Model-based rsfMRI connectomes improve accuracy, reliability, and validity

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INTRODUCTION

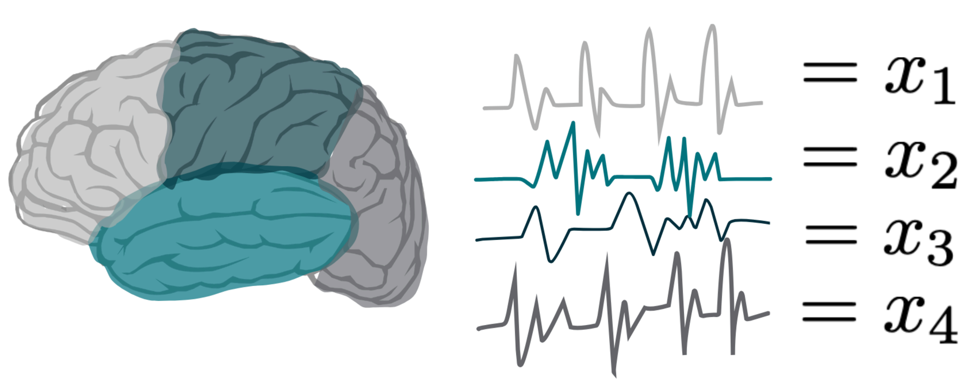
The theoretical properties of functional connectomes are constrained by methodological properties of our interaction estimate.[*1*]

Desireable theoretical properties:

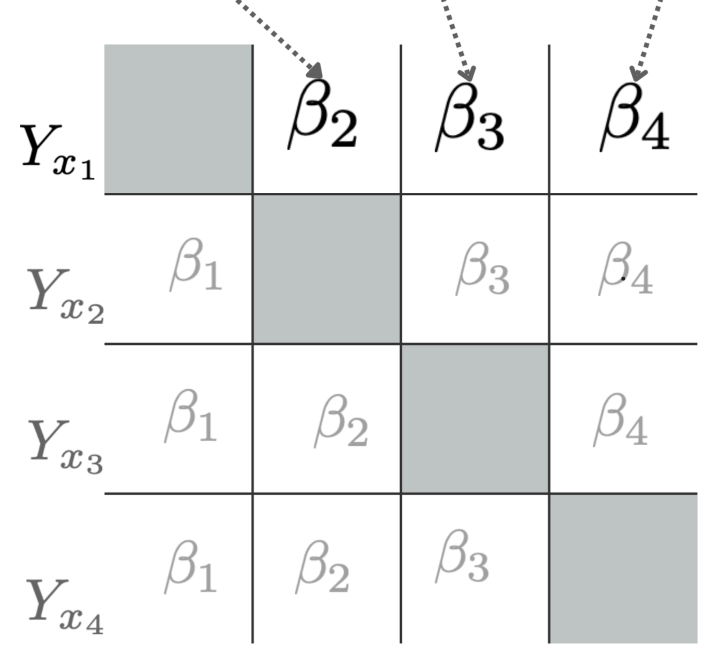
- interaction between *two* brain regions (valid)
- biologically plausible (sparse)
- stable across time (reliable)
- related to cognitive constructs (predictive)

Model-based rsfMRI connectomes have methodological properties that satisfy these theoretical properties.

METHODS



$$Y_{x_1} = \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4$$

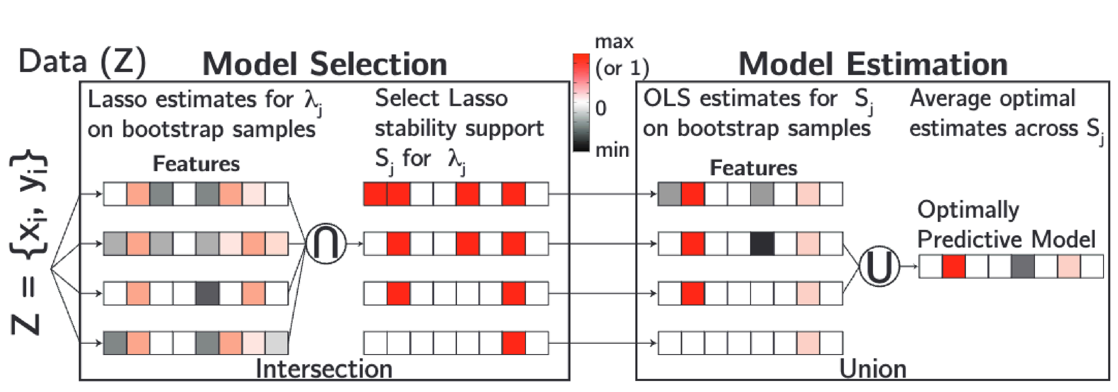


Model-based functional connectomes. Functional connectomes can be estimated by fitting models to timeseries and evaluated with cross-validation.

LASSO models fit with L1 regularization.

$$Loss = Error(Y - \widehat{Y}) + \lambda \sum_{1}^{n} |w_i|$$

Union of Intersections (UoI) models fit with a combination of model selection and estimation with resampling. Figure from [*2*].



Pearson connectomes constructed from pair-wise Pearson correlations

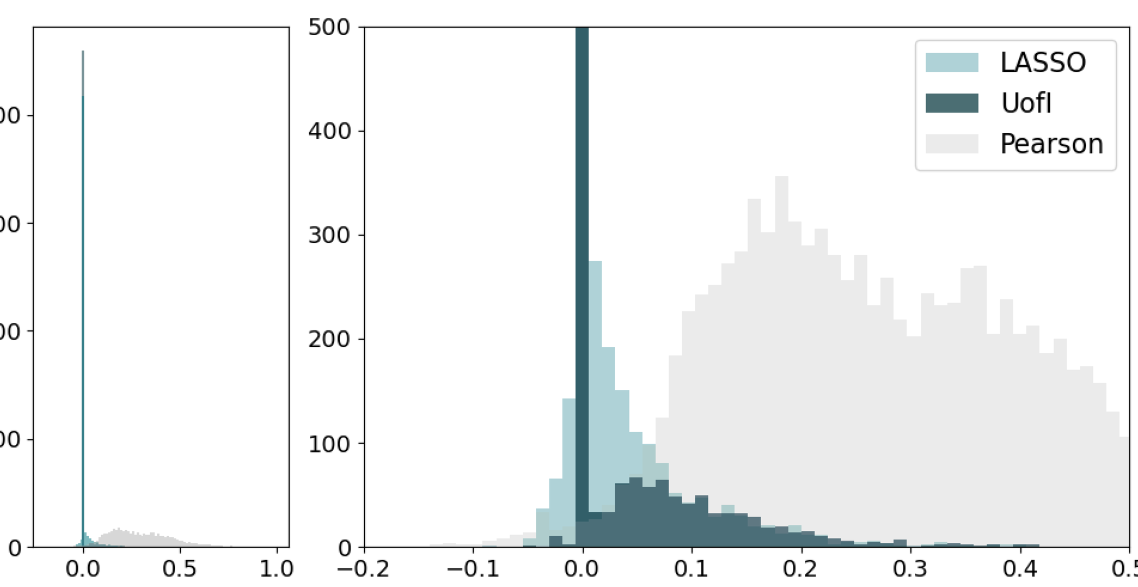
Data: Human Connectome Project - 100 randomly selected participants for preliminary analyses.

- Schaefer 100 Parcellation
- "Minimally preprocessed" [*3*]

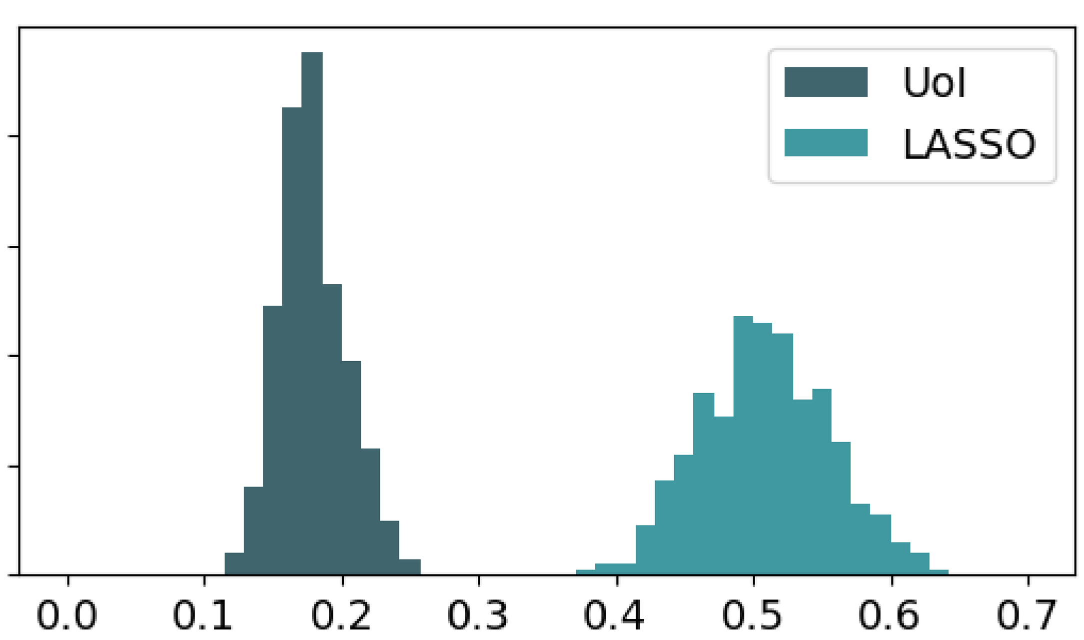
RESULTS

Connectomes evaluated using on desirable theoretical properties for empirical functional connectivity analyses: sparsity, reliability, identifiability ("fingerprinting"), correlation with motion ("qcfc").

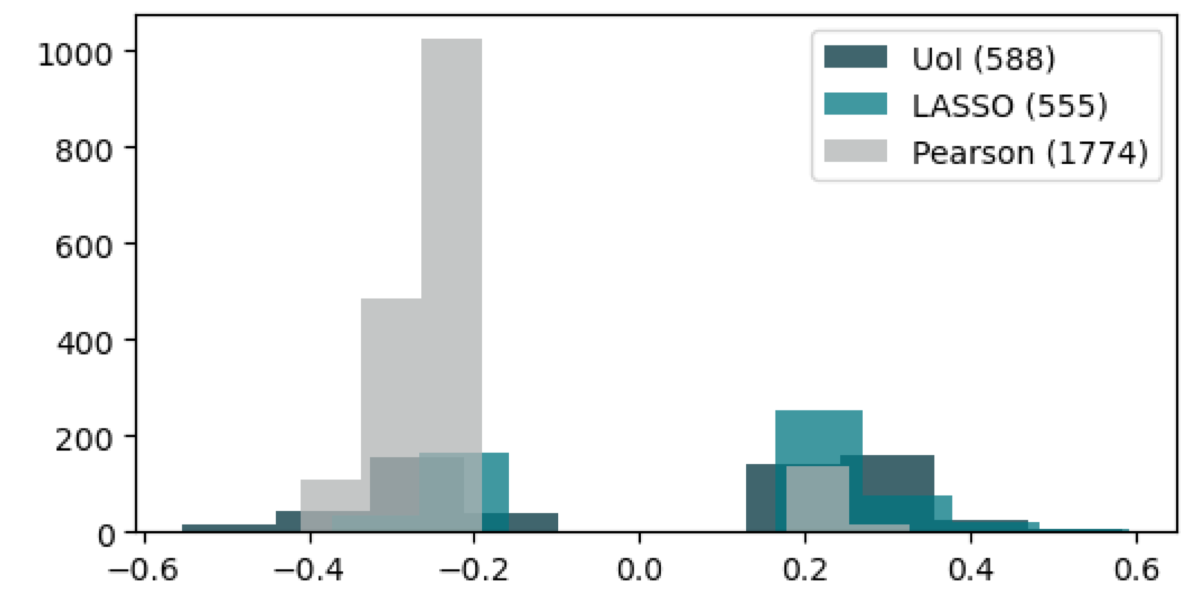
- The model fit accuracy for both UoI and LASSO connectomes are $R^2 = 0.70$, showing that both methods estimate highly accurate connectomes.



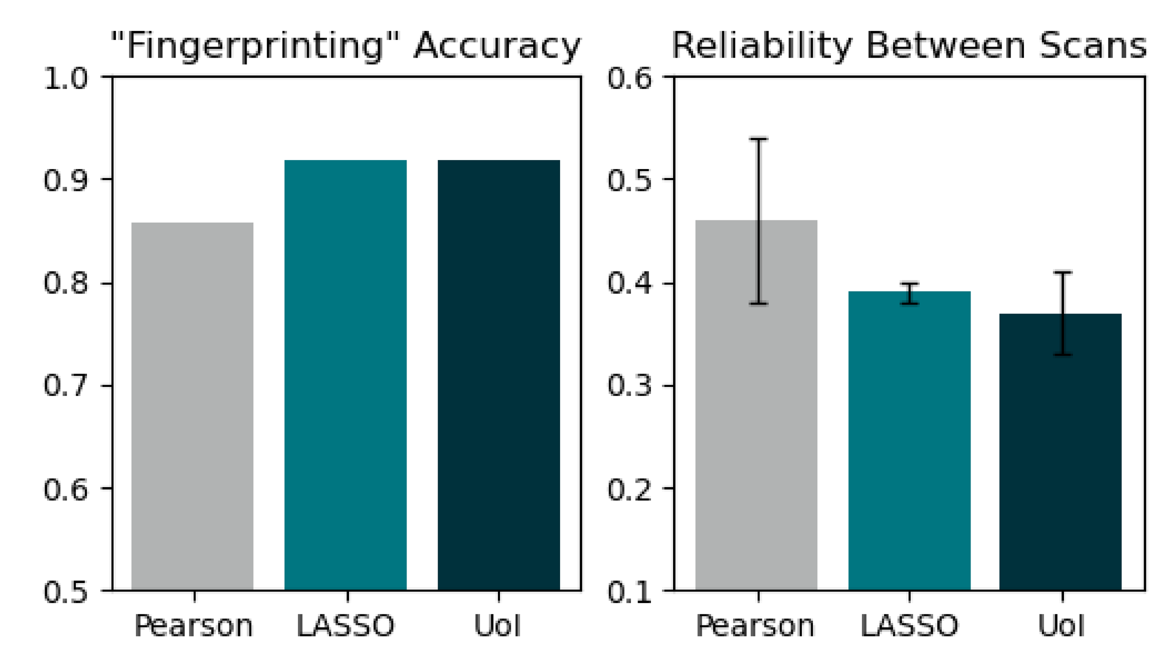
Sparcity - median edge weight Across participants, the median edge weights are centered around zero for the UoI and LASSO, with many of the low magnitude edges identified in LASSO being set to zero by UoI.



Sparsity - selection ratio. The proportion of selected edges by each model for each participant. UoI selects far fewer edges than LASSO.



Edge correlation with motion. Pearson connectomes have more edges that are significantly correlated with particpant motion during scanning, suggesting that they are not capturing true connectivity, but motion-induced spurious correlations.



Psychometric Properties. UoI and LASSO perform equally well as Pearson correlation on participant identification and I2C2 [*6*] reliability (error bars: 95% CI).

CONCLUSIONS

- For valid theoretical inferences, model-based connectomes show improvements over Pearson correlation connectomes in their sparsity, with equivalent performance for reliability, fingerprinting, and qcfc.
- Between the two model-based methods, UoI creates sparser connectomes that LASSO, with no decline in other evaluation metrics.

Future Directions:

- Build out robust post-processing software for model-based connectome estimation.
- Expand evaluation criteria to network-based statistics.
- Investigate model-based connectomes in datasets with higher motion (i.e. ABCD, HBN)
- Explore other model-based estimation methods [*4*] [*5*].

	Sparse	Dense
Directed	-Regularized linear models	-Partial correlation -Unregularized linear models
Undirected	-Graphical LASSO -Graphical Ridge	-Pearson correlation -Coherence

DATA & FUNDING

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