Department of Psychology - Columbia University

Fundamentals of human brain imaging: from theory to practice

GU4930 Course Syllabus / Fall 2020

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Class Meets: Tuesday 12.10 – 2PM
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Course Bulletin Description

Fundamentals of human brain imaging is a new advanced course open to undergraduates students from the Psychology, Neuroscience, Engineering, and Statistics Departments, that traces the key steps of the recent "neuroimaging revolution", and introduces the various methodologies and associated analytic approaches that are now available in the field of cognitive neuroscience. Specifically, the course develops around three main questions, currently under-represented in our undergraduate curriculum: **1) What is the advantage to study human cognition using correlational methodologies (e.g., EEG, MEG, fMRI)? 2) Which is the particular contribution of each method in the understanding of brain/behavior relationship? 3) Which are the most common ways to approach the analyze the neuroimaging data?** By promoting an inclusive environment and implementing active learning strategies, this course stimulates critical thinking and fosters collaboration among students from different departments.

Prerequisites

The course is open to advanced undergraduate students who have taken an introductory psych course (e.g., PSYC 1001), a research method and/or one statistics course, and a course in neuroscience or neuropsychology (e.g., UN2430/2450/2470). Graduate students in the Psychology department or other related departments interested in learning the basics of human neuroimaging can also enroll. Instructor permission is required to be officially enrolled in the course, by either emailing Dr. Spagna or Dr. He.

Full Description

Overview of design, delivery of the material, and learning goals: This course will be open to a maximum of fifteen students. Instructors' permissions will be required prior to enrollment, to ensure a balanced distribution of backgrounds. To promote active engagement among students, which is a precursor of learning outcomes and enhanced retention of the material, a mix of offline and in-class activities will be used. **Offline - factual knowledge:** the day before each class period, students will be asked to submit a reading response, discussing something interesting they found in the assigned weekly readings or asking substantive questions about concepts in the reading they found to be challenging. **Offline - collaboration and critical thinking:** groups of students will collaborate to prepare a detailed walkthrough of current analytic pipelines used to analyze datasets from their elective methodology. **In-Class - active learning:** typically, each class period will begin with a short lecture from the Instructors providing the background in neuroimaging necessary to better explore the issue of the day. Topics covered will span across all the steps of the scientific method applied to neuroscience, from a brief intro of basic neuroscience knowledge and experimental design, to programming and implementation of the design, measuring signals from a variety of methodology (e.g., EEG, MEG, fMRI), how to and interpret them. Class time will be also devoted to group presentation of theoretical and practical walkthroughs, experiments conducted in class, and discussion, with a specific emphasis on the use of portable EEG handsets for real-world neuroscience studies.

Learning Objectives

At the end of this course students will be able to:

1. Summarize the major assumptions that underlie the study of brain-behavior relationships;
2. Use the neuroimaging terminology in reviewing the history and explaining the essential concepts of the field.
3. Differentiate among major neuroimaging methods and describe how advantages and pitfalls of each method.
4. Evaluate different analytic pipelines used in neuroimaging, through identifying inconsistencies and fallacies with current processes.
5. Apply their knowledge to develop an EEG neuroimaging study design and conduct the research study, drawing from current state-of-the-art pipelines.
6. Present their work, peer revise other students' work, and lead a discussion.

Role of PSYC GUXYZ in the curriculum

PSYC GUXYZ is an advanced methods course, designed particularly for undergraduates who are majoring in Psychology or in Neuroscience and Behavior, for students participating in the Post-bac Psychology Program, and for Psychology Graduate Students who wants to start learning about neuroimaging. Students with a background in the computational sciences and philosophy are also welcome to apply. In covering the cognitive and neural bases of many cognitive functions, this advanced method course provides an integrated perspective on topics of current interest in the fields of psychology and cognitive neuroscience.

Course website

The most up-to-date information, including changes to the syllabus or to the class schedule, announcements, lecture slides and additional materials are contained on the course website on CourseWorks. Be sure you are familiar with it, that you are easily able to login to the website, and that you always have the lecture slides with you (whether printed or electronic). If you have problems accessing the course website at any point during the semester, please let me know.

The advanced method course fulfills the following degree requirements

- The Advanced Research Methods requirement of the Psychology major, and of the Psychology Post-Bac certificate program.
- For the Neuroscience and Behavior joint major, UN19XYZ will count as an elective. Students are invited to contact the Instructors to obtain special permission to count it towards the seminar requirement, if interested.
- For Psychology Graduate Students, PSYC G60XY will apply toward the "One Additional Statistics/Methods Course requirement" for the M.Phil.

Readings: There is no textbook required for this course

Readings will comprise scientific articles from peer - reviewed journals, literature reviews, and commentaries in the fields of neuroimaging. The readings listed in the Schedule below are provisional but illustrative of the types of articles we will be reading and discussing. All readings will be posted in PDF form on CourseWorks.

Timeline of the activities

The calendar below details topics, readings, and assignments for each class period. It may be subject to changes to reflect interests of students. Students are responsible to be prepared to discuss the assigned readings for each class period. Typically, each class period will begin with an introduction delivered by the Instructors (one hour) providing the background in neuroscience necessary to better explore the issue of the day. The rest of class time will be devoted to student presentations and discussion (1/2), and data analysis (1/2) (detailed in Course Requirements). As an example, for the class on Week 2, Dr. Spagna will start giving an introduction to the main basic concepts of fMRI and MEG (25 mins), followed by Dr. He introducing EEG and fNIRS (25 mins). After a short break, a student will present an article introducing the most commonly used open data repositories (e.g., BIDS apps: Improving ease of use, accessibility, and reproducibility of neuroimaging data analysis methods), while another will present OpenNeuro—a free online platform for sharing and analysis of neuroimaging data. Then, the remainder of class time will be devoted to a discussion addressing questions related to the weeks' topic and to advance student's data analysis skills. Optional, supplementary readings are also included for those who might be interested in exploring the topic of a specific class more in depth, and students are encouraged to do so, especially by contributing to the discussion with more recent knowledge.

Course Requirements:

1. **Class preparation and participation:** The assigned readings are designed to expand your knowledge on the latest advancement in the field of reproducible neuroimaging data analysis and to hone your critical thinking skills. The topics discussed during the course are complex, leaving plenty of space to discuss and debate. Strong preparation and participation will enable us to have high-level, thought-provoking discussion.

2. **Weekly Response:** The day before each class period you will be asked to submit a short (one-paragraph) reading response to CourseWorks by 5:00pm. Goals of these reading responses are to help you keep current on course topics and to help me understand where students may have had difficulty with the readings and which topics students were most intrigued by and, therefore, which areas may warrant more focus during class time. Each reading response should be no more than a short paragraph, either discussing something interesting you found in the readings or asking substantive questions about concepts in the reading you found challenging. As the goal of these assignments is to keep you up to speed and to help guide my teaching and our class discussions, the assignments will just be graded on a pass/fail basis. (I can only accept responses submitted before the deadline.)

3. **Thorough reading enables thoughtful discussion**. It is important to engage with the material during the Instructors introduction as well as during class discussions, since your active participation in these discussions will contribute to your final grade. Some of the topics discussed in the course could be harder to digest, please do reach out to the Instructors in private / outside of class time when something is unclear. If you feel that regularly contributing to class discussions is difficult for you, you should raise this issue with me as soon as possible. In such cases, we might be able to work out a way for you to participate thoughtfully through your reading responses.

Generally speaking, effective class preparation and participation could include:

- Asking insightful or clarifying questions.
- Connecting the reading to other reading we've done in the course or reading you've done on your own, drawing parallels and/or contrasts among findings.
- Actively listening to fellow classmates and responding to their ideas.
- Offering thoughtful critiques of the research methodology and providing suggestions for how it might be improved.
- Bringing in outside sources – potentially from the news media or other sources – that shed light on neuroscience findings or that illustrate ways in which these findings are interpreted and applied.

4. **Leading discussions:** You will be responsible for presenting one articles and leading the class discussion for at least one class meetings. We'll provide more information and give a demonstration of the sort of presentation we are looking for in the first week of class. But, briefly, you'll walk us through your assigned article, describing the main concepts introduced, methods and results (if not a review), highlighting any strengths or weaknesses of the study design, and giving your thoughts on the meaning and importance of the findings. To make sure that your presentation is effective, we ask you to complete a handout and email that to the Instructors at least two days before the date of your presentation, so that we can provide feedback in advance of your actual presentations. As the goal is for you to become more skilled in presenting research findings and leading discussions, in calculating grades, the second presentation will be weighted more heavily than the first.

5. **Final Assignment (Team Work)**: The culmination of this course is the creation of a novel research proposal relating to the material of the class. Good writing is good thinking, and a primary goal of this assignment is to help you hone your writing and critical thinking skills. The process of writing the research paper follows three steps:
   a) Early in the course you will be asked to identify a method you would like to know more about among the ones discussed in class. As soon as you identify it, you are expected to email the Instructors stating the method you chose, so that together we can decide whether it is appropriate and how to build the various teams (6 or 7 in total). The specific content of this project can vary, but should make use of a dataset neuroscience (publicly available, or that you would like to collect). Add a list of at least five (and no more than 10) references you intend to use as part of the final submission (see below). We will make suggestions regarding focus, potential sources, etc. **Deadline for Topic Proposal is set to (ADD DATE – week 5 day before class).**
   b) Once your topic is approved, you will begin work in teams to collect (or download if publicly available) the datasets and start the analysis. The motivation behind the analyses needs to be clear, and some prediction of the results should be given, but the results do not need to be placed within a wider context of literature. The focus is on learning how to report a neuroimaging data analysis. Generally, you want to choose a topic that is appropriately narrow to address in an 8-10 pages paper (not including references). Since this is a team-work, it is extremely important that each author contributes fairly to the writing (See Academic Integrity section. Below). **Deadline for Paper Draft is set to (ADD DATE – week 9 day before class).**
   c) **Anonymous Peer Review:** In order to make this activity also an opportunity for students to actively learn, one of the steps in the revision process will be a round of "anonymous peer review," in which each student will be asked to review the drafts of at least two of their colleagues. This will put each student in the position of the "reviewer," by critically analyzing and understanding pitfalls, shortcomings, but also strengths of the writing of their peers; this is expected to influence also the student's own writing by adjusting the focus and clarifying potential issues. Students will be randomly assigned to anonymously peer review the drafts written by two other students. Comments and suggestions from the peer-review process should be appropriately considered when writing the final manuscript based on the student's judgment. Students will be evaluated on their own writing, the feedback provided to other students, as well as their ability to incorporate the feedback into their work. Make sure you provide valuable feedback to your peers in order to get full points on the final writing assignment. **Deadline for the Anonymous Peer Review to (ADD DATE – week 12 day before class).**
   d) Towards that end, The Instructors will provide comments and suggestions on your first draft, and you will be expected to make substantive changes – not just copyediting, but rather larger edits such as, reworking entire sections, drawing on new sources, and providing more analysis. The final draft of the paper will be graded not only

as a standalone paper but also in how it demonstrates improvement upon the earlier draft. The grade submitted will be the same for the entire team. **Deadline for Final Submission (ADD DATE – week 15 day before class).**

Evaluation criteria: in line with the learning goals, namely: (a) the acquisition of factual knowledge at the base of human brain imaging; (b) develop the ability to collaborate with peers and produce a final product that reflects each individual's contribution as well as the group effort; (c) actively engage in data analysis exercises and scientific communication, students will be evaluated on (a) clarity and depth of their weekly responses; (b) quality and clarity of their in-class walkthrough; (c) a final project, redacted in groups, in which students introduce the method used, the pipeline used to analyze the data, and discuss the results.

Letter Grade Assignment

97-100: A+	94-96: A	90-93: A-
87-89: B+	84-86: B	80-83: B-
77-79: C+	74-76: C	70-73: C-
69-60: D	<60: F	

Grading

Grades will be calculated based on the percentages outlined below.

A. Class preparation, participation, and data analysis……………………… 30%
- Reading responses 33%
- Contribution to class discussion 33%
- In Class Data Analysis session 33%

B. Presentation and Leading Discussion ………………………………………… 20%
- First presentation 50%
- Class Discussion 50%

C. Final Assignment……………………………………………………………………… 50%
- Proposal 10%
- First draft 20%
- Peer Review 30%
- Final draft 40%

Class policies: Important Information below – please read carefully!

Disability Services: In order to receive disability-related academic accommodations for this course, students must first be registered with their school Disability Services (DS) office. Detailed information is available online for both the Columbia and Barnard registration processes. Refer to the appropriate website for information regarding deadlines, disability documentation requirements, and drop-in hours (Columbia)/intake session (Barnard).
For this course, Columbia students are not required to have testing forms or accommodation letters signed by faculty. However, students must do the following:

1. The Instructor section of the form has already been completed and does not need to be signed by the professor.
2. The student must complete the Student section of the form and submit the form to Disability Services.
3. Master forms are available in the Disability Services office or online: https://health.columbia.edu/services/testing-accommodations

Religious observances: If you are going to miss class(es) due to religious holidays, you must notify me during the first week of class so that accommodations may be made.

Sexual Respect: Any form of gender-based misconduct will not be tolerated. Columbia University is committed to fostering an environment that is free from gender-based discrimination and harassment, including sexual assault and all other forms of gender-based misconduct. Visit this website for more information: http://sexualrespect.columbia.edu/

Academic integrity: As members of this academic community, we are responsible for maintaining the highest level of personal and academic integrity: "Each one of us bears the responsibility to participate in scholarly discourse and research in a manner characterized by intellectual honesty and scholarly integrity.... The exchange of ideas relies upon a mutual trust that sources, opinions, facts, and insights will be properly noted and carefully credited. In practical terms, this means that, as students, you must be responsible for the full citations of others' ideas in all of your research papers and projects... [and] you must always submit your own work and not that of another student, scholar, or internet agent" (from the Columbia University Faculty Statement on Academic Integrity)
http://www.college.columbia.edu/academics/academicintegrity .

Cheating and plagiarism – whether intentional or inadvertent – is a serious violation of academic integrity. Plagiarism is the practice of claiming or implying original authorship of (or incorporating materials from) someone else's written or creative work, in whole or in part, without adequate acknowledgement. If you have any questions about what constitutes plagiarism and/or how to properly cite sources, please come to me. I am more than happy to help. Similarly, if you put yourself in a situation in which you think your best option might be to cut some corners, see me. If you feel like you are falling behind, don't understand the material, or are not confident about your ability to take tests, talk to me as soon as possible instead of taking measures that go against principles of academic integrity. We are here to learn, not to merely judge. It is a far better option to come talk to me than compromise your academic integrity and potentially put your academic standing in jeopardy.

Attendance: Coming to class is meaningless if class time is spent inappropriately. Chatting with friends, watching videos online, and browsing social media are not appropriate activities for the classroom. Also, remember to silence your cell phone before class. Generally, eliminate distractions as much as possible to respect your classmates, as well as increase your chance of staying focused and learning the material during class.

Schedule

The calendar below details topics, readings, and assignments for each class period. Students are responsible to be prepared to discuss the assigned readings for each class period.

Date	Topics and Assignments	To do in class	Notes	Readings & Open Access Public Data
Week 1	Introduction to the course Syllabus and Brain basics (Basic Neuroanatomy check)	Assign the machines, sign in, start using	Keep track of the assignment on the Instructor's side.	Survey Computational Skills
Week 2	Non-invasive data acquisition (fMRI, EEG, fNIRS, MEG) Reading response due (Alfredo add slides on MEG)	First half AS: fMRI and MEG Spatial resolution XH: EEG and fNIRS Temporal resolultion	For fMRI, EEG, fNIRS and MEG we can use open data / publicly available dataset to do it.	*Readings:* 1) Plewes DB, Kucharczyk W. Physics of MRI: a primer. Journal of magnetic resonance imaging. 2012 May;35(5):1038-54 2) Tadel, F., Baillet, S., Mosher, J. C., Pantazis, D., & Leahy, R. M. (2011). *Brainstorm*: a user-friendly application for

				MEG/EEG analysis. Computational intelligence and neuroscience, 2011. *3) http://www.mayfieldclinic.com/pe-anatbrain.htm* *4) Fundamentals of Neuroscience* *Software:* https://neuroimage.usc.edu/brainstorm/ https://sccn.ucsd.edu/eeglab/index.php
Week 3	Experimental design I Theory (Alfredo) Reading response due	Explain the theory	→ For next class download Psychopy	*Readings:* 1) Amaro Jr et al., Study design in fMRI: Basic principles, Brain and Cognition 2006 2) Liu TT. The development of event-related fMRI designs. Neuroimage. 2012 Aug 15;62(2):1157-62. *Software:* https://www.psychopy.org
Week 4	Experimental design II PsychoPy (Xiaofu) Reading response due	Explain Psychopy 30 minutes exercise in class: create a short block design	Think and start working (as homework) on your experimental design (the more you advance the better)	*Readings:* 1) Wager TD, Nichols TE. Optimization of experimental design in fMRI: a general framework using a genetic algorithm. Neuroimage. 2003 Feb 1;18(2):293-309. 2) Peirce, J., & MacAskill, M. (2018). Building experiments in PsychoPy. Sage. 3) Psychopy Manual (for scripting)
Week 5	Practicum: Create your own block design Deadline for Topic proposal (AS)	No Lecture AS and XH Just supervise and help if issues arise	During the week, students are expected to work on their own block design using Psychopy	*No Readings*
Week 6	EEG: all in one bite (XH) Brief theory about EEG (30 mins) EEG data acquisition (30 mins) EEG Preprocessing Pipeline Theory (30 mins) EEG Preprocessing Pipeline (start the practice) Reading response due	4 blocks of 30 minutes: two repetitions of theory to practice.	Choose a very stable experiments that students can replicate. 15 students and 6/7 teams (so they can replicate) Demo 1) Visually Evoked Potential task SSVEP demo MUSE bring to class 2) Auditory Oddball Task SSAVEP demo	*Readings:* 1) Zhang, X. L., Begleiter, H., Porjesz, B., Wang, W., & Litke, A. (1995). Event related potentials during object recognition tasks. Brain Research Bulletin, 38(6), 531-538. 3) Thuné, H., Recasens, M., & Uhlhaas, P. J. (2016). The 40-Hz auditory steady-state response in patients with schizophrenia: a meta-analysis. JAMA psychiatry, 73(11), 1145-1153. *Supplementary* 1) Niso, G., Tadel, F., Bock, E., Cousineau, M., Santos, A., & Baillet, S. (2019). Brainstorm Pipeline Analysis of Resting-State Data From the Open MEG Archive. Frontiers in neuroscience, 13 2) Norcia, A. M., Appelbaum, L. G., Ales, J. M., Cottereau, B. R., & Rossion, B. (2015). The steady-state visual evoked potential in

				vision research: a review. Journal of vision, 15(6), 4-4. *Data:* *Open MEG Archive OMEGA* *https://www.mcgill.ca/bic/resources/omega*
Week 7	Practicum EEG Collect data and preprocess them Reading response due	Pick from OMEGA a dataset, download, and apply what you have learned!	Use MUSE to acquire data and use Psychopy to replicate the results of the task Bring MUSE to class Ask students to practice with setup Data acquisition Data processing Result plotting (or HW)	*Reading:* 1) Tadel, F., Bock, E. A., Niso, G., Mosher, J. C., Cousineau, M., Pantazis, D., ... & Baillet, S. (2019). MEG/EEG group analysis with brainstorm. Frontiers in neuroscience, 13, 76. Analysis Code on GitHub
Week 8	MEG Week (AS) Spatiotemporal dynamics Reading response due	Publicly available dataset for EEG / ERP	ERP: More sensitive to artifacts ERP task on Github	*Reading:* 1) Gross, J., Baillet, S., Barnes, G. R., Henson, R. N., Hillebrand, A., Jensen, O., ... & Parkkonen, L. (2013). Good practice for conducting and reporting MEG research. Neuroimage, 65, 349-363. Analysis Code on GitHbu
	SPRING BREAK			
Week 9	fMRI: all in one bite (AS) Brief theory about fMRI (30 mins) fMRI data acquisition (30 mins) fMRI Preprocessing Pipeline Theory (30 mins) fMRI Preprocessing Pipeline (start the practice) Deadline for Paper Draft	Online video clip about how to collect fMRI data?	Organize visit to fMRI scanner at Zuckerman → For next class Download MRIcron; → Download Matlab → Download SPM; Use a little of Matlab and just follow the SPM manual	*Reading:* 1) Di Bono, M. G., Priftis, K., & Umiltà, C. (2017). Bridging the gap between brain activity and cognition: beyond the different tales of fMRI data analysis. Frontiers in neuroscience, 11, 31. Software: https://www.nitrc.org/projects/mricron https://www.fil.ion.ucl.ac.uk/spm/
Week 10	Preprocessing and Practicum Clarify pipeline and make them practice (XH) Reading response due	Repeat the Preprocessing main steps (first hour) Publicly available dataset (second hour)	Run the analysis pipeline in SPM	*Reading:* *1)* SPM-12 manual chapters 1-7, and 31 (practice: 31.1.1 ~31.1.4) *(practice: 31.1.5 ~31.1.7)* 2) Esteban O, Markiewicz CJ, Blair RW, Moodie CA, Isik AI, Erramuzpe A, Kent JD, Goncalves M, DuPre E, Snyder M, Oya H. fMRIPrep: a robust preprocessing pipeline for functional MRI. Nature methods. 2019 Jan;16(1):111-6. Data from SPM Manual: - Auditory Dataset (1st level) - Face Dataset (1st and 2nd level)

Week 11	fMRI First and second Level (AS) Reading response due	General Linear Modeling		*Reading:* 1) SPM-12 manual chapters 8-10 (practice: 31.2) 2) Beckmann, C. F., Jenkinson, M., & Smith, S. M. (2003). General multilevel linear modeling for group analysis in FMRI. Neuroimage, 20(2), 1052-1063. 3) Friston, K. J., Stephan, K. E., Lund, T. E., Morcom, A., & Kiebel, S. (2005). Mixed-effects and fMRI studies. Neuroimage, 24(1), 244-252. 4) Roels, S. P., Loeys, T., & Moerkerke, B. (2016). Evaluation of second-level inference in fMRI analysis. Computational intelligence and neuroscience, 2016. *Supplementary:* Nichols TE, Holmes AP. Nonparametric permutation tests for functional neuroimaging: a primer with examples. Human brain mapping. 2002 Jan;15(1):1-25.
Week 12	Practicum fMRI data analysis in class Reading response due	No Lecture AS and XH Just supervise and help if issues arise	Full hands-on day to analyze the data, from the preprocessing to the second level. Important is to batch the sequence of steps (for time constraints) and let the analysis run.	*No Readings*
Week 13	Brain Econding / Decoding (XH)	Multivariate Pattern Analysis		*Reading:* 1) 1. LaConte et al., Real-Time fMRI Using Brain-State Classification, Human Brain Mapping 2007. 2) Kerri Smith, Reading Minds, Nature, 2013
Week 14	Other neuroimaging modalities fNIRS (XH) Reading response due			*Reading:* 1) Irani, F., Platek, S. M., Bunce, S., Ruocco, A. C., & Chute, D. (2007). Functional near infrared spectroscopy (fNIRS): an emerging neuroimaging technology with important applications for the study of brain disorders. The Clinical Neuropsychologist, 21(1), 9-37. 2) Baker, J. M., Rojas-Valverde, D., Gutiérrez, R., Winkler, M., Fuhrimann, S., Eskenazi, B., ... & Mora, A. M. (2017). Portable functional neuroimaging as an environmental epidemiology tool: A how-to guide for the use of fNIRS in field studies.

				Environmental health perspectives, 125(9), 094502.
Week 15	Reproducibility Deadline for Final Submission		No Exam; Project-based (3 or 4 groups) Method elected by the students and analysis conducted either on open data set or on their own data.	*Reading:* 1) Poldrack RA, Baker CI, Durnez J, Gorgolewski KJ, Matthews PM, Munafò MR, Nichols TE, Poline JB, Vul E, Yarkoni T. Scanning the horizon: towards transparent and reproducible neuroimaging research. Nature reviews neuroscience. 2017 Feb;18(2):115.