CONNECTION STRENGTH OF THE MACAQUE CONNECTOME AUGMENTS TOPOLOGICAL AND FUNCTIONAL NETWORK ATTRIBUTES

Based on a paper by de Lange et al. (2019)

Presented in front of a live audience

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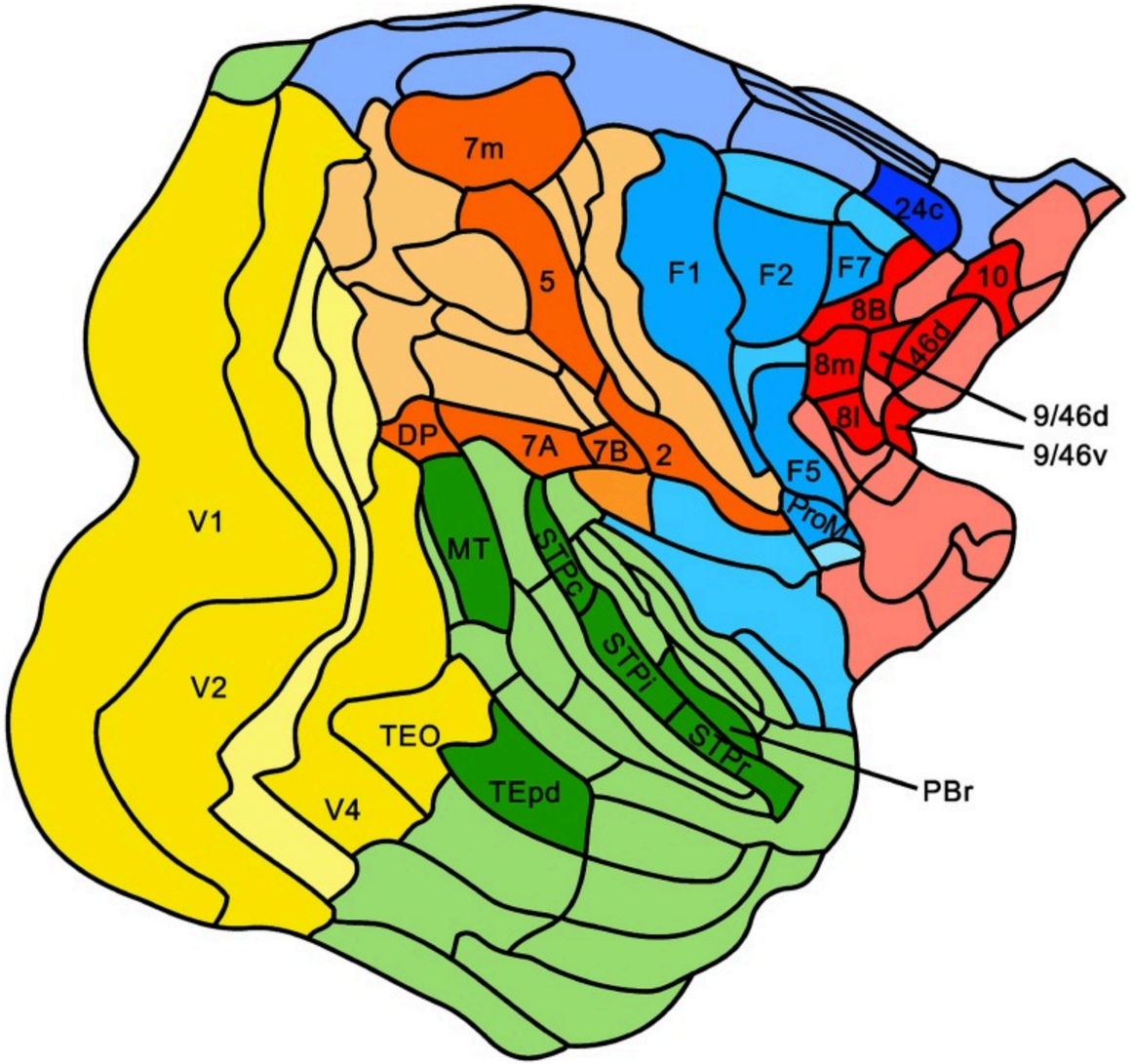
Dataset

(Markov et al., 2014)

- Anatomical macaque cortico-cortical structural connectivity dataset
- Inter-areal strength of projection resulting from injections of retrograde tracers in 29 cortical areas in macaque monkeys



Interactive surface maps of Projections http://core-nets.org/index.php?action=map

Graph representation

- 29 nodes
- 536 directed connections
- Labelled neurons form a log-normal distribution
- $\log(P_{ij} + 1)$ used as connection strength
- FLNe of an area is estimated from the number of labeled neurons in that area relative to the total number of labeled neurons less the neurons intrinsic to the injected area

Network measures

- Clustering coefficient
- Shortest path length
- Modularity
- Rich club organization

Network measures

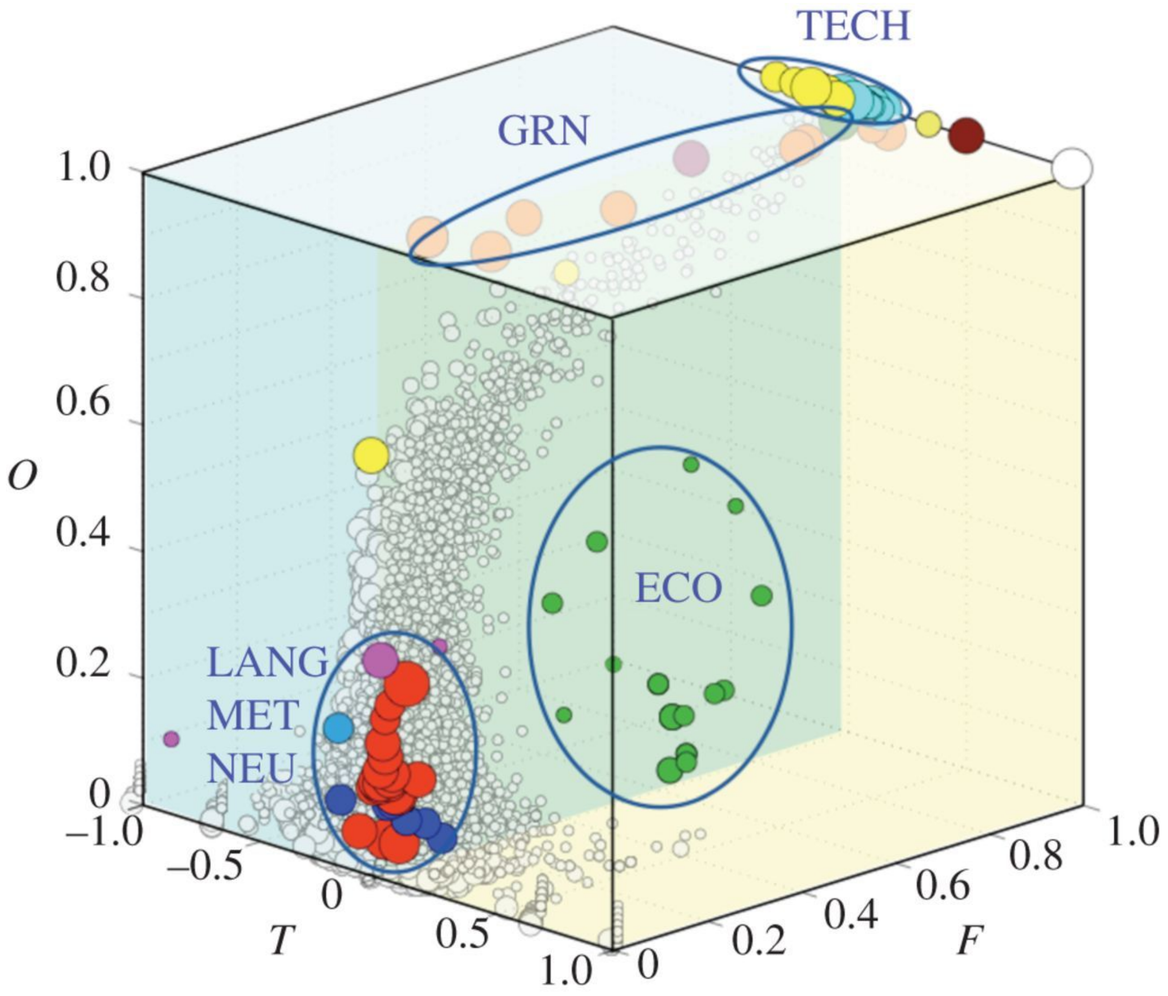
Continued

- Binary and weighted clustering coefficients compared with randomized networks
- Characteristic path length comparisons for binary and random networks
- Rand index comparison for binary and weighted modules and compared with random networks
- Connectivity strength comparison for intramodular and intermodular connections
- Rich club coefficient $\phi^{w}(k_{in})=\frac{W_{>k_{in}}}{\sum_{i=1}^{E_{>k_{in}}} w_i^{\text{rank}}}$ (ratio of the total weight of connections between highest degree nodes and the sum of the strongest connections in the network)

Network Morphospace

Walks in network space

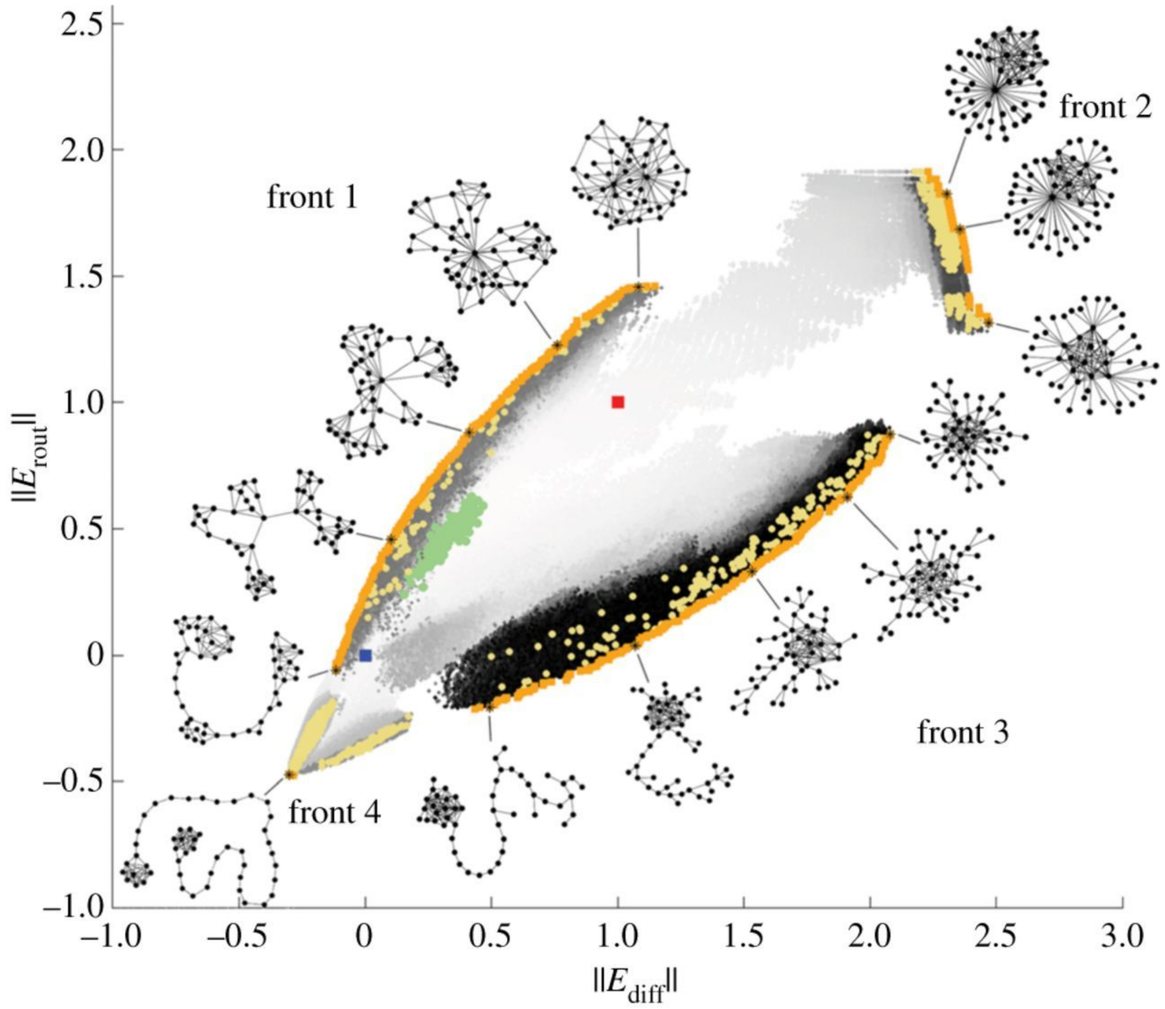
- What exists, what is possible but does not exist and what is impossible
- Constructed morphospace using evolutionary algorithms
- Max C & Min L to explore strong small-world organization



Pareto front

No one is worse off, Someone is better off

- Competing resources / parameters
- Pareto networks marked as non dominant
- 4 edges switched, degree and strength preserved
- 4 edges switched, binary topology and strength distribution preserved

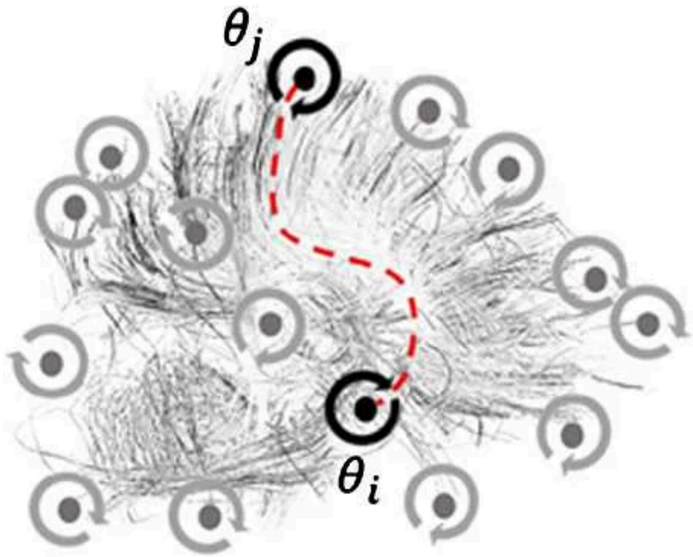


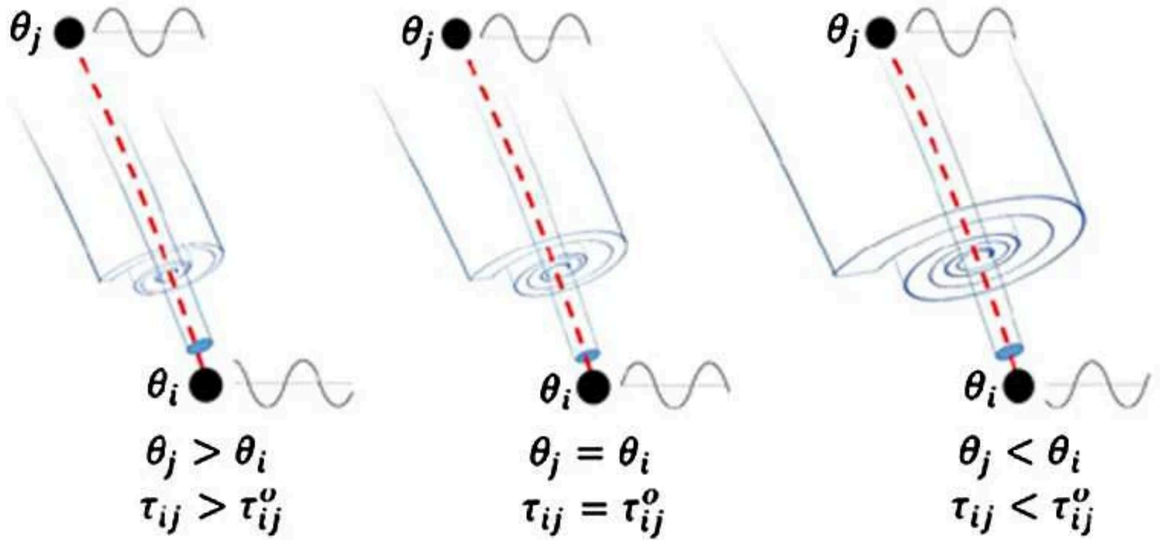
Socially awkward Steve https://www.youtube.com/watch?v=Fvuwqtbz94s

Functional Dynamics

Kuramoto!

- $$\dot{\theta}_i(t) = \omega_i + \lambda \sum_{j=1}^{N} A_{ji} \ \sin(\theta_j(t) - \theta_i(t))$$
- λ -> cortical coupling strength
- Comparison with shuffled networks
- Inter and intramodular synchrony compared
- Effect of rich club organization on synchronization measured

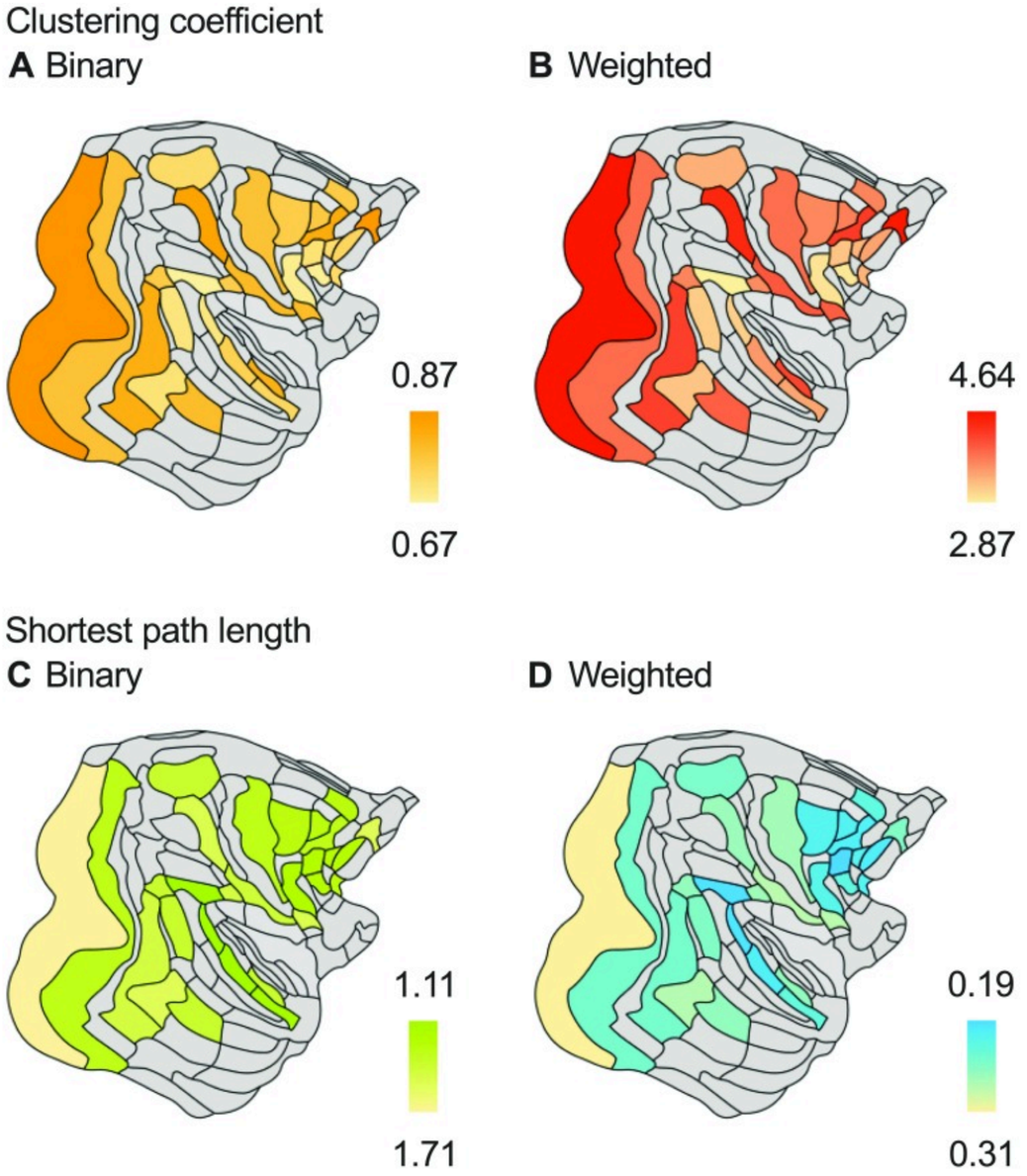




Results

Clustering coefficient & Shortest path length

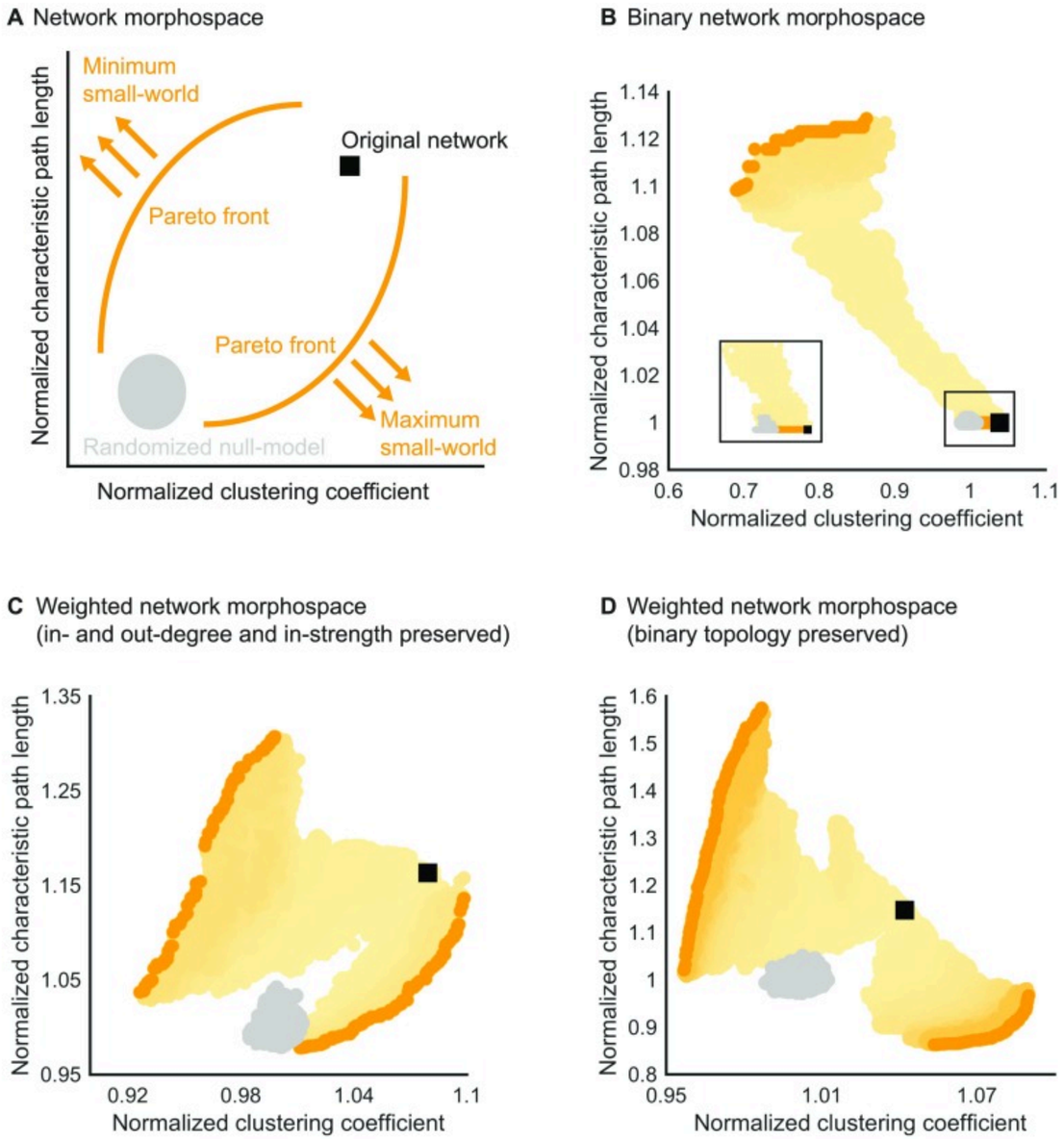
- Weighted C > binary C > random C
- High clustering regions in binary and weighted networks overlap
- Characteristic path length higher in weighted than average, no significant difference in binary



Results

Network morphospace

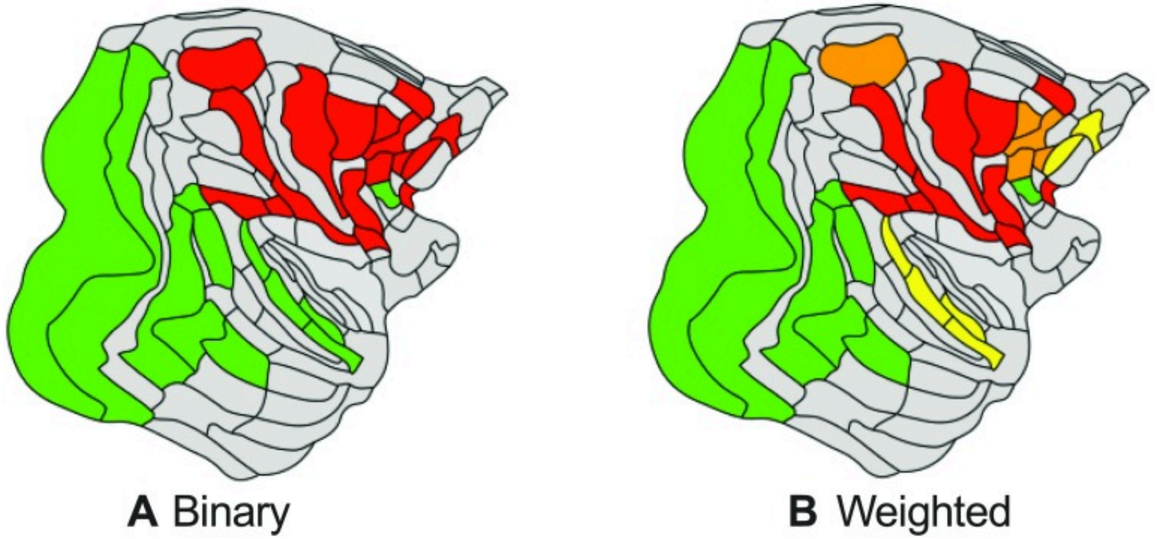
- Binary macaque network at Pareto front of degree-preserved morphospace
- Weighted network in between fronts



Results

Modular Organization

- 62 % connections intramodular
- Stronger intramodular connections ??
- High overlap between binary and weighted

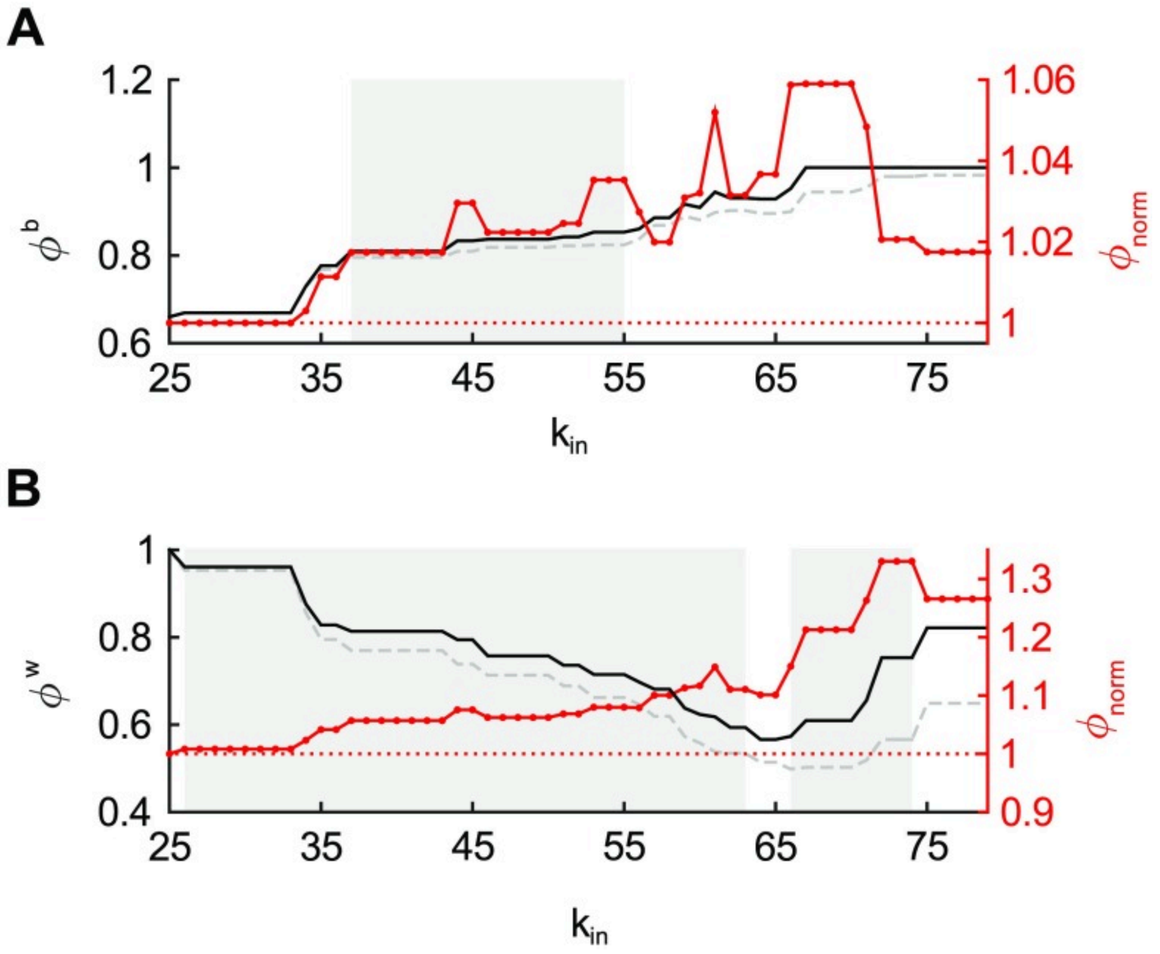


A Binary **B** Weighted

Results

Rich club organization

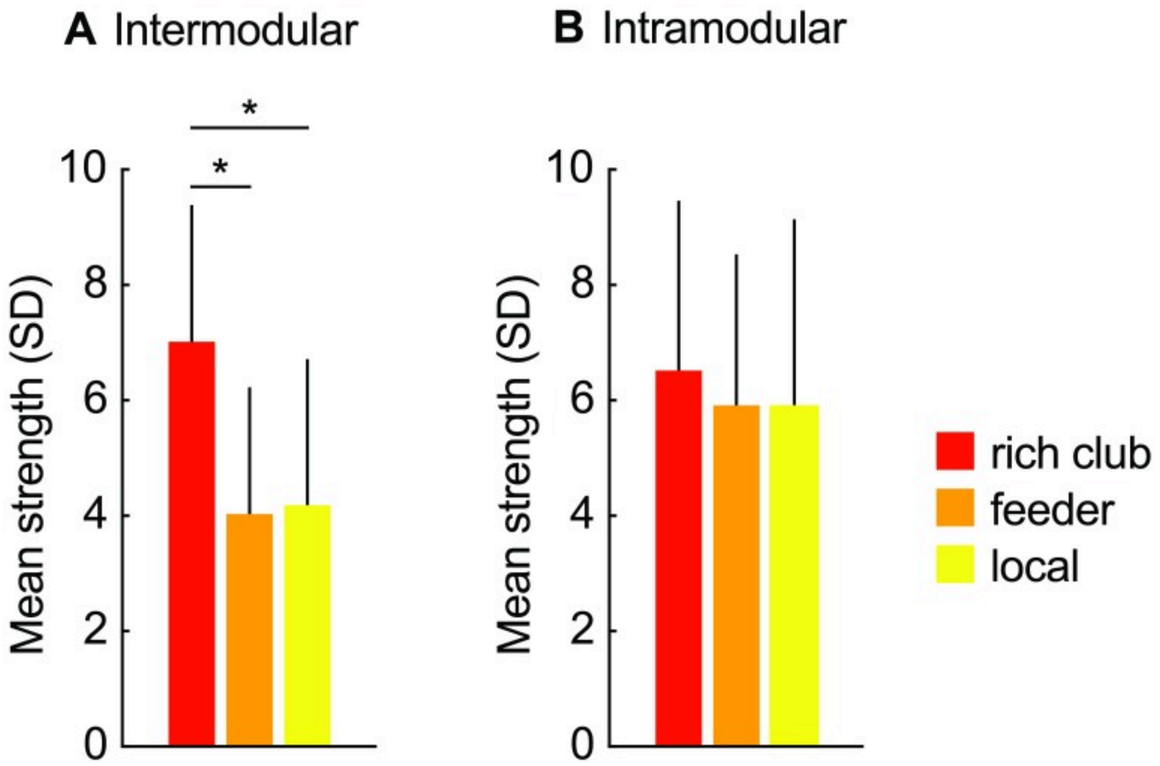
- Rich club organization in weighted network for in-degree between 25 to 75
- 81, 8m, 9/46d, 9/46v, F5, and 7m - highest in-degree nodes
- They formed a fully connected clique



Results

Rich club connection strength

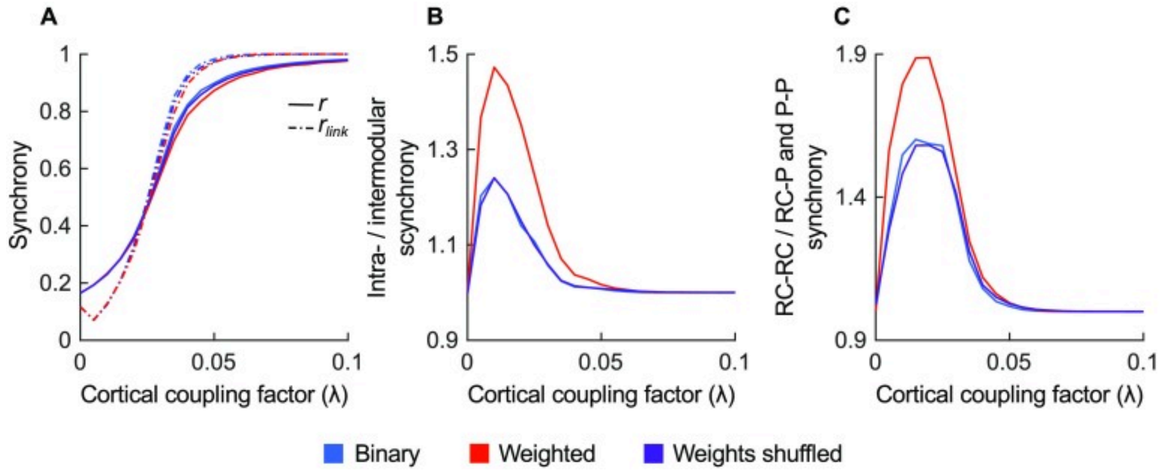
- Intermodular rich club connections were on average stronger than intermodular feeder connections present in the network
- No significant difference between feeder and local pathways



Results

Functional dynamics

- Synchronization within modules to precede intermodular synchronization
- Higher intra- and intermodular synchrony ratio in the weighted network compared to shuffled network
- Simulated synchrony of both binary and weighted networks was higher among rich club regions than the synchrony between rich club regions and peripheral regions



Local specialization combined with systems-level topological integration


Questions ?

Discussion

The paper

Novelty

Significance

Pitfalls

Next steps

Discussion

Pitfalls & next steps

- Incorporate global time delays in effective functional connectivity ?
- Individual differences ?
- Separation of roles of strength and nearness
- Is our notion of strength analogous with speed or redundancy ?
- Tracer vs tractograph
- Microcircuit complete ?
- Reciprocity and loops