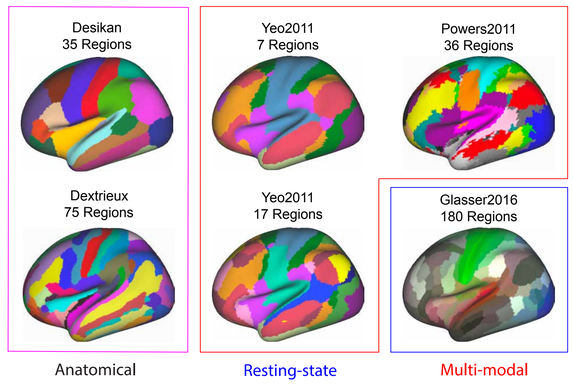
Evaluation Result

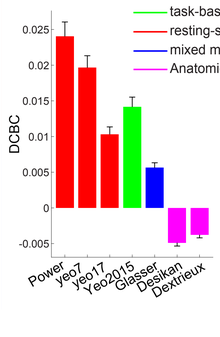
Evaluate on random parcellations (24 subjects)





Evaluate on existing parcellations (Anatomical, resting-state, task-based, mixed)





- Anatomical parcellations do not relate to functional boundaries at all
- Resting-state parcellations predict task-relevant functional boundaires well
- Multi-model parcellation not better than pure resting-state parcellations

Conclusion

1. This work proposed a new evaluation method (DCBC) for human neocortical parcellations which relies on a multi-domain task battery (MDTB).

2. The results uncover task and resting-state parcellations are superior to parcellations that include anatomical information

3. The MDTB raw data is available online:
https://openneuro.org/datasets/ds002105/versions/1.1.0

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