Structural brain network topologies associate with aspects of value-based decision-making

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Background & Motivation

- Most complex tasks require coordinating across macroscopic brain networks
- These large brain networks rely on white matter pathways to communicate
- It remains unclear how individual differences in the topological pattern of structural brain networks influences individual differences in complex behaviors like value-based decision-making

Hypothesis

- Individual differences in brain network topology predict differences in value-based decision making

Methods

Participants

- Sample consisted of 124 community dwelling adults (27 male; M = 44.38 years of age, SD=8.49; M=16 years of education, SD=2.67)

Iowa Gambling Task (IGT)

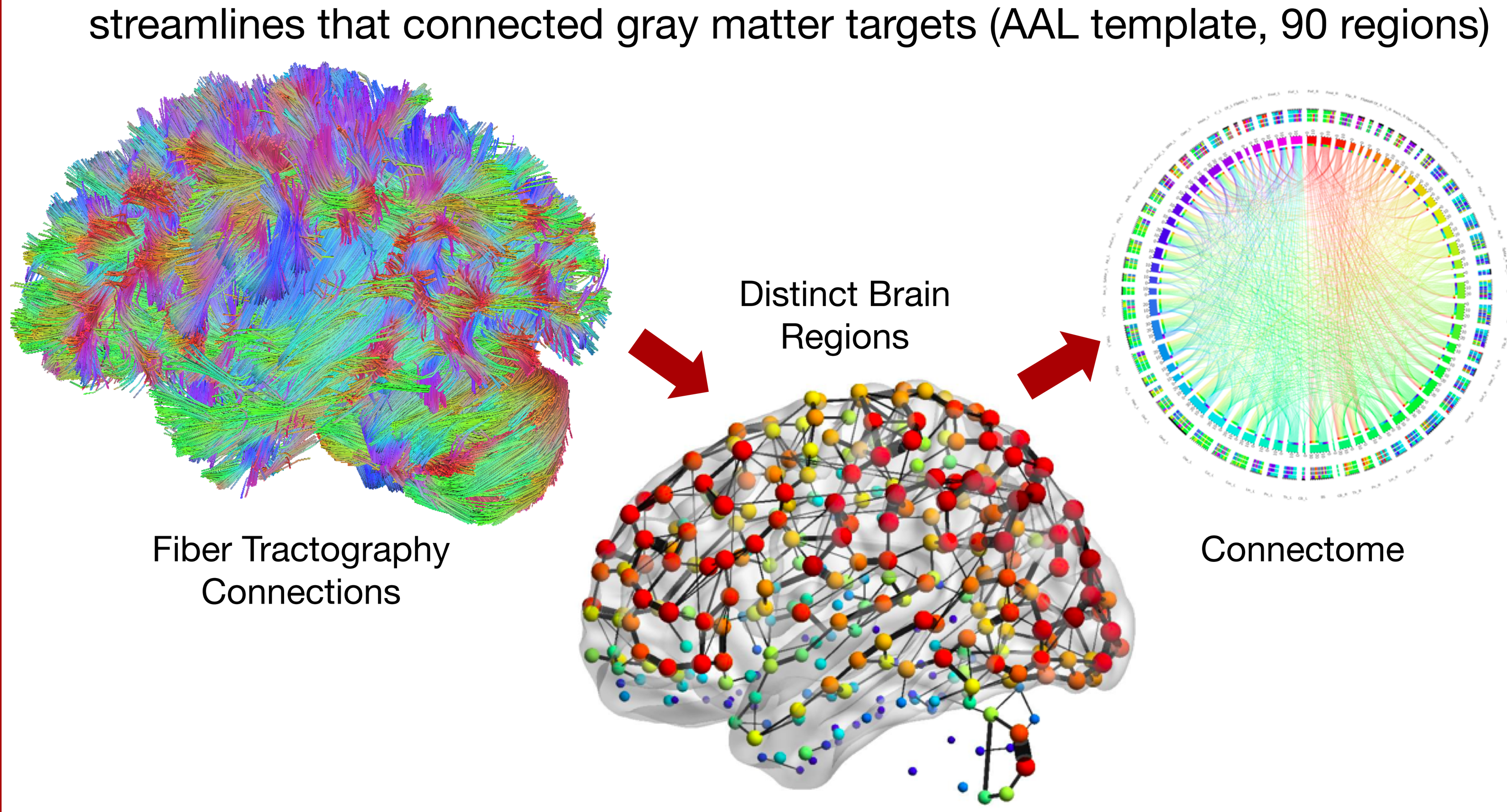
- The goal of the IGT is to maximize profit with a set amount of number of draws possible from 4 decks of cards that vary in the amount and frequency of rewards and punishments
- Payoff: P = (C + D) - (A + B)
- Sensitivity to frequency of gain: Q = (B + D) - (A + C)

IGT Deck Specifications

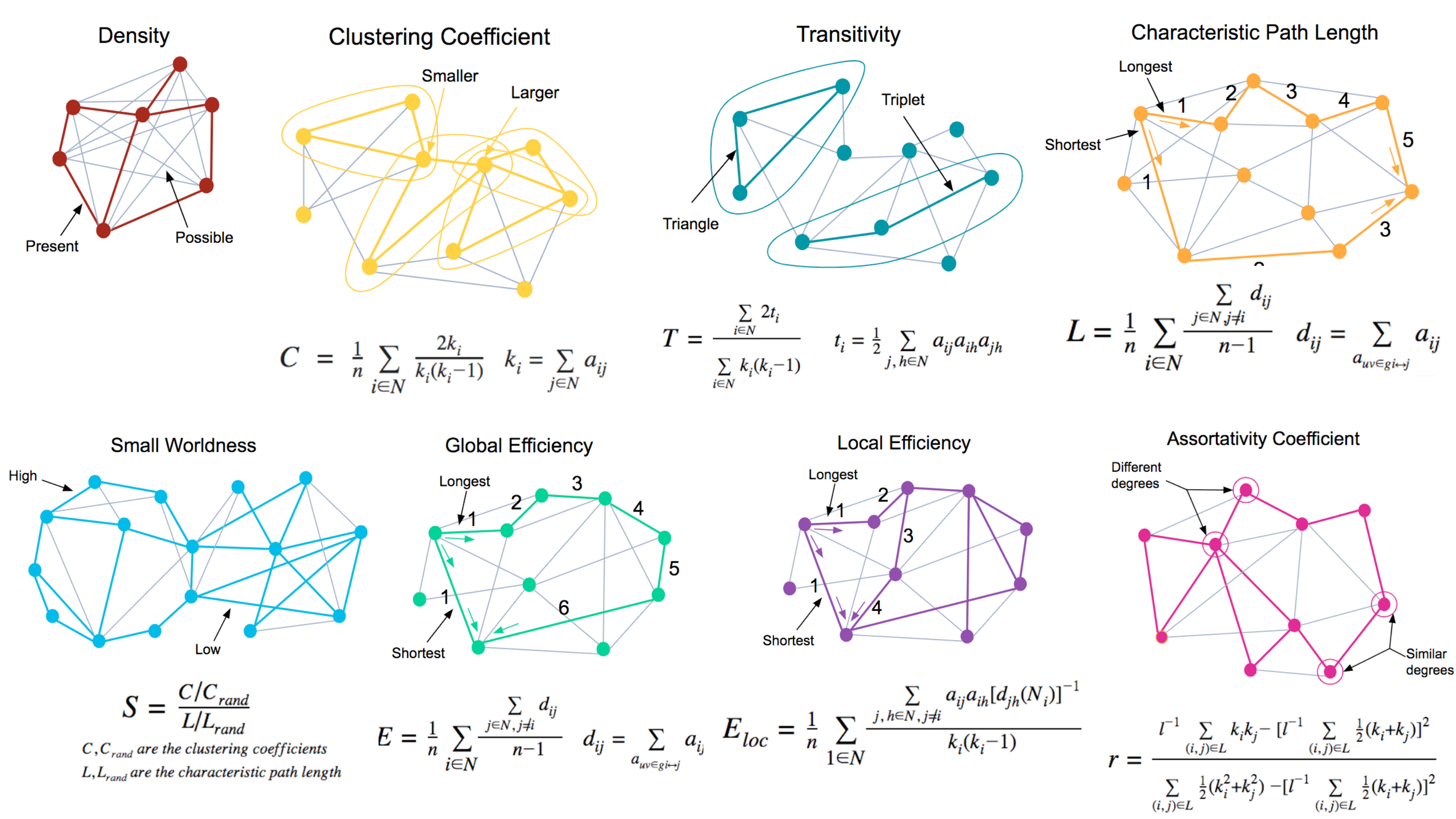
	A	B	C	D
Reward	$100	$100	50	$50
Frequency of Reward	Low	High	Low	High
Net Yield	Loss	Loss	Gain	Gain

Structural connectivity

- 64 direction DTI acquisition (2.4mm³ voxels, v=2000s/mm²). Data was reconstructed into MNI-space using QSDR (Yeh et al., 2011) and connectivity was estimated using a deterministic fiber tracking method (Yeh et al. 2013) to find the number of streamlines that connected gray matter targets (AAL template, 90 regions)



Graphed Topology Measures



- For each subject we looked at 8 measures of structural network topology, related to the "small worldness" of the brain networks (Rubinov & Sporns 2010; Bassett & Bullmore 2006)

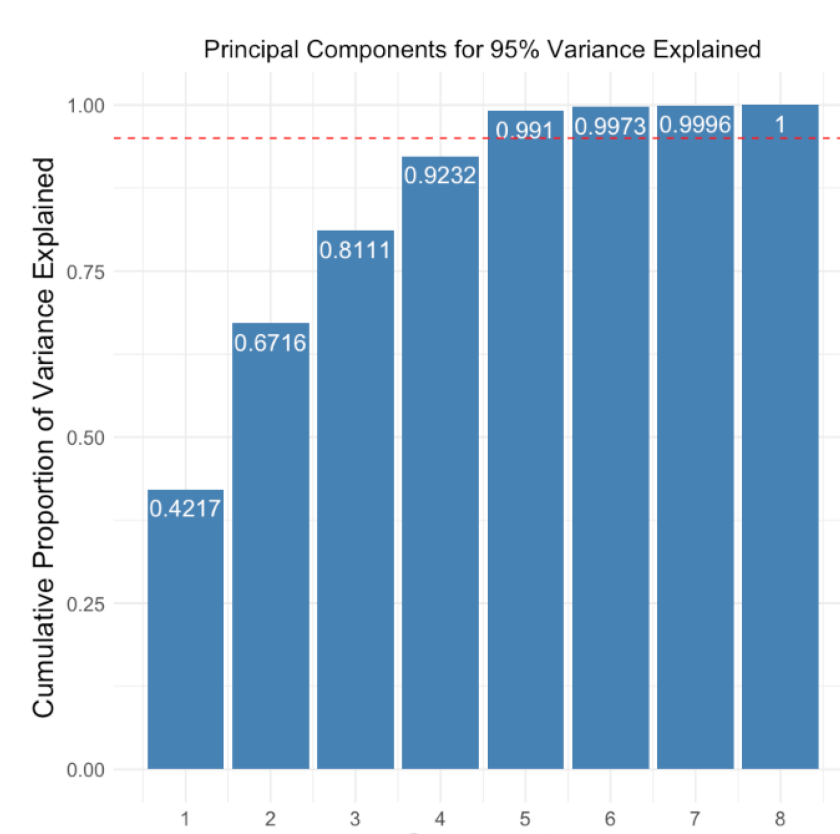
Results: Dimensionality

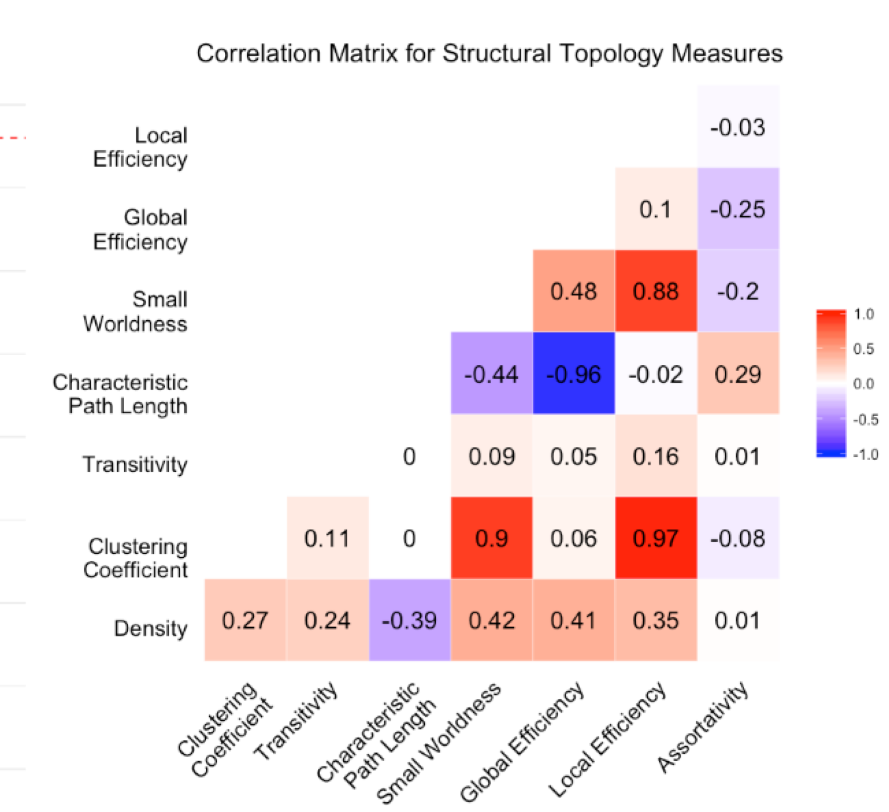
Correlation in topologies

- Topology metrics were partially correlated across individuals, with particularly strong correlations between Small Worldness and Density, Small Worldness and Characteristic Path Length, Global Efficiency and Density, Global Efficiency and Characteristic Path Length, Global Efficiency and Small Worldness, Local Efficiency and Clustering Coefficient, and Local Efficiency and Small Worldness

Principal Components Analysis (PCA)

- The PCA revealed a lower dimensional structure to the correlations, with 5 components explaining more than 95% of the variance





Results: Associations with P&Q

Payoff (P)

- None of the components reliably associated with Payoff (P)

Sensitivity (Q)

- One component reliably associated with Sensitivity (Q) to high frequency rewards. When this association was projected back into topology space, we found that Density, Transitivity, Global Efficiency, & Assortativity all were strongly associated with Q

Coefficient Estimate (Std. Error)

	P Score	Q Score
Intercept	21.41(2.48)***	31.44(2.59)***
Component 1	1.86(1.35)	-0.81(1.41)
Component 2	2.86(1.75)	2.30(1.83)
Component 3	0.55(2.35)	-3.37(2.46)
Component 4	-3.56(2.62)	3.23(2.74)
Component 5	3.51(3.37)	7.46(3.52)*

Weights in Topology Space

	Weight	Lower Bound	Upper Bound
Density	5.8887	0.436	11.3414
Clustering Coefficient	-0.4626	-0.8909	-0.0342
Transitivity	-2.4371	-4.6937	-0.1804
Characteristic Path Length	1.5615	0.1156	3.0073
Small Worldness	-1.0107	-1.9465	-0.0748
Global Efficiency	-2.0043	-3.8602	-0.1484
Local Efficiency	-0.2793	-0.5379	-0.0207
Assortativity	-2.6949	-5.1904	-0.1995

Conclusion

Summary

1. White matter networks have a low dimensional structure in their topological organization
2. None of the components were found to associate with individual difference in the ability to use feedback to maximize long-term rewards.
3. One component, linked to several small-world network measures, reliably correlated with individual differences in sensitivity to high-frequency rewards.

Future Directions

Applications

- Neuroimaging markers of decision-types
- Diagnostic tools for possible pathologies in decision-making (e.g., addiction)

Experimental directions

- Similar analysis on other complex decision tasks (e.g., Stroop)
- More detailed focus on regions of interest such as the striatum
- Integration with functional connectivity measures

References & Acknowledgements

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