The predictive power of functional network connectivity in cognitive function

Charley Cornali, Nicco Reggente[1], Jesse Rissman[1,2]

[1]Department of Psychology, [2]Department of Psychiatry & Biobehavioral Sciences, University of California, Los Angeles

Introduction

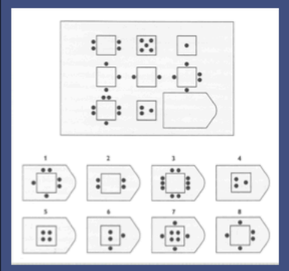
- Distinct neural networks, Resting State Networks (RSNs), are active during rest and appear to be temporally synchronous, reflecting their functional connectivity (FC).
- RSNs have been found to be associated with particular cognitive functions, but an individual's unique FC profile within these networks could account for the observed individual behavioral differences. We sought to test this belief with the behavioral measure of fluid intelligence.
- To date, there has not yet been found a region that is able to predict a person's intelligence (the gross cortical volume is only the best minor predictor). However, the Cingulo-Opercular Network (CON) is known to be associated with fluid intelligence.
- We hypothesized that the FC in the CON can predict a person's intelligence, due the CON role as a domain general, task control network, responsible for high-order cognitive functions.
- In the current investigation, we analyzed resting state fMRI (rs-fMRI) data provided by the Human Connectome Project (HCP) to examine the relationship between CON functional connectivity and fluid intelligence.

Cognitive Task Paradigm

Raven's Progressive Matrices

Figure 1.

Exemplar Raven's Matrix Pattern

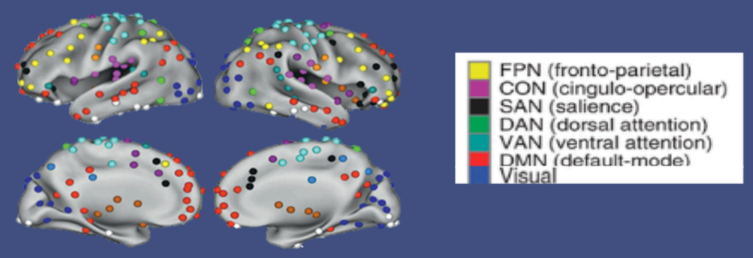


- Assessed fluid intelligence with the behavioral measure was assessed with this test, the Penn Progressive Matrices: Number of Correct Responses (PMAT).
- Subjects were presented with patterns organized in either a 2x2, 3x3 or 1x5 formation with one missing square (Figure 1.).
- Subject must select 1 correct pattern out of the 5 possible response patterns that best fits the missing square.
- Task consisted of 24 items plus an additional 3 items and they were presented with increasing difficulty.
- If the participant chose the incorrect response 5 consecutively, the task was stopped.

Methods

- We acquired resting-state data (1200 TRs) for 221 subjects from the Human Connectome Project.
- Using regions of interest (ROI) from a meta-analysis[2],that labeled each ROI by network membership (Figure 2.), we took the mean activity within each ROI and created a "mean-time-course" for each.

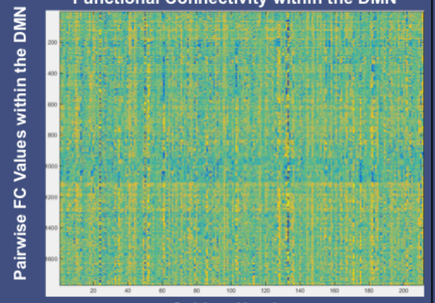
Figure 2.



- By correlating the "mean-time-course" for each node with every other node in a network, we were able to create a "Functional Connectivity Matrix" for each network. Figure 3 shows a vectorized representation of each subject's network-specific Functional Connectivity Matrix.
- Using a leave-one-subject-out cross-validation framework, we trained a Support Vector Regression Model (nu-SVR; polynomial kernel; penalty =.02) to *learn* the relationship between an individual's network-specific Functional Connectivity Matrix and their Fluid Intelligence score.
- We then fed the model a new subject's network-specific Functional Connectivity Matrix and probed it to predict their Fluid Intelligence score.

Figure 3.

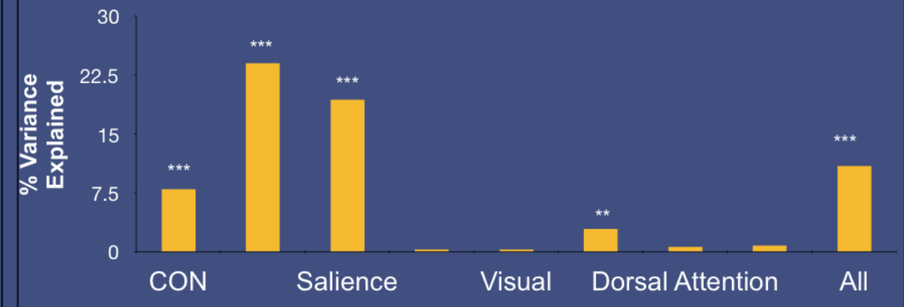
Exemplar Feature Set For All Subjects: Functional Connectivity within the DMN



Results

- By correlating the array of predicted Fluid Intelligence scores with the matched array of each subject's actual score, we were able to obtain an R^2 value-- the percent of the variance in Fluid intelligence that our model was able to account for.
- The model's success was selective to the functional connectivity within particular networks, most prominently the Default Mode Network (DMN), the Salience Network, and the Cingulo-Opercular Network.

Network-Specific Predictive Power



Conclusions

- Individual difference in cognition can be predicated by the structural scaffolding of functionally defined networks, FC profile. Utilizing the voxel data gathered from rs-fMRI , we were motivated to link the RSNs in the brain to certain cognitive functions, such as fluid intelligence.
- Our results, identified that the FC with in the DMN, CON, and the Salience Network explained the degrees of variance in individual fluid intelligence scores.
- Pending further analysis, our predictive model will help to grow the knowledge about the relationship between FC and structural connectivity (SC) and how they are intertwined to produce individual differences in production of cognition.

Contact

Charley Cornali - Undergraduate Research Assistant charleyncc@ucla.edu
Nicco Reggene - Graduate Student Mentor nreggente@psych.ucla.edu
Jesse Rissman – Principle Investigator – rissman@psych.ucla.edu

Lab Website
http://rissmanlab.psych.ucla.edu

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2) Power, Jonathan D., et al. "Functional network organization of the human brain." Neuron 72.4 (2011): 665-678.