Topological Brain Network Changes in Psychiatric Disorders

Paria Rezaeinia, Piya Pal and R. McKell Carter

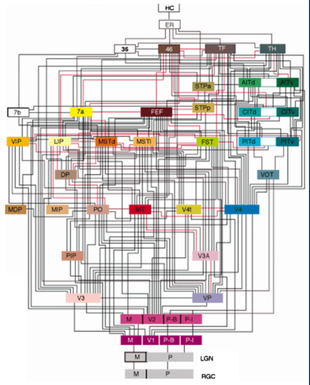
Electrical and Computer Engineering, University of California San Diego,

Institute of Cognitive Science and Department of Psychology and Neuroscience, University of Colorado Boulder

University of Colorado Boulder

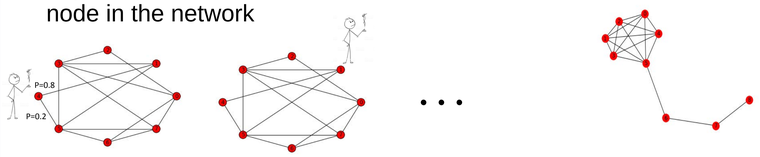
Sensory areas of the cortex exhibit graph theoretic properties of hierarchical processing streams

- Hierarchical processing streams are information processing structures central to neuroscience [1].
- **How can we detect hierarchical processing streams in the brain?**
- We use fMRI activation in the brain to create a network model of functional connectivity.
- Hierarchical processing streams are similar to linear components in a graph.

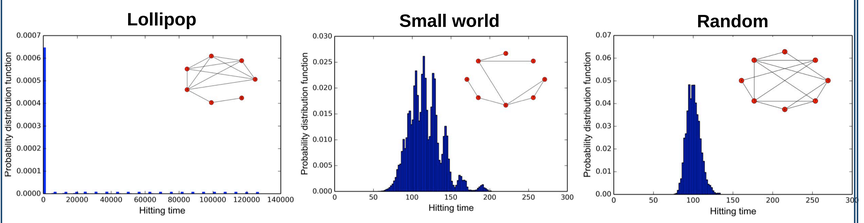


How can we detect linear components in a graph?

- Hitting time is the expected number of hops to go from one node to another node in the network
- Lollipop networks generate maximal hitting times [2].

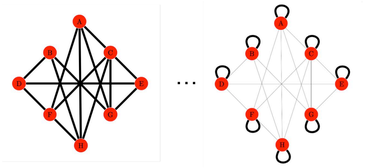


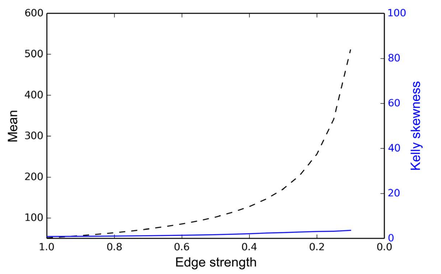
Linear component present in lollipop network increase the skewness of hitting time distribution



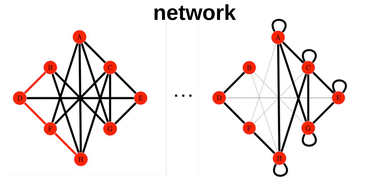
Reducing overall connectivity vs. adding a linear component?

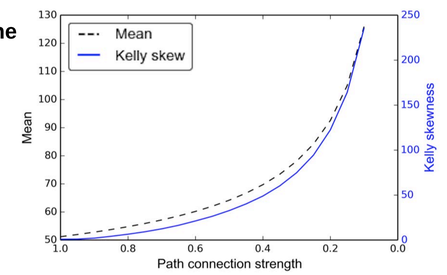
Reduced overall connectivity





Introducing a linear component in the network



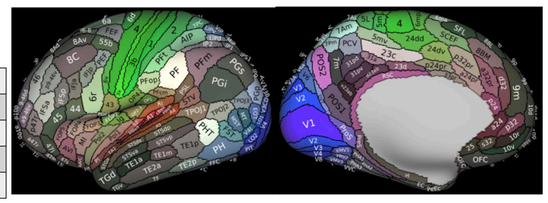


fMRI data:

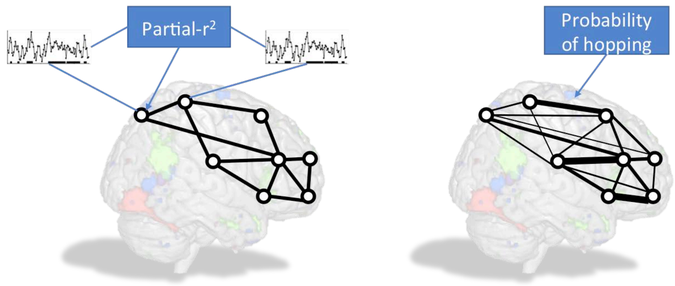
- LA5c Study, collected by the UCLA (CNP), [3].
- Rest and BART data

Group	Subjects
Control	119
ADHD	39
Bipolar	48
SCHZ	49

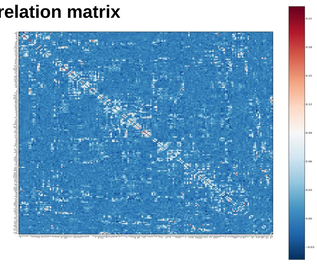
Multi-modal parcellation, Glasser, et al. [4].



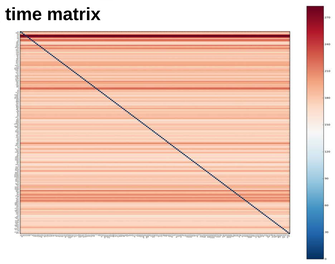
Brain network analysis



Partial correlation matrix



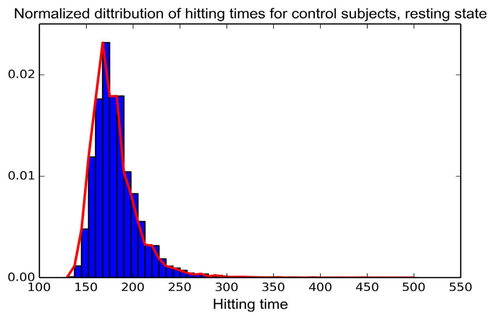
Hitting time matrix



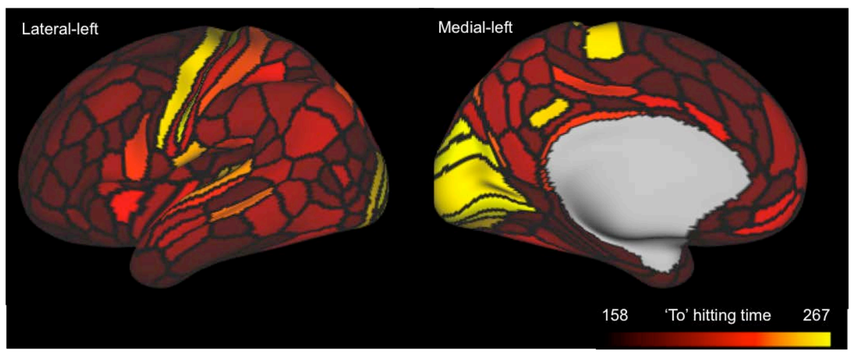
Is the hitting time distribution skewed for brain network?

- Pearson's coefficient of skewness = 2.3
- Kelly skewness = 15.04
- D'Agostino-Pearson test:

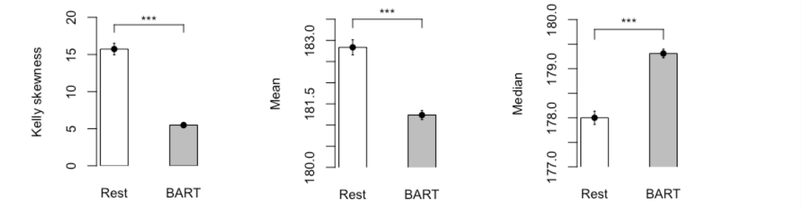
Z (skew) = 110, $chi^2(2) = 17864.8$, $p < 0.001$



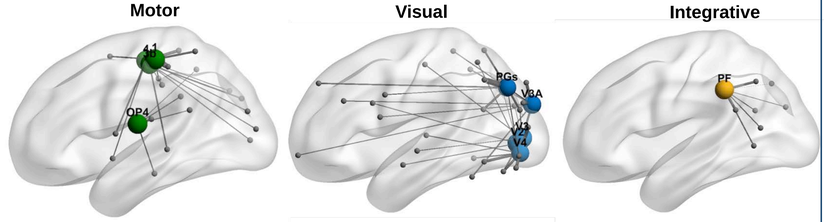
Nodes located on the hierarchical processing stream generate the largest "to" hitting times



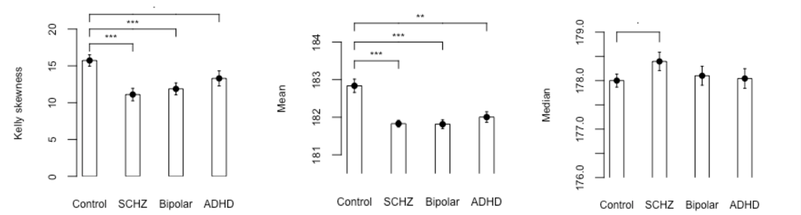
Skewness is significantly smaller for BART compared to Rest



Motor **Visual** **Integrative**

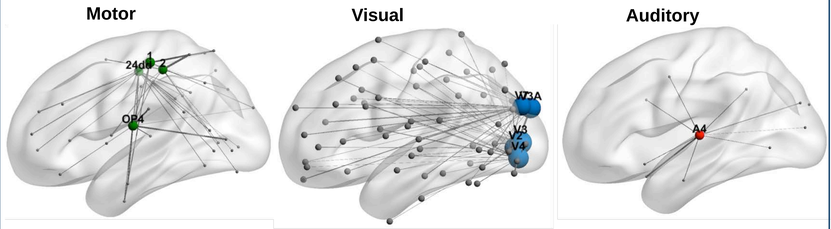


Skewness is significantly smaller for schizophrenia and bipolar



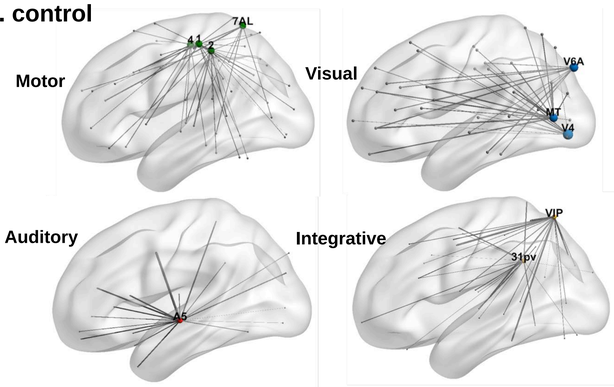
Schizophrenia vs. control

Motor **Visual** **Auditory**



Bipolar vs. control

Motor **Visual** **Auditory** **Integrative**



Summary

- Sensory streams are most isolated during rest and more integrated with other brain areas during task performance.
- Schizophrenia and bipolar psychiatric disorders represent less segregated sensory pathways compared to NT

Acknowledgement

The research was supported by Department of Electrical and Computer Engineering, University of California San Diego and Institute of Cognitive Science and Department of Psychology and Neuroscience of the University of Colorado Boulder.

References

[1] Van Essen, D. C., & Maunsell, J. H. R. (1983). Hierarchical organization and functional streams in the visual cortex. *Trends in neurosciences*, *6*, 370–375.

[2] Brightwell, G., & Winkler, P. (1990). Maximum hitting time for random walks on graphs. *Random Structures & Algorithms*, *1*(3), 263-276. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1002/ rsa.3240010303 doi: 10.1002/rsa.3240010303

[3] Glasser, M. F., Coalson, T. S., Robinson, E. C., Hacker, C. D., Harwell, J., Yacoub, E., . . . Van Essen, D. C. (2016). A multi-modal parcellation of human cerebral cortex. *Nature*, *536*, 171 EP -. Retrieved from http://dx.doi.org/ 10.1038/nature18933

[4] Poldrack, R., Congdon, E., Triplett, W., Gorgolewski, K., Karlsgodt, K., Mumford, J., . . . Bilder, R. (2016). A phenome-wide examination of neural and cognitive function. *bioRxiv*. Retrieved from http://biorxiv.org/content/early/ 2016/06/19/059733 doi: 10.1101/059733