Human Brain Imaging for Cognitive Neuroscience: Data Acquisition, Analysis, and Sharing

PSYC GR6060 (lecture)/GR6061 lab
4 points

Spring 2020

Lectures: Wednesdays, 10:10a-12p, Schermerhorn 352
Co-requisite lab (PSYC GR6061): Fridays 10:10a-12p, Schermerhorn 200C

Instructors: Lila Davachi and Nikolaus Kriegeskorte

Prerequisites: Instructors' permission, basic programming skills in Matlab or Python, and some background in at least one of the following three subjects: cognitive psychology, neuroscience, engineering. Enrollment will be limited to a maximum of 20 students.

Co-requisite: Students should also plan to register for GR6061 Human Brain Imaging for Cognitive Neuroscience Lab.

Course description: This course provides an introduction to the most widely used methods for measuring and analyzing human brain activity and their application in cognitive neuroscience, complemented by weekly hands-on interactive labs to deepen understanding, experience measurements, and explore analyses.

Detailed description: Human brain imaging includes a range of techniques for noninvasive measurement of the structure and activity of the human brain. These techniques have revolutionized the study of the human brain in health and disease and play a key role in medical diagnosis. Drawing insight from the large amounts of data acquired with these techniques requires sophisticated techniques for imaging, statistical analysis, and visualization. Modern analysis combines structural and functional data: The cortex of an individual human subject is segmented and reconstructed as a polygon mesh. This three-dimensional representation of cortical structure can then be used to constrain the inference of activity sources and, after virtual flattening of the cortical sheet, to provide a canvas for color-coded maps of statistical results indicating brain activation and information. This graduate-level course will cover human brain imaging methods including magnetic resonance imaging (MRI), electroencephalography (EEG), and magnetoencephalography (MEG). Students will understand the mechanism, potential and limitations of each measurement modality and each major analysis technique, and how these methods can be used to gain insights about brain information processing.

Role in the Psychology curriculum: This course is intended for graduate students and can be used to fulfill the One Additional Statistics/Methods Course requirement for the M.Phil.

Textbook: Poldrack, R. A., Mumford, J. A., & Nichols, T. E. (2011). *Handbook of functional MRI data analysis*. Cambridge University Press.

Grading:
- 20% Lecture attendance and participation
- 20% Lab attendance and participation
- 60% Lab projects and course notes assignments

Grades will be rounded only to the nearest 0.1%, and assigned letter grades as follows:
A+: 97-100% A: 93-96.9% A-: 90-92.9%
B+: 87-89.9% B: 83-86.9% B-: 80-82.9%
C+: 77-79.9% C: 73-76.9% C-: 70-72.9%
D: 60-69.9% F: 0-59.9%

Weekly lectures and labs

Jan 21: Week 1
Lecture: **Physics of MRI: getting images from magnetic resonance signals**
Lab: **Visit to Zuckerman Institute Magnetic Resonance Imaging (MRI) facility**

Jan 27: Week 2
Lecture: **Physiology of fMRI: hemodynamic response and its relation to neural activity**
Lab: **Imaging hemodynamics in animal models**

Feb 3: Week 3
Lecture: **Experimental design for fMRI: sequencing the experimental conditions**
Lab: **Linear response models and hands-on optimization of fMRI experimental sequences**

Feb 10: Week 4
Lecture: **Preprocessing of fMRI data**
Lab: **Hands-on preprocessing of fMRI data**

Feb 17: Week 5
Lecture: **Univariate brain mapping: finding activated regions**
Lab: **GLM, multiple comparisons, family-wise error, false-discovery rate**

Feb 24: Week 6
Lecture: **Volume- and cortical-surface-based alignment**
Lab: **Cortical-surface-based fMRI analysis**

March 2: Week 7
Lecture: **Functional connectivity: understanding covariation of brain activity**
Lab: **Linear systems and convolution**

<u>March 9: Week 8</u>
Lecture: **Interactions between regions: causal inference and effective connectivity**
Lab: **Understanding Granger-causality and dynamic causal modeling**

<u>March 23: Week 9</u>
Lecture: **Network neuroscience: graph-theoretic analyses of brain networks**
Lab: **Special topic – TBD**

<u>March 30: Week 10</u>
Lecture: **Studying memory and cognition with fMRI**
Lab: **Special topic – TBD**

<u>April 6: Week 11</u>
Lecture: **Decoding models: testing for regional pattern information**
Lab: **Hands-on multivariate pattern information analysis**

<u>April 13: Week 12</u>
Lecture: **Representational models: testing brain-computational models with fMRI**
Lab: **Adjudicating among computational models with representational similarity analysis**

<u>April 20: Week 13</u>
Lecture: **Multimodal imaging: fMRI and scalp electrophysiological imaging**
Lab: **Hands-on EEG experimentation**

<u>April 27: Week 14</u>
Lecture: **Avoiding overfitting, selection bias, and circular analysis**
Lab: **Pitfalls of selection bias**

Syllabus subject to revision