**Advanced Connectivity Modeling in Neuroimaging**

PSYC 859

Fall 2018

Fridays, 10:10-11:00, (Phillips 0301)

**Overview:** This course is a 1 hour weekly seminar series that is meant to introduce students from all years to the network neuroscience approach. It focuses on applied examples and aims at getting students familiar enough with the approaches that they can intelligently critique applications and propose novel substantive network neuroscience analyses. This course, due to time constraints, will not cover the how-to directly, but resources will be provided for interested students (See Below).

**Assignments:** Each week two relevant articles will be assigned. Students would be expected to write a 1 paragraph response to the articles, with questions and/or ideas how they could apply the method in question to their research. Response paragraphs will be assessed on a 0-1-2 point scale as follows:

* 0 point: Nothing was turned in, or it was painfully clear the reading wasn’t even attempted.
* 1 point: Response summarized the article, but no questions or original thoughts were supplied.
* 2 points: Response summarized the article, and included original questions about the article content, ideas for application to own research, and/or ideas you would like to cover in class.

Response paragraphs will be **due the Wednesday before class**, as I want to integrate your questions into my slides.

**Grading scale:** 11 weeks at maximum 2 points a week implies 22 points in total. Grades will be given out as follows: Fail: 0 points. Low Pass: 1-5 points, Pass: 6-13 points, High Pass: 14-22 points.

**Attendance:** As this is a seminar course on methodology, I would strongly prefer all students attend all lectures. However, as this is a graduate level course, I am not enforcing any attendance policy. If you know you are going to miss a week due to a personal event, or a conference, just let me know.

**Resources and Applicability:** Given the short nature of this course, focus will be on understanding the topics rather than learning the tools to apply them directly. Resources, in the form of example code and guides, will be available for students who want to learn to implement these methods, but the lectures will not be a how-to. All lectures and example code will be available on my GitHub page. All assigned articles will be available on the class Sakai page.

**Introduction and Overview:**

**Week 1: Network Neuroscience**

* What it is
* What it looks like
* What questions it can answer

Papers:

1. Bassett, D. S., & Sporns, O. (2017). Network neuroscience. Nature Neuroscience, 20(3), 353–364.
2. Logothetis, N. K. (2008). What we can do and what we cannot do with fMRI. Nature, 453(7197), 869–878.

**Week 2: Functional Preprocessing Blitz**

* Functional Data
  + What it looks like
  + What file formats there are
* Overview of preprocessing steps

Papers:

1. Ciric, R., Wolf, D. H., Power, J. D., Roalf, D. R., Baum, G. L., Ruparel, K., … Satterthwaite, T. D. (2017). Benchmarking of participant-level confound regression strategies for the control of motion artifact in studies of functional connectivity. NeuroImage, 154, 174–187.
2. Power, J. D., Barnes, K. A., Snyder, A. Z., Schlaggar, B. L., & Petersen, S. E. (2011). Spurious but systematic correlations in functional connectivity MRI networks arise from subject motion. NeuroImage, 59(3), 2142–2154.

**Week 3: Functional Connectivity**

* What is functional connectivity?
  + Correlations?
  + Partial Correlations?
  + Coherence?
  + Other?
* Choice of building the network
  + Parsimonious
  + Maximally informative

Papers:

1. van den Heuvel Hulshoff Pol, H.E., M. P. (2010). Exploring the brain network: A review on resting-state fMRI functional connectivity. European Neuropsychopharmacology.
2. Smith, S. M., Miller, K. L., Salimi-Khorshidi, G., Webster, M., Beckmann, C. F., Nichols, T. E., … Woolrich, M. W. (2011). Network modelling methods for FMRI. NeuroImage, 54(2), 875–891.

**Network Construction:**

Moving from fMRI time series to a connectivity network.

**Week 4: Thresholding**

* Oldie but a goodie
* Construction of functional connectivity matrices from correlations
* Absolute vs. degree preserving thresholding

Papers:

1. van Wijk, B. C. M., Stam, C. J., & Daffertshofer, A. (2010). Comparing Brain Networks of Different Size and Connectivity Density Using Graph Theory. PLoS ONE, 5(10), e13701.
2. Henry, T. R. & Cohen, J. R. (In Review). Thresholding functional connectivity: A question of density. NeuroImage.

**Week 5: Parsimonious Networks**

* Methods to build sparse partial correlation networks
* Adaptive lasso
* Elastic net

Papers:

1. Kim, J., Wozniak, J. R., Mueller, B. A., & Pan, W. (2015). Testing Group Differences in Brain Functional Connectivity: Using Correlations or Partial Correlations? Brain Connectivity, 5(4).
2. Pineda-Pardo, J. A., Bruntilda, R., Woolrich, M., Marcos, A., Nobre, A. C., Maestu´, F., & Vidaurre, D. (2014). Guiding functional connectivity estimation by structural connectivity in MEG: An application to discrimination of conditions of mild cognitive impairment. NeuroImage, 101, 765–777.

**Week 6: Causal Search Algorithms for Network Building**

* Causality as it applies to fMRI
* What causal search can and cannot do

Papers:

1. Gates, K. M., & Molenaar, P. C. M. (2012). Group search algorithm recovers effective connectivity maps for individuals in homogeneous and heterogeneous samples. NeuroImage, 63(1), 310–319.
2. Ramsey, J. D., Hanson, S. J., Hanson, C., Halchenko, Y. O., Poldrack, R. A., & Glymour, C. (2010). Six problems for causal inference from fMRI. NeuroImage, 49(2), 1545–1558.

**Network Analysis:**

Now that we have connectivity networks, how do we go about understanding them?

**Week 7: Graph Theory – Analyzing your networks**

* Integration/segregation approach
* Network statistics
  + Reduction of networks to statistics
* Modeling individual connections
  + Pro/Cons

Papers:

1. Zalesky, A., Fornito, A., & Bullmore, E. T. (2010). Network-based statistic: Identifying differences in brain networks. NeuroImage, 53(4), 1197–1207.
2. Sporns, O. (2013). Network attributes for segregation and integration in the human brain. Current Opinion in Neurobiology, 23(2), 162–171.

**Week 8: Graph Theory – Graph Topology**

* Small Worldness
* Graph Null Models

Papers:

1. Hallquist, M. N., & Hillary, F. G. (2018). Graph theory approaches to functional network organization in brain disorders: A critique for a brave new small-world. Network Neuroscience, 243741.
2. Bassett, D. S., & Bullmore, E. T. (2017). Small-World Brain Networks Revisited. Neuroscientist, 23(5), 499–516.

**Week 9: Graph Theory – Dynamic/Multilayer Networks**

* Networks. In. Time…….
* Multilayer networks

Papers:

1. De Domenico, M. (2017). Multilayer modeling and analysis of human brain networks. GigaScience, 6(5).
2. Betzel, R. F., Fukushima, M., He, Y., Zuo, X. N., & Sporns, O. (2016). Dynamic fluctuations coincide with periods of high and low modularity in resting-state functional brain networks. NeuroImage, 127, 287–297.

**Group Level Analysis:**

You have your network statistics, what now?

**Week 10: Secondary analysis – understanding results**

* Regression
  + All our standard methods apply.
  + Note multiple comparisons might need corrections

Papers:

1. Cohen, J. (1968). Multiple regression as a general data-analytic system. Psychological Bulletin, 70(6 PART 1), 426–443. **Note: Struggle through it, wonderful paper.**
2. Kim, J., Wozniak, J. R., Mueller, B. A., Shen, X., & Pan, W. (2014). Comparison of statistical tests for group differences in brain functional networks. Neuroimage, 101, 681–694.

**Week 11: Whole Brain and Localized Differences**

* The issue with inference equifinality
* Network robustness methods
* NBS Jackknife

Papers:

1. Henry, T. R., Duffy, K., Rudolph, M., Mostofsky, S. H. & Cohen, J. R., (In Review). Bridging global and local topology in whole brain networks using the network-based statistic jackknife. NeuroImage.
2. Achard, S., Salvador, R., Whitcher, B., Suckling, J., & Bullmore, E. (2006). A Resilient, Low-Frequency, Small-World Human Brain Functional Network with Highly Connected Association Cortical Hubs. Journal of Neuroscience, 26(1), 63–72.

**Bonus Round: DTI Blitz**

Structural imaging is an excellent source of network data for neuroimaging. All previously discussed analysis methods can be applied.

**Week 12: DTI – Analysis**

* Fractional Anisotropy
* Tractography
* Combining Structure and Function
  + Review restricted functional connectivity matrices.

Papers:

1. Zalesky, A., Fornito, A., Harding, I. H., Cocchi, L., Yücel, M., Pantelis, C., & Bullmore, E. T. (2010). Whole-brain anatomical networks: Does the choice of nodes matter? NeuroImage, 50(3), 970–983.
2. Damoiseaux, J. S., & Greicius, M. D. (2009). Greater than the sum of its parts: a review of studies combining structural connectivity and resting-state functional connectivity. Brain, 525–533.