McGill University, Department of Neurology & Neurosurgery

**NEUR608**

**Neuroimaging Data Science**

Fall term 2018 Course Syllabus

Montreal Neurological Institute

BT100

Time: Fridays 10:30-13:30

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**Overall goal.** The goal is to familiarize students with several powerful analytical approaches that can be applied to complex datasets, such as those derived from modern neuroimaging. After providing the basics of neuroimaging and statistical analysis, we will cover unsupervised as well as supervised learning, associative techniques and causal models, and give an introduction into graph theoretical analysis and meta-analyses. We will also provide guidelines for effective data visualization. A basic understanding of statistical analysis and MATLAB based programming are prerequisites to this course.

**Learning Objectives.** By the end of the course, the students should be able to:

1. Have an understanding of the covered analytical techniques.

2. Be able to implement these techniques in their own data.

3. Propose a neuroimaging analysis project in which these techniques are applied.

**Instructional method.** In the 3-hour long seminar, the instructors will first provide a brief overview of the methodology. Students will read the assigned articles prior to the class and prepare a critical summary of the article’s strengths and weakness. One student will present the article to the class, and lead the discussion. In the second part of the class, students will carry out practical exercises on some of the covered techniques on their own laptop, with guidance by both instructors. As a final assignment, students will present a mock research paper with analyses utilizing one or more of the covered methods.

**W01:Introduction (B. Misic)**

The session discusses the organization of the course. At the end of the class, a short Matlab crash course is given.

**Practice:**

Matlab 101

**W02: Multi-modal imaging and in-vivo connectivity analysis (B. Bernhardt)**

This section provides a brief introduction into state-of-the-art neuroimaging techniques.

**Papers:**

Craddock et al. (2015) *Connectomics and new approaches for analyzing human brain functional connectivity*. Gigascience.

Jbabdi et al. (2015*) Measuring Macroscopic Brain Connections in vivo*. Nat. Rev. Neurosci.

**Practice:**

Visualization of neuroimaging data.

**W03: The generalized linear model and linear mixed models (B. Bernhardt)**

The session gives an overview into the generalized linear model and linear mixed effects models. The practical session provides an introduction to SurfStat for Matlab, where an exemplary cross-sectional group comparison of cortical thickness data is provided, a covariance network analysis, and longitudinal cortical thickness analysis.

**Papers:**

Raznahan et al. (2013) *Patterns of coordinated anatomical change in human cortical development: a longitudinal neuroimaging study of maturational coupling.*

Neuron. 72(5): 873-84

Lebel (2011) *Longitudinal Development of Human Brain Wiring Continues from Childhood into Adulthood.* JNeurosci. 31(30):10937–10947

**Practice:**

Cortical thickness analysis using SurfStat for Matlab

**W04: Data compression and dimensionality reduction (B. Misic)**

The session is focused on exploratory multivariate dimensionality reduction techniques. We will give a theoretical overview of Eigen-decomposition and singular value decomposition (SVD). We will then discuss the implementation and interpretation of these techniques with a focus on principal components analysis (PCA), factor analysis (FA) and independent components analysis (ICA), non-negative matrix factorization (NMF).

**Papers:**

Smith et al. (2009). *Correspondence of the brain’s functional architecture during activation and rest.* PNAS, 106(31): 13040-13045.

Amico & Goni (2017) *The quest for identifiability of human functional connectomes.* Sci Rep 8(1): 8254.

**Practice**:

PCA/FA/ICA analysis of imaging. Model complexity, statistical inference, interpretation.

**W05: Associative Techniques (B. Misic)**

This session will focus on techniques used to associate two or more data sets to one another, with a particular focus on canonical correlation analysis (CCA) and partial least squares (PLS) analysis.

**Papers:**

Drysdale et al. (2016) *Resting-state connectivity biomarkers define neurophysiological subtypes of depression.* Nat Med

Smith et al. (2015) *A positive-negative mode of population co-variation links brain connectivity, demographics and behavior.* Nat Neurosci, 18, 1565-1567.

**Practice:**

PLS analysis of a sample fMRI data set using the Rotman-Baycrest toolbox.

**W06: Clustering techniques (B. Bernhardt)**

The session will provide an overview of different techniques to partition high dimensional datasets into subgroups.

**Paper:**

Kelly et al. (2012) *A convergent functional architecture of the insula emerges across imaging modalities.* NeuroImage 61: 1129-42

Yeo et al. (2011) *The organization of the human cerebral cortex estimated by intrinsic functional connectivity.* J Neurophysiol. 106: 1125–1165, 2011.

**Practice:**

Performing k-means and hierarchical clustering in Matlab and R

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**W07: Confirmatory techniques and causal models (B. Misic)**

Confirmatory analyses to assess “causal” influence, including mediation analysis, path analysis/structural equation modeling (SEM), dynamic causal modeling (DCM) and confirmatory factor analysis.

**Papers:**

Brodersen et al. (2011) *Generative embedding for model-based classification of fMRI data.* PLoS Comput Biol, 7(6):e1002079.

Atlas et al. (2010) *Brain mediators of predictive cue effects on perceived pain.* JNeurosci. 30(39): 12964–12977

**No practice session but feed-back on project ideas**

**W08: Graph theory I (B. Misic)**

The section will give a short refresher on neuroimaging based connectome analysis and introduce basic graph theoretical concepts (definition of a graph, small world model, centrality analysis).

**Paper:**

Hagman et al. (2008) *Mapping the structural core of human cerebral cortex.* Plos Biology. 6(7): 1480-1493

Van den Heuvel et al. (2012) *High-cost, high-capacity backbone for global brain communication.* PNAS. 11372–11377

**Practice:**

Comparative connectome analysis in animal models, based on the brain connectivity toolbox.

**W09: Graph theory II (B. Misic)**

The section will provide further important theoretical and practical insights into graph theoretical analysis (partitions and communities, stochastic block modeling, network diffusion models).

**Paper:**

Goni et al. (2015) *Resting brain functional connectivity predicted by analytic measures of network communication.* PNAS, 111(2), 833-838.

Bertolero (2015) *The modular and integrative functional architecture of the human brain.* PNAS, E6798

**Practice:**

Brain connectivity toolbox 2.

**W10: Statistical learning (B. Bernhardt)**

The section will introduce several supervised learning frameworks (e.g., LDA, Support Vector Machines, Trees, Random forests).

**Paper:**

Berman et al. (2013) *Dimensionality of brain networks linked to life-long individual differences in self-control.* Nature Communications. 4: 1373

Chang (2015) *A sensitive and specific neural signature of picture induced negative affect.* PLoS Biology, 13(6): e1002180.

**Practice:**

Supervised prediction task in Matlab.

**W11: Meta analysis techniques (B. Bernhardt)**

This session will review methods of identifying and amalgamating data from published and unpublished sources. It will further address methods of evaluating for publication bias and between study heterogeneity. Finally, we will introduce available tools in the neuroimaging literature (Neurosynth, BrainMap).

**Papers:**

* Pauli et al (2016*) Regional specialization within the human striatum for diverse psychological functions* PNAS, 113 (7): 1907–1912

Smith et al (2019) *Correspondence of the brain's functional architecture during activation and rest.* PNAS.106(31): 13040–13045.

**Practice:**

*Interaction with Neurosynth.*

**W12) Visualization + Data science methods (B. Misic & B. Bernhardt)**

**Papers:**

Tufte (1990) *The visual display of quantitative information*. Graphics press.

Partially available on: <http://people.tamu.edu/~alawing/materials/ESSM462/Tufte.pdf)>

Holten (2006) Hierarchical Edge Bundling: visualization of adjacency relations. IEEE

**W13) Students present final papers (B. Misic & B. Bernhardt)**