Department of Psychology - Columbia University
Fundamentals of human brain imaging: from theory to practice
GU4442 Course Syllabus
Fall 2024

Class Meets: Monday 4.10 – 6PM
Room: Schermerhorn 200B

Instructor: Alfredo Spagna, Ph.D. (email)
Office Hours (calendar link): Schermerhorn 315 Tue 10 – 12PM

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) What is the 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 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 knowledge 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:** by Sunday night 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. **In-Class - active learning:** typically, each class period will begin with a short lecture from the instructor 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 and discussion, scientific writing sessions, 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 essential concepts of the field.
3. Differentiate among major neuroimaging methods and describe how dis/advantages of each method.
4. Evaluate different analytic pipelines used, identify inconsistencies and fallacies with current processes.
5. Present their work, peer revise other students' work, and lead a discussion.

Role of PSYC GU4442 in the curriculum

PSYC GU4225 is an advanced methods course, designed particularly for undergraduates who are majoring in Psychology or in N&B, for students participating in the Post-bac Psych 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.

The advanced method course fulfills the following degree requirements.

- For the Psychology major or concentration in the College and in G. S., for the Psychology minor in Engineering, and for the Psychology Post-bac certificate, PSYC GU4225 will meet the Group II (Psychobiology and Neuroscience) distribution requirement.
- For the Neuroscience and Behavior joint major, GU4225 will fulfill the 5th Psychology requirement: "one advanced psychology seminar from a list approved by the Psychology Department advisor to the program."
- For Psychology Graduate Students, PSYC GU4225 will apply toward the "One Additional Statistics/Methods Course requirement" for the M.Phil.
- For the Barnard Psychology major, PSYC GU4225 will fulfill the senior seminar requirement.

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.

I. 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.

II. 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 introducing the main basic concepts of fMRI and MEG. 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.

III. 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 (20%):**

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.

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.

2. **Weekly Responses (30%):**

The Sunday before each class period you will be asked to submit a short (one-paragraph) reading response (i.e., summary of the article + reflections on each of the weekly readings) to CourseWorks by 10:00pm. 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 summary+ reflection should be no more than a short paragraph, either discussing something interesting you found in the reading or asking substantive questions about concepts in the reading you found challenging. These assignments will be graded on a two-point scale with 0 = not submitted / incomplete; 1 = completed but superficial / lacking / late; 2 = completed on time and discusses all the material properly.

Careful reading enables thoughtful discussion. It is important to engage with the material during the instructor's introduction as well as during class discussions. Your active participation 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 instructor if 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 will work out a way for you to participate thoughtfully through your reading responses.

3. **Present and Lead discussion section (30%):**

Everyone is required to give a 30-minute slide presentation during one class period, on one of the papers assigned that week. Paper assignments will be decided during the first week. Use this shared google sheet to (self) sign up for a presentation. Follow this structure when building your presentation:

I. Introduce the authors and journal where the article is published.
II. Briefly introduce the topic and create an outline of the topics you'll be discussing;
III. Describe the main concepts introduced, methods and results (if not a review).
IV. Highlight strengths or weaknesses of the study design.
V. Give your thoughts on the meaning and importance of the findings.
VI. To make sure that your presentation is clear and effective, all students must:
    a. complete a handout and email that to the instructor at least one week before the date of your presentation. I will provide feedback in advance of your actual presentations. A penalty of 5 points will be applied if the student does not submit the handout ahead of time.
    b. Schedule a time to meet with me during office hours at least one week before the date of your presentation. A penalty of 5 points will be applied if the student does not schedule a meeting.

Each presentation will be graded out of 50 points, following this grading scheme:

1. 10 points: What question is this paper trying to answer? This will require reading some of the papers cited in this paper's introduction, to help provide context.
2. 10 points: For papers reporting a new experiment, what is the experimental method? For review or theory papers, what are the details of the theory or theories being proposed?
3. 10 points: What evidence is given in support of the hypothesis or theory?
4. 10 points: Propose questions for discussion. Are there potential weakness or limitations to the conclusions of the paper? Do these results connect to topics from other sessions of the class or from other classes you've taken? Do these findings have implications for how writing or filmmaking can be made more effective?
5. 10 points: Clarity of slides, presentation, and class engagement. Slides should consist primarily of figures, images, and diagrams with only small amounts of text. You should engage your classmates by posing questions throughout your presentation and answering their questions about the paper (when possible).

4. **Final Assignment (Manuscript) (20%)**:

The culmination of this course is the creation of a novel research proposal relating to the material of the class. Students are expected to select a theory (genetic algorithms), a study (e.g., from the recent fMRI literature), a method (e.g., EEG acquisition pipelines), or general topic (e.g., open data and reproducibility) related to neuroimaging and discuss it in depth. All students will be required to produce a 7-9 pages written manuscript (double spaced, excluding references). Students should discuss the challenges encountered by the field in studying the selected theory or implementing and validating the method, as well as the value of replicating research findings. There will be a strong emphasis on critiquing, adapting, and validating the claims made in other studies and advancing the field by creating new ones.

Good writing is good thinking, and a primary goal of this assignment is to help you hone your writing and critical thinking skills. Follows these two steps:

Step 1: Choose your Topic. Identify early in the course the theory / method / topic you would like to deepen your knowledge on among the ones discussed in class. Email the Instructor stating the study you chose and why, by Tuesday March 4th at 10PM. We will decide together whether the topic is appropriate and whether the effort is worth pairing you with one of more peers (therefore, building a team). Though not necessary, you could also propose to conduct a small project that includes building an experiment using PsychoPy or MNE/Brainstorm/ SPM/Python/R for data analysis of existing data. **Deadline for Topic Selection is set to Week 7 - March 4th at 10PM.** A penalty of 5 points will be applied if the student does not email the instructor before the deadline.

Step 2: Submission. Each manuscript will be graded out of 50 points, following this grading scheme:

- 10 points: Is the topic clearly identified, relevant to the course content, and thoroughly discussed?
- 10 points: Are multiple references (more than 10, at least 5 not from the reading list) included in the manuscript?
- 10 points: Did the student identify challenges to study the theory / method / topic selected, and how to solve them?
- 10 points: Did the student propose some adaption to one or more aspects of the method used, or a revision of the theory?
- 10 points: Does the writing convey a student's learning? After the course, does the student have a deeper understanding about the topic? The grade submitted will be the same for the entire team. **Deadline for Final Submission April 29th at 10PM.**

Letter Grade Assignment

A+: 100%	B+: 87-89.9%	C+: 77-79.9%	D: 60-60.9%
A: 95-99%	B: 83-86.9%	C: 73-76.9%	F: 0-59/9%
A-: 90-94.9	B-: 80-82.9%	C-: 70-72.9%	

Class policies: Important Information below – please read carefully!

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 to be familiar with it, to be able to login to the website, and that you always have the readings with you (whether printed or electronic). If you have problems accessing the course website at any point during the semester, please let me know.

Disability Services: 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

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	Outside of Class	Readings & Open Access Public Data & Softwares
Week 1 Jan 22	Introduction to the course Syllabus and Brain basics (Basic Neuroanatomy check)	Explain Syllabus, check Readings	Keep track of the assignment page on Courseworks	[No Readings]

Week 2 Jan 29	Non-invasive data acquisition (fMRI, EEG, fNIRS, MEG) **Reading response due**	Lecture + Student Presentation	Browse fMRI, EEG, fNIRS and MEG open data / publicly available datasets on your own.	*Readings:* 1) Caplan, D. (2009). Experimental design and interpretation of functional neuroimaging studies of cognitive processes. Human Brain Mapping, 30(1), 59-77. Supplementary: *2*) Botvinik-Nezer, R., & Wager, T. D. (2023). Reproducibility in neuroimaging analysis: Challenges and solutions. Biological Psychiatry: Cognitive Neuroscience and Neuroimaging, 8(8), 780-788. *3) http://www.mayfieldclinic.com/pe-anatbrain.htm* *4) Fundamentals of Neuroscience* *Software:* https://www.psychopy.org
Week 3 Feb 5	Experimental design I Theory **Reading response due**	Lecture + Student Presentation	Download Psychopy on your computer and check out this video tutorial	*Readings:* 1) Amaro Jr et al., Study design in fMRI: Basic principles, Brain and Cognition 2006 2) Culham, J. C. (2006). Functional neuroimaging: Experimental design and analysis. *Handbook of functional neuroimaging of cognition*, *2*, 53-82. 3) Psychopy Manual: begin reading the "Builder sections on *concepts*, *routines*, *flow*, *blocks of trials and counterbalancing*, *experiment settings*". Supplementary: 2) Liu TT. The development of event-related fMRI designs. Neuroimage. 2012 Aug 15;62(2):1157-62.
Week 4 Feb 12	Experimental design II PsychoPy **Reading response due**	Student Presentation + Discuss Psychopy		*Readings:* 1) D'Esposito, M., Zarahn, E., & Aguirre, G. K. (1999). Event-related functional MRI: implications for cognitive psychology. Psychological bulletin, 125(1), 155. 2) Wang, Z., & Wang, Z. (2021). Building Experiments with PsychoPy. Chapter (2) Supplementary: 3) Nastase, S. A., Goldstein, A., & Hasson, U. (2020). Keep it real: rethinking the primacy of experimental control in cognitive neuroscience. NeuroImage, 222, 117254. https://psychopy.org/builder/index.html
Week 5 Feb 19	Practicum: Create your own block design	No Lecture; bring your laptop / device and use Psychopy	During the week, students are expected to work on their own block design using Psychopy Builder	1) Psychopy Manual: read parts that are relevant for your block design study https://psychopy.org/coder/index.html

Week 6 Feb 26	Practicum: Learn PsychoPy	No Lecture Complete Tutorial:	Look at Psychopy Coder Build together a simple block design just by coding it on Psychopy.	1) Psychopy Manual: read parts that are relevant for your block design study *Software:* https://neuroimage.usc.edu/brainstorm/ https://sccn.ucsd.edu/eeglab/index.php
Week 7 Mar 4	EEG: all in one bite Brief theory and data acquisition about EEG (30 mins) EEG Preprocessing Pipeline Theory (30 mins) EEG Preprocessing Pipeline (start the practice) **Reading response due** **Deadline for topic selection**	Lecture going from theory to practice.	Read about stable EEG experiments / data Demo Visually Evoked Potential task SSVEP demo MUSE bring to class 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. 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* 1) *https://www.mcgill.ca/bic/resources/omega*
Week 8 Mar 11	SPRING BREAK			
Week 9 Mar 18	EEG data processing and analysis **Reading response due**	Publicly available dataset for EEG / ERP	ERP: More sensitive to artifacts ERP task on Github	*Reading:* 1) 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. *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
Week 10 Mar 25	Practicum EEG Collect data and discuss how to preprocess them. **Reading response due**			*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.

Week 11 Apr 1	fMRI: all in one bite - Brief theory and data acquisition about fMRI mins) - fMRI Preprocessing - Pipeline Theory (30 mins)	How to collect fMRI data	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 12 Apr 8	Preprocessing Pipelines **Reading response due**	Discuss Preprocessing main steps	Browse fMRI, EEG, fNIRS and MEG open data / publicly available datasets.	*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 13 Apr 15	fMRI First- and second-Level Analyses **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 14 Apr 22	Practicum fMRI data analysis **Reading response due**	No Lecture	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.	1) SPM-12 manual chapters 8-10 (practice: 31.2)
Week 15 Apr 29	Submission of Final Writing	*No Class Held*		