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.

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

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

March 30: Week 10
Lecture: Studying memory and cognition with fMRI
Lab: Special topic – TBD

April 6: Week 11
Lecture: Decoding models: testing for regional pattern information
Lab: Hands-on multivariate pattern information analysis

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

April 20: Week 13
Lecture: Multimodal imaging: fMRI and scalp electrophysiological imaging
Lab: Hands-on EEG experimentation

April 27: Week 14
Lecture: Avoiding overfitting, selection bias, and circular analysis
Lab: Pitfalls of selection bias

Syllabus subject to revision