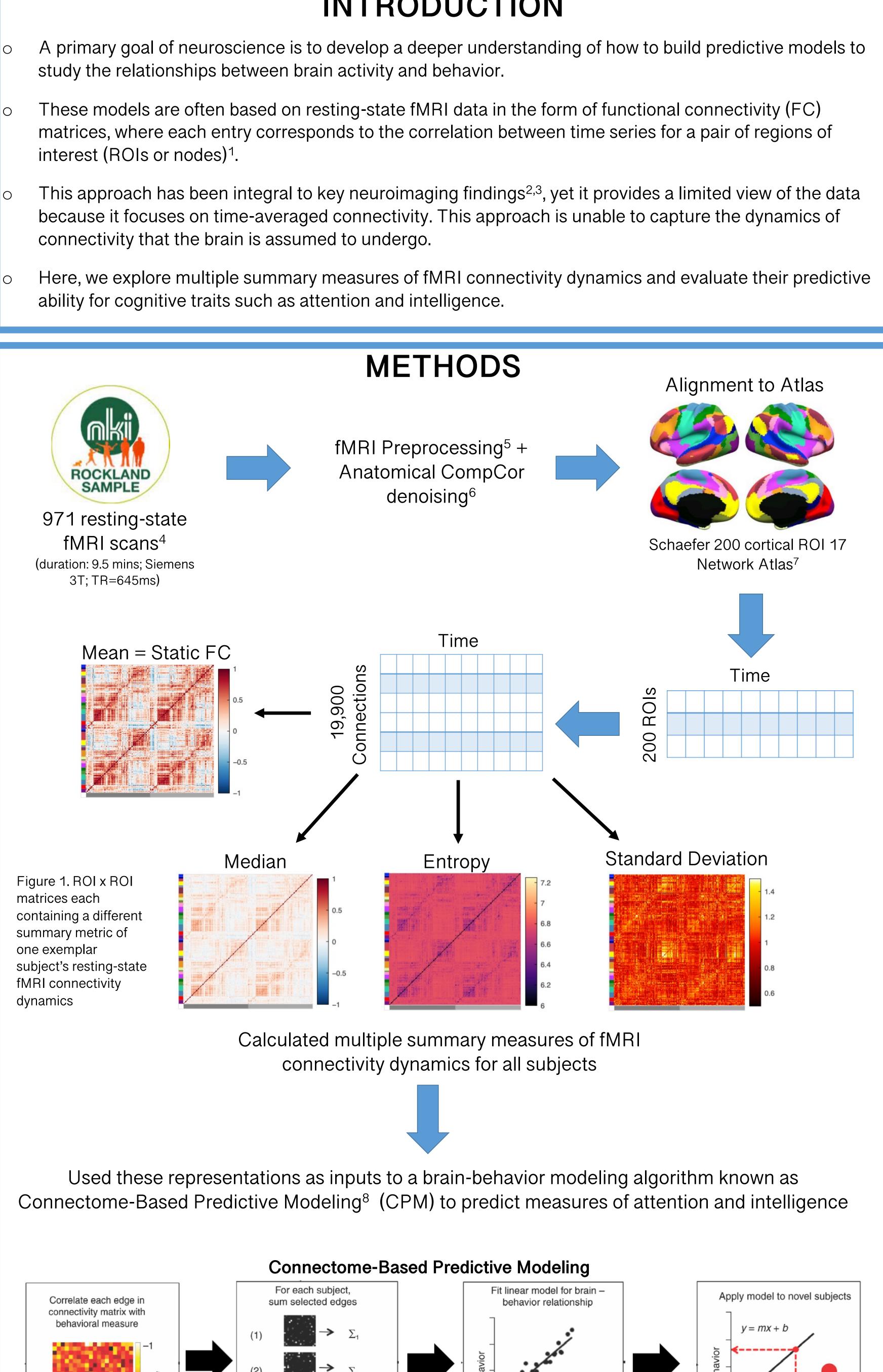
### Building brain-behavior predictions from multiple measures of fMRI connectivity dynamics Megan Spurney<sup>1</sup>, Joshua Faskowitz<sup>1</sup>, Javier Gonzalez-Castillo<sup>1</sup>, Daniel A. Handwerker<sup>1</sup>, Peter A. Bandettini<sup>1,2</sup> National Institute of Mental Health



- study the relationships between brain activity and behavior.
- interest (ROIs or nodes)<sup>1</sup>.
- connectivity that the brain is assumed to undergo.
- ability for cognitive traits such as attention and intelligence.





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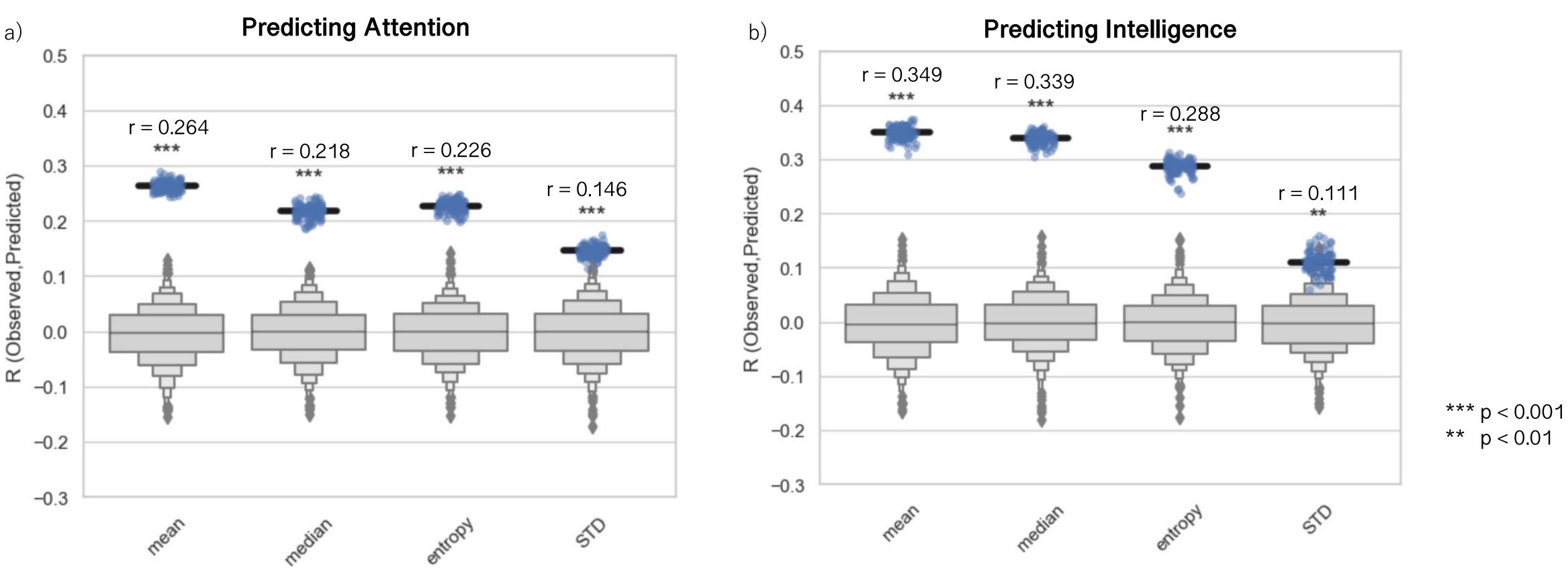


Figure 3. Results from Connectome-Based Predictive Modeling for predicting Attention Network Task scores (a) and WASI-II scores (b). Y-axis represents Pearson's R value between observed and predicted behavioral values. Blue dots show results of 100 iterations of 10-fold cross validation using true data, and gray boxen plots show distribution of results from 1,000 iterations using randomized data. Black line represents median accuracy for true models

- 0

| a) Mean  | <sub>b)</sub> Median   | c) Entropy  | d) Standard Deviation   |
|--|--|---|---|
| TempPar-25 25 36 41 36 37 34 30 67 27 33 36 17 21 33 56 53   | 100 TempPar-25 26 27 31 28 30 26 25 53 21 27 26 14 21 27 47 47   | 7 TempPar-8 8 14 12 8 8 11 7 11 6 12 13 3 11 12 39 13   | TempPar-1 0 3 2 1 2 1 0 3 4 0 0 3 1 0 0 0   |
| DefaultC - 24 38 39 37 32 25 26 17 36 42 31 43 28 32 39 80 56  | DefaultC - 17 38 26 29 31 23 22 17 36 29 25 28 19 27 32 67 43  | 7 DefaultC - 4 3 11 8 6 8 6 8 17 17 6 14 8 8 15 20 39   | DefaultC - 1 1 7 0 0 0 2 0 0 2 4 1 0 2 1 0 0  |
| DefaultB - 29 29 40 33 38 34 29 23 30 26 25 41 41 30 24 39 33  | DefaultB - 32 28 34 28 35 31 21 17 30 23 21 35 32 26 19 32 27  | DefaultB - 12 10 17 13 8 19 11 4 9 11 5 13 10 8 7 15 12   | DefaultB - 0 0 3 2 2 1 1 1 1 1 3 2 2 0 1 1 0  |
| DefaultA - 21 30 39 35 30 30 31 24 35 31 17 20 26 29 30 32 21  | Bo DefaultA - 20 26 29 32 30 26 27 23 29 24 13 16 12 20 26 27 2  | DefaultA - 13 8 12 10 12 12 12 9 15 10 6 5 15 9 8 8 11  | DefaultA - 0 1 3 0 1 3 2 1 4 2 2 1 1 0 2 1  |
| ContC - 32 24 32 26 29 28 23 33 42 31 23 26 20 26 41 28 17   | ContC - 19 19 33 21 24 23 18 32 39 25 18 21 13 12 32 19 14   |   | ContC - 3 1 3 0 3 0 1 0 3 0 0 0 0 1 2 0 3   |
| ContB - 21 42 41 35 31 35 31 25 31 35 26 35 26 41 43 36  | ContB – 17 38 31 31 26 32 25 18 27 28 20 24 21 16 35 28 26   | ContB – 9 11 11 8 8 13 9 9 7 12 9 14 11 5 13 14 13  | ContB – 3 3 4 3 1 1 2 1 1 0 4 2 0 2 2 1 0   |
| ContA - 18 30 33 33 34 30 29 26 34 36 28 26 23 17 25 31 33   | $\begin{array}{c c c c c c c c c c c c c c c c c c c $   |   | ContA - 0 1 1 1 0 1 2 2 6 3 3 4 0 2 3 4 0   |
| LimbicA - 21 41 43 37 44 26 27 19 23 25 36 35 31 31 26 42 27   | LIMBICA - 17 33 34 32 40 24 27 19 19 10 30 20 23 24 23 29 2  |   | LimbicA – 1 1 3 2 2 4 3 2 4 4 3 0 0 2 1 2 4   |
| LimbicB - 26 54 35 27 31 28 34 23 27 23 34 31 42 35 30 36 67   | LimbicB - 19 43 32 21 26 27 29 25 20 19 27 27 39 29 30 36 53   |   | LimbicB - 1 4 3 2 1 5 1 0 20 4 6 1 3 4 1 0 3  |
| SalVentAttnB - 22 32 43 31 33 24 24 11 23 19 26 25 33 24 23 17 30  | SalVentAttnB - 21 24 39 25 28 21 23 11 25 19 15 18 32 23 17 17 25  |   | SalVentAttnB - 1 0 2 3 3 1 3 0 0 2 2 1 0 1 1 0 0  |
| SalVentAttnA - 26 23 33 30 35 30 33 24 34 27 29 31 23 31 29 26 34  | 40 SalVentAttnA - 24 21 28 25 29 25 30 23 29 27 21 25 18 27 21 22 26   |   | SalVentAttnA - 2 4 1 2 1 4 3 3 1 3 2 2 1 2 1 2 1  |
| DorsAttnB - 19 22 32 27 28 20 30 24 28 26 30 35 28 30 34 25 37   | DorsAttnB - 16 18 23 24 26 20 25 21 27 24 24 32 23 26 31 23 30   |   | DorsAttnB - 2 1 3 1 2 11 4 1 5 4 1 1 0 3 1 0 2  |
| DorsAttnA - 28 30 32 34 36 28 35 33 31 44 34 31 29 30 38 32 36   | $\frac{9}{20}$ DorsAttnA - 22 26 27 30 35 26 29 28 26 40 30 26 24 30 35 31 28  |   | DorsAttnA - 0 2 2 3 0 2 1 3 1 2 0 1 3 1 2 0 1   |
| SomMotB - 31 20 39 20 34 27 30 31 27 37 33 35 26 35 33 37 41   | 20 SomMotB - 28 16 26 17 30 24 25 25 21 32 29 31 21 32 28 29 3<br>SomMotA - 26 23 27 26 27 23 28 39 32 34 26 31 33 29 34 26 27 |   | SomMotB - 2 2 4 0 3 1 2 3 2 2 1 3 0 0 2 0 2   |
| SomMotA - 35 25 31 39 32 32 33 43 35 43 33 41 32 39 40 39 36   | VisPeri - 26 24 23 16 26 18 21 24 43 35 26 38 19 26 28 38 26   |   | SomMotA - 2 1 1 4 2 3 1 2 3 3 1 4 3 3 7 3   |
| VisPeri - 31 26 25 20 30 22 23 32 54 41 30 42 24 30 29 38 25   | VisCent - 29 26 26 28 22 16 24 21 19 17 15 17 19 20 32 17 25   |   | VisPeri - 0 0 1 2 2 1 4 0 4 1 1 3 1 1 0 1 0   |
| VisCent - 23 31 35 31 28 19 26 22 26 21 18 21 32 21 29 24 25   |  |   | VisCent - 2 0 2 2 0 2 2 1 1 1 0 3 3 0 0 1 1   |
| VisCent -<br>VisCent -<br>VisPeri -<br>SomMotA -<br>SomMotB -<br>SomMotB -<br>SomMotB -<br>DorsAttnA -<br>DorsAttnA -<br>DorsAttnA -<br>ContA -<br>ContA -<br>ContA -<br>ContA -<br>ContA -<br>ContA -<br>DefaultA -<br>DefaultA -<br>DefaultA -<br>DefaultA - | Contd<br>Contd<br>Contd<br>Contd<br>Contd<br>Defaulta<br>Defaulta<br>Defaulta<br>Defaulta<br>Defaulta<br>Defaulta              | VisCent<br>VisCent<br>VisPeri<br>SomMotA<br>SomMotA<br>SomMotB<br>DorsAttnA<br>DorsAttnA<br>DorsAttnA<br>DorsAttnA<br>DorsAttnA<br>DorsAttnA<br>DorsAttnA<br>DorsAttnA<br>ContA<br>ContA<br>ContA<br>DefaultA<br>DefaultB<br>DefaultB | VisCent<br>VisCent<br>VisPeri<br>SomMotA<br>SomMotA<br>SomMotB<br>SomMotB<br>SomMotB<br>SomMotB<br>SomMotB<br>SomMotB<br>SomMotB<br>SomMotB<br>ContA<br>ContB<br>ContA<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB<br>ContB |

Figure 4. Results from Connectome-Based Predictive Modeling for predicting Attention Network Task. Results for predicting WASI-II showed similar trends but are not shown. Each heatmap shows the percentage of between-network edges that were included in the model built using the representation denoted in the title: a) mean b) median c) entropy d) standard deviation

# CONCLUSIONS

- connectivity dynamics.

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# RESULTS

We used CPM to predict attention and intelligence scores through a 10-fold cross-validation framework using each representation of connectivity dynamics and evaluated the accuracy of the predictions by computing the Pearson's correlation between the observed and predicted values.

We were able to significantly predict attention and intelligence scores (Figures 3a and 3b) using all four representations of brain dynamics (all parametric p-values < 0.005), but the mean (equal to functional connectivity) consistently performs the best.

• Figures 4a through d show the percentage of edges, grouped by functional system, that were significantly correlated with attention in the 4 models built using different representations of brain dynamics

The amount of edges included in the model decreases significantly when we are not using the mean, which decreases interpretability of results and may decrease generalization of the models to novel data

Our results demonstrate that average co-fluctuation, i.e., product-moment correlation, performs best as input to our predictive modeling framework.

Future work will concentrate on if alternative time series measures, or multivariate combinations thereof, can boost brain-behavior predictive modeling from fMRI

ACKNOWLEDGEMENTS

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| h      |    | <ul> <li>Visual A</li> <li>Visual B</li> <li>Somatomotor A</li> <li>Somatomotor B</li> <li>Temporal Parietal</li> <li>Dorsal Attention A</li> <li>Dorsal Attention B</li> <li>Salience/VenAttn A</li> <li>Salience/VenAttn B</li> </ul> |
|--------|----|---|
| $\sim$ | d) |   |

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