A Connectivity-based Psychometric Prediction Framework for Brain-behavior Relationship Studies

Jianxiao Wu[1,2], Simon B. Eickhoff[1,2], Felix Hoffstaedter[1,2], Kaustubh R. Patil[1,2], Holger Schwender[3], & Sarah Genon[1,2]

1 Institute of Systems Neuroscience, Heinrich Heine University Düsseldorf, Düsseldorf, Germany;
2 Institute of Neuroscience and Medicine (INM-7: Brain and Behaviour), Research Centre Jülich, Jülich, Germany
3 Mathematical Institute, Heinrich Heine University Düsseldorf, Düsseldorf, Germany

j.wu@fz-juelich.de

Introduction

- Relationships between brain regions and behavioral functions can be studied by relating inter-individual psychometric variability to variability of brain regional connectivity
- Recent availability of population-based neuroimaging datasets with extensive psychometric characterisation [1] opens promising perspectives to investigate these relations
- The multivariate nature of connectivity-based prediction models severely limits interpretation from a cognitive neuroscience perspective.
- To address this issue, we propose a connectivity-based psychometric prediction (CBPP) framework based on individual region's connectivity profile.

Methods

1. Pre-processing of RS-fMRI data
   - HCP minimal preprocessing pipeline ("minimal")
   - Minimal + ICA-FIX (FIX)
   - FIX + global signal regression (FIX+GSR)
2. Parcellate RS-fMRI data with Schaefer atlas [2]
   - 100-parcel granularity
   - 200-parcel granularity
   - 300-parcel granularity
   - 400-parcel granularity
3. Compute functional connectivity (FC)
   - Pearson correlation
   - Partial correlation (with L2 regularization)
4. Adjust for confounds
   - Age, Gender, Handedness, Brain size, Age^2, Gender*age, Gender*age^2, ICV, Acquisition quarter
5. Train and test regressors using 10-fold cross-validation
   Accuracy = Pearson correlation between actual and predicted psychometric scores
   - Multiple Linear Regression (MLR) [3]
   - Linear Support Vector Regression (SVR) [4]
   - Elastic Nets (EN) [4]

Preliminary evaluation

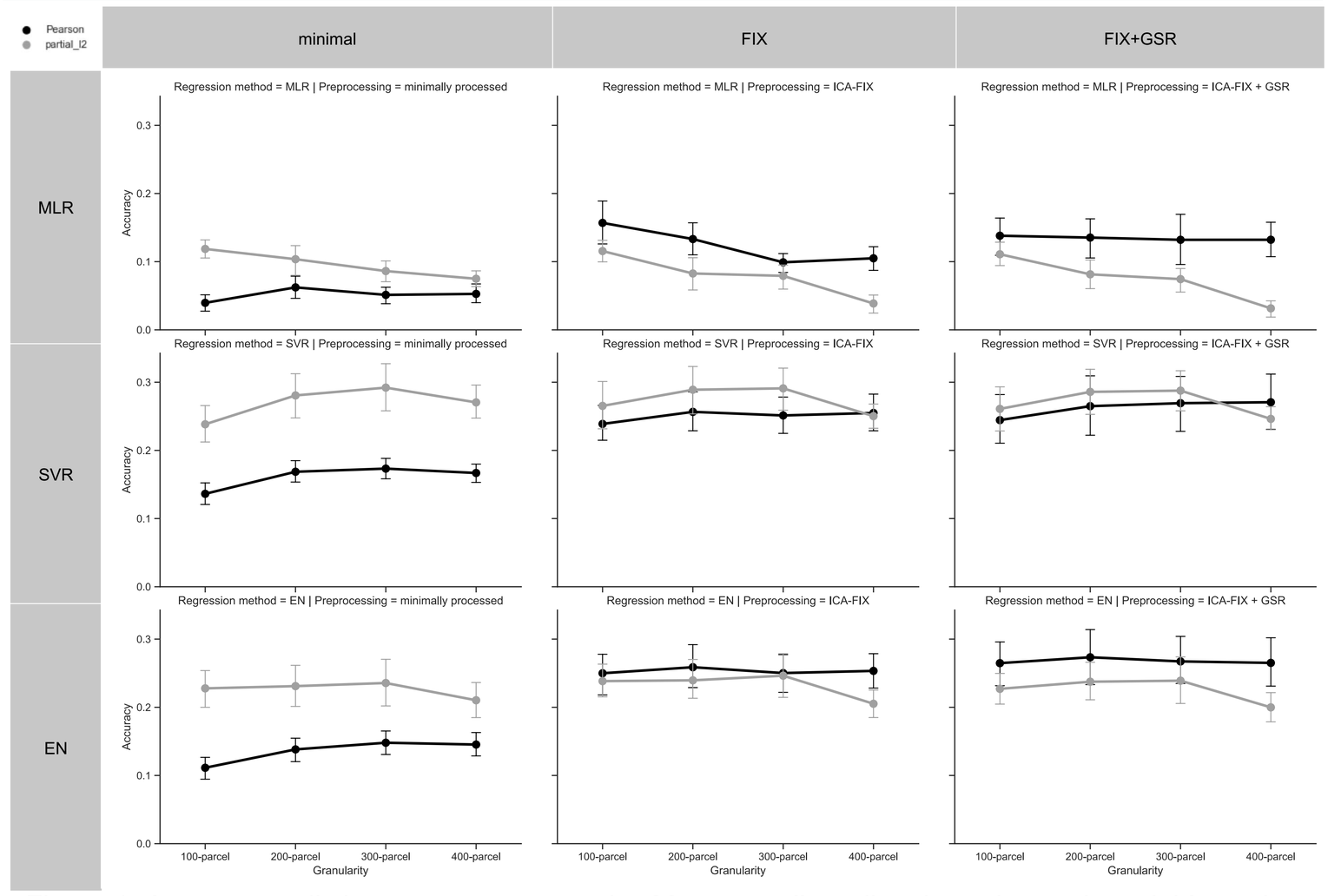

Figure 1. Average prediction accuracy across the 20 most well predicted psychometric variables using whole-brain connectivity. Error bars represent 95% confidence interval across psychometric variables.

Parcel-wise prediction

Methods: FIX, 300-parcel granularity, Pearson correlation, SVR

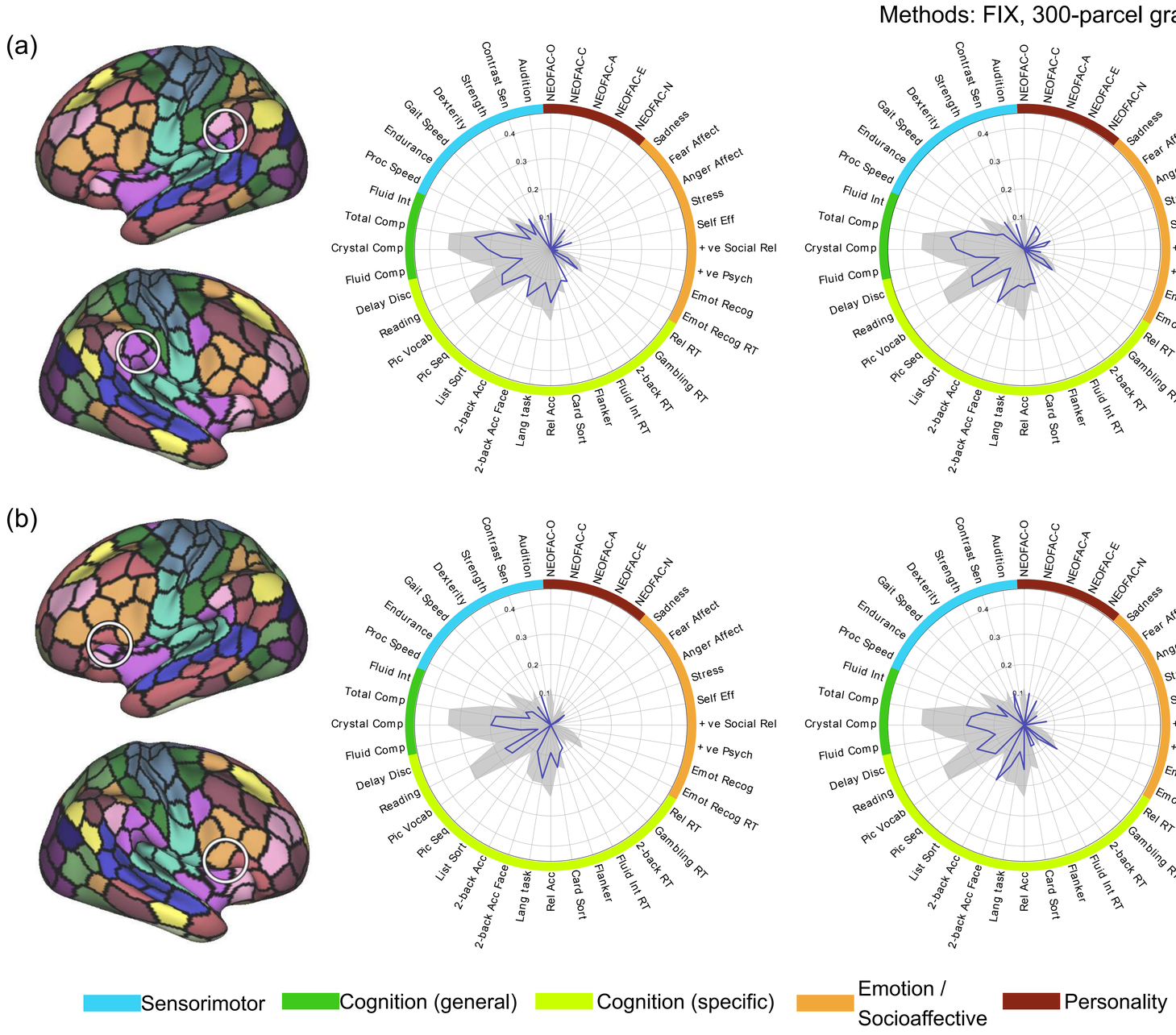

Figure 2. Parcel-wise psychometric profiles for two pairs of selected parcels. Yellow filled contour shows whole-brain prediction pattern, while blue contour shows parcel-based prediction profile.

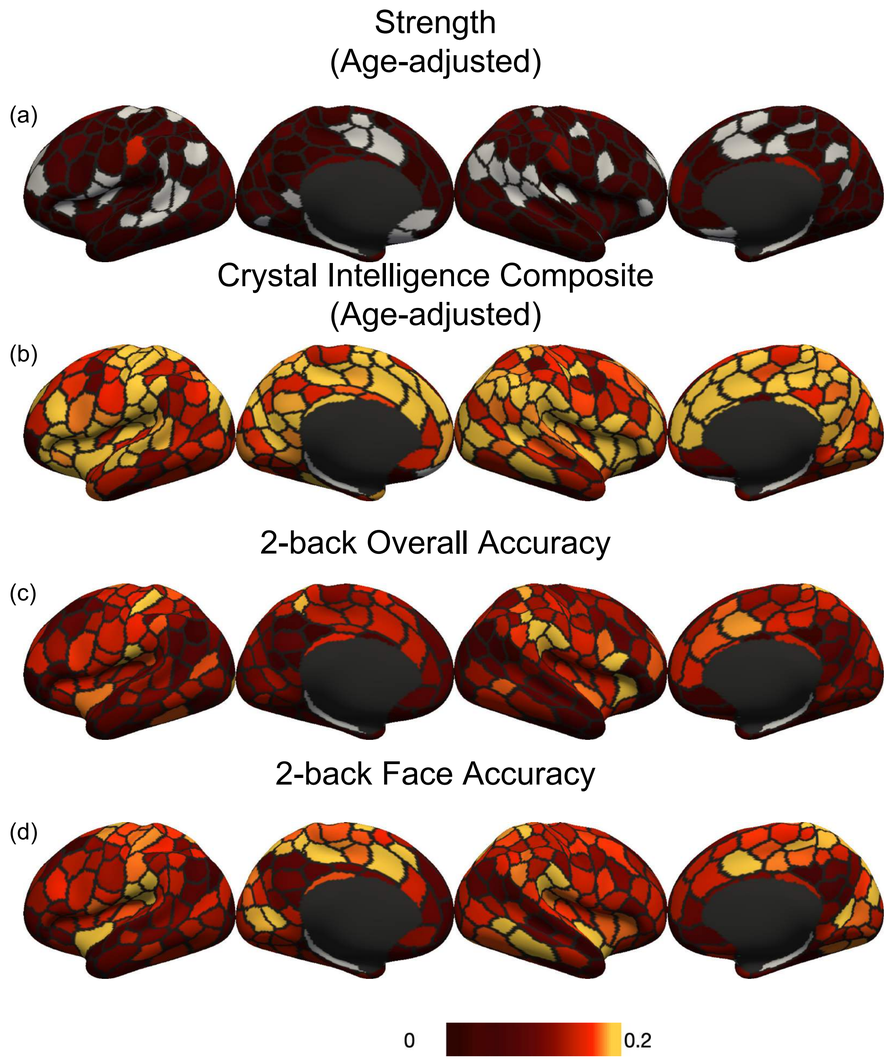

Figure 3. Prediction accuracy variation across the brain in left and right hemisphere, for four selected psychometric scores. Negative accuracies were set to zero and shown in gray.

Conclusion

- Highest performance observed following FIX with GSR, Pearson correlation connectivity and EN
- Overall, FIX and GSR pre-processing improve prediction accuracy
- SVR and EN perform comparably well
- Parcel-based predictions allow investigations of the neurobiological relevance of the prediction model and hence of the selected framework
- Future studies should investigate the transferability of this framework to older and clinical populations.

References: [1] Van Essen DC, et al. 2012. "The Human Connectome Project: a data acquisition perspective". *Neuroimage*. [2] Schaefer A, et al. 2018. Local-Global parcellation of the human cerebral cortex from intrinsic functional connectivity MRI. *Cerebral Cortex*. [3] Chatterjee S, Hadi AS. 1986. "Influential observations, high leverage points, and outliers in linear regression". *Statistical Sciences*. [4] Cortes C and Vapnik VN. 1995. "Support-vector networks:. *Machine Learning*. [5] Zou H and Hastie T. 2005. "Regularization and variable selection via the elastic net". *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*.

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