Department of Psychology - Columbia University
Fundamentals of human brain imaging: from theory to practice
GU4930 Course Syllabus
Fall 2026

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Class Meets: Friday 2:10 – 4PM
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Course Bulletin Description

Fundamentals of human brain imaging is a course open to graduate students in Psychology, Neuroscience, and similar departments. This course aims for students to gain hands-on training and critical thinking skills for analysis of functional magnetic resonance imaging (fMRI) data, with a particular emphasis on developing applied skills for cognitive neuroscience research. Specifically, students will **(1) Learn to make informed decisions in building fMRI preprocessing and analysis pipelines, (2) Build skills in implementing and troubleshooting fMRI preprocessing and analysis pipelines, and (3) Develop confidence in interpreting fMRI data, including both quality assurance decisions and statistical results.** This course will begin with an introduction to tools in programming and data (python, bash) and will focus on using open-source fMRI software (e.g., fMRIprep, FSL). By promoting an accessible learning environment and implementing active learning strategies, this course stimulates critical thinking and fosters collaboration.

Prerequisites

The course is open to Graduate students in the Psychology department (and similar departments) interested in learning the fundamentals of fMRI analysis. This is intended to be a hands-on introductory methods course. **No prior experience with fMRI, programming, or statistics is required. Students with any amount of prior fMRI experience are welcome.**

Full Description

Overview of design, delivery of the material, and learning goals: This course will be open to a maximum of fifteen students. The instructor's permission will be required prior to enrollment. 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.

Outside of class: In order to develop hands-on expertise with fMRI analysis, students will complete weekly practical assignments each focused on a particular tool (e.g., fMRIprep preprocessing, FSL models for task analysis).

In-Class: Typically, each class period will begin with a 1) review of the last week's practical assignment, and 2) a short introduction to a topic from the Instructor providing the background necessary to better explore the issue of the day. Class topics will include fundamentals of open-source software, relevant theory and literature for understanding fMRI analysis workflows, and applications and interpretations of specific analysis steps. Most of the class time will be devoted to hands-on activities building cumulatively towards putting together full fMRI analysis pipelines. Hands-on activities will be a mix of individual, paired, and group work. We will use the final 10-15 minutes of class sessions to reflect on and discuss these hands-on activities as a group.

Learning Objectives

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

1. Comfortably use open-source software tools for research, and independently troubleshoot technical problems
2. Evaluate different analytic pipelines used in fMRI and make informed choices for each key decision point
3. Interpret fMRI data, including both quality assurance decisions and statistical results
4. Apply their knowledge to conduct fMRI analysis using field-standard tools
5. Communicate their work and peer review others' MRI work clearly and effectively, both via written and verbal means

Learning these topics be challenging, so this course will also encourage students to work collaboratively in class, develop research community around fMRI, and to support one another on fMRI research projects beyond the scope of the course.

Role of PSYC GU4930 in the curriculum

PSYC GU4930 is a methods course designed particularly for graduate students in Psychology, Neuroscience, and similar departments who hope to use fMRI analysis in their research.

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 Canvas. 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

For Psychology Graduate Students, PSYC GU4930 will apply toward the "One Additional Statistics/Methods Course requirement" for the M.Phil.

Readings:

There is no textbook required for this course.

Compared to seminar courses, readings in this course are relatively minimal to make time for hands-on practical assignments outside of class. Selected readings will comprise scientific articles from peer - reviewed journals, literature reviews, textbooks, and commentaries in the fields of neuroimaging as well as primers and use documentation for key analysis tools. 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 as PDFs or links on Canvas. 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.

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 a 5-10 minute review of the practical assignment and an introduction delivered by the Instructor (30 min) providing the background on the topic. For most sessions, the majority of the class time will be devoted to active, hands-on activities applying analysis tools, with a final 10-15 minutes for discussion and reflection at the end of each session.

Course Requirements:

1. **Class preparation and participation:**

The practical assignments are selected for you to hone your critical thinking skills and build expertise in fMRI analysis. The topics discussed during the course can be difficult and complex, leaving plenty of space to discuss and debate. Strong preparation and participation will enable us to have high-level, thought-provoking discussion.

It is important to engage with the material during the Instructor 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 Instructor 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 assignments.

Generally speaking, effective class preparation and participation could include:

- Asking insightful or clarifying questions.
- Connecting the reading or assignments to other parts of the course 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 MRI findings or that illustrate ways in which these findings are interpreted and applied.

2. **Weekly Practical Assignment:**

The day before each class period you will be asked to submit a practical assignment on canvas. Details will be provided for each assignment, but these will typically involve:

1. Completing an analysis step or exploring a method using a specific tool
2. A reflection on the practical, including any questions you have from the process, any issues you ran into, and thoughts on how you would (or wouldn't) apply this tool in your own research.

For the reflection, you should write no more than 1 paragraph yourself, although you can also submit any output files or error documentation from software tools to contextualize questions. As the goal of these assignments is to help you to build skills and independence in applying analysis tools in your own time and guide our class activities and discussions, <u>the assignments will just be graded on a pass/fail basis</u>. Assignment submissions indicating I can only accept responses submitted before the deadline.

3. **Final Assignment (Analysis Project)**:

The final project for this course is an independent fMRI analysis project completed in four stages throughout the semester. The goal is to provide hands-on experience developing, preregistering, reviewing, conducting, and reporting a complete neuroimaging analysis using open-source tools and publicly available data. Students are not expected to conduct "novel" research or collect/bring in their own fMRI data, rather **students must choose a publicly available dataset for this project**. The emphasis of this project is on developing a feasible, well-reasoned analysis plan and carrying it through to completion in order to build both practical expertise and gain a broader perspective on fMRI research.

Stage 1: Project Proposal (20%)
Students will select a publicly available fMRI dataset and submit a one-page project proposal.
The proposal should describe:

- The dataset to be analyzed (provide links so the Instructor can verify)
- The primary research question
- The proposed analysis approach (e.g., task-based or resting-state connectivity).
- Key methodological decisions and rationale.
- A feasibility assessment, including information that a) the data can be successfully accessed and downloaded, b) the proposed analyses can be completed using the student's available computing resources, and c) the project can be completed without access to a remote computing cluster or institutional server.

Students will then have a 10-15 minute conversation during class with the Instructor about their proposal to discuss rationale, feasibility, and steps for completing the work. Proposal grades will be based on both the written proposal and in-class conversation.

Notes in choosing your dataset and question:

- A list of suggested datasets will be provided, although students may propose alternative publicly available datasets with instructor approval.
- The research question does not have to be "novel". It is entirely expected that projects will conduct analyses that are replications or otherwise very similar to published work.
- Projects should be small enough in scope to be conducted from a single computer (e.g., not a cluster). Therefore, the size of datasets is necessarily limited. This should be taken into account in the feasibility assessment. No projects will be penalized for low statistical power due to these computing constraints.

Stage 2: Preregistration (20%)
After proposal approval, students will submit a preregistration document.
The preregistration should include:

- A brief introduction section (approximately one paragraph). This section should include your specific research questions and hypotheses.
- A detailed analysis plan describing preprocessing, quality-control procedures, statistical analyses, and outcome measures.
- At least 1 methods figure detailing your analysis plan (e.g., a flow diagram).
- Predicted results.

The goal of the preregistration is to specify the intended analyses before examining the final results.

Stage 3: Anonymous Peer Review (15%)
Each student will anonymously review another student's preregistration.
Reviews should:

- Evaluate the clarity, completeness, and feasibility of the proposed analysis.
- Identify potential weaknesses, ambiguities, or missing details.
- Highlight strengths of the proposal in addition to areas for improvement.

- Be organized as numbered points.
- Contain no more than five major comments.

Peer reviews will be evaluated primarily on attention to detail, constructiveness, and engagement with the proposed analysis plan.

Stage 4: Final Report (35%)
Students will complete the proposed analyses and submit a final report.

The report should include:

- A brief introduction section (approximately one paragraph). This section should include your specific research questions and hypotheses.
- Methods including the following:
    - Your updated analysis plan, including your methods figure
    - Changes you made to your analysis plan from your preregistration should be noted
    - You will be required to submit your **analysis code** as part of this submission
- Results.
    - Results should include at least 1 figure
- A separate Response to Review section. This section should address reviewer comments in a point-by-point format and explain how each comment was incorporated into the project or, if not incorporated, why an alternative approach was taken.

A discussion section is not required.

Evaluation will emphasize methodological rigor, transparency, reproducibility, quality of analysis, and clarity of reporting rather than the statistical significance or novelty of the findings. Projects will not be penalized for low statistical power resulting from computing constraints.

Stage 5: Presentation (10%)
During the final class session, students will prepare a short presentation of their analysis project to share with the class. This should involve:

- A presentation (e.g., slides) of no more than 3 minutes.
- Presentation should include your research question, overall analysis methods, and main takeaways.
- Presentation of at least one fMRI results figure.
- 1-2 minutes of Q&A with the class and Instructor.

Note: You will not have time to describe all of your analysis steps in detail. The goal of this presentation is to simulate a brief research talk, where you will have to condense all of the hard work you put into your fMRI analysis into a clear and concise presentation.

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-

60-69: D <60: F

Grading

Grades will be calculated based on the percentages outlined below.

A. Practical Assignments………………………… 25%
B. In-Class Participation …………………………25%
C. Final Assignment……………………………….. 50%
  - Proposal 20%
  - Preregistration 20%
  - Peer Review 15%
  - Final Submission 35%
  - Presentation 10%

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 (https://www.health.columbia.edu/content/register-disability-services). Detailed information is available online for the Columbia registration processes. Refer to the appropriate website for information regarding deadlines, disability documentation requirements, and drop-in hours.

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. Template forms and info are available in the Disability Services office or online: https://health.columbia.edu/services/testingaccommodations

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 .

Using AI Tools: AI tools such as ChatGPT, Gemini, and Claude (including coding assistants like Claude Code or Codex) can be useful for learning to work with fMRI data, but relying on them too heavily can get in the way of learning. For example, if a tool makes analytic decisions for you, this will not help you learn to make those decisions yourself (which is a key learning goal of this course). For this reason, several assignments will include a *verbal* component, so that we can prioritize your own understanding and communication of the analyses you conduct. The instructor will specify appropriate uses of AI tools for each assignment, and all use of AI tools should be clearly noted in submitted assignments. If you're ever unsure what counts as appropriate use, please ask.

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 (including use of AI tools, such as ChatGPT, Gemini, or Claude). 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.

Class Date	Topic	To Do in Class	Reading/Assignments Due This Class
11-Sep-26	Introduction to the course	**Introduction:** Foundational brain concepts **Activity:** Viewing MRI Data with FSLeyes	Reading: • Poldrack, Russell A., Jeanette A. Mumford, and Thomas E. Nichols. *Handbook of functional MRI data analysis*. Cambridge University Press, 2011: Chapter 1: Introduction
18-Sep-26	MRI Data Structures	**Introduction:** Brief intro to MRI acquisition, data formats, and data structures **Activity:** Downloading and BIDS validating an MRI dataset, setting up conda environments	Practical #1: Using the Bash Command Line Reading: • Introduction to BIDS • Markiewicz, C. J., Gorgolewski, K. J., Feingold, F., Blair, R., Halchenko, Y.

			O., Miller, E., ... & Poldrack, R. (2021). The OpenNeuro resource for sharing of neuroscience data. *Elife*, *10*, e71774.
25-Sep-26	Containerized Computing	**Introduction:** Reproducible computing environments **Activity:** Docker, Jupyter Notebooks	Practical #2: Python for scientific computing Reading: • Chopra S, Labache L, Dhamala E, Orchard ER, Holmes A. A Practical Guide for Generating Reproducible and Programmatic Neuroimaging Visualizations. Aperture Neuro. 2023;3:1-20. doi:10.52294/001c.85104
2-Oct-26	Preprocessing 1	**Introduction:** Overall flow of fMRI preprocessing **Activity:** Setting up a preprocessing pipeline with fMRIPrep	Practical #3: Using FSLUTILS via a Docker Containers Reading: • *Handbook of functional MRI data analysis:* Chapter 3: Preprocessing fMRI Data • Esteban, O., Markiewicz, C. J., Blair, R. W., Moodie, C. A., Isik, A. I., Erramuzpe, A., ... & Gorgolewski, K. J. (2019). fMRIPrep: a robust preprocessing pipeline for functional MRI. *Nature methods*, *16*(1), 111-116.
9-Oct-26	Preprocessing 2	**Introduction:** Brain extraction, motion correction, slice-timing correction **Activity:** Using FSL for individual preprocessing steps	Practical #4: Intro to fMRIPrep Reading: • Jeanette Mumford Video: Brain Extraction & QA • *Handbook of functional MRI data analysis:* Chapter 4: Spatial normalization
16-Oct-26	Preprocessing 3	**Introduction:** Anatomical preprocessing, registration, spatial smoothing **Activity:** Practice with registration & in-class discussions of project proposals with Instructor	Project Stage 1 Due: One-Page Project Proposal
23-Oct-26	Nuisance Regressors & Confounds	**Introduction:** Strategies to mitigate head motion and physiological confounds **Activity:** Understanding framewise displacement and generating confound regressors	Practical #5: Running and Evaluating a full fMRIPrep preprocessing pipeline • Jeanette Mumford Video: What is framewise displacement? • Liu, T. T., Nalci, A., & Falahpour, M. (2017). The global signal in fMRI: Nuisance or

			Information?. *Neuroimage*, *150*, 213-229.
30-Oct-26	Task Design & General Linear Models (GLMs)	**Introduction:** Block versus Event-Related Designs **Activity:** Setting up Level-1 Designs and Contrasts in FSL	Practical #6: Using contrasts with regression to test hypotheses Reading: • *Handbook of functional MRI data analysis:* Chapter 5: Statistical modeling: single-subject analysis
6-Nov-26	Group-Level Task Analysis	**Introduction:** Group-level fMRI analyses **Activity:** Setting up Level-2 and Level-3 Analyses in FSL	Project Stage 2 Due: Preregistration
13-Nov-26	Region-of Interest & Whole-Brain Analyses	**Introduction:** Region-of-Interested (ROI) &. Whole-Brain Analyses, Multiple Comparisons, and "Double-Dipping" **Activity:** Comparison of Whole-Brain and ROI Analyses using the same data	Practical #7: Running a group-level task-based analysis with FSL Project Stage 3 Due: Anonymous Peer Review Reading: • Bennett, C. M., Miller, M. B., & Wolford, G. L. (2009). Neural correlates of interspecies perspective taking in the post-mortem Atlantic Salmon: an argument for multiple comparisons correction. *Neuroimage*, *47*(Suppl 1), S125.
20-Nov-26	Resting State Functional Connectivity Analysis	**Introduction:** Resting-state fMRI, functional connectivity, and network analysis **Activity:** Calculating seed-to-seed and network connectivity	Practical #8: Conducting an ROI and Whole-Brain Analysis Reading: • Craddock, R. C., Jbabdi, S., Yan, C. G., Vogelstein, J. T., Castellanos, F. X., Di Martino, A., ... & Milham, M. P. (2013). Imaging human connectomes at the macroscale. *Nature methods*, *10*(6), 524-539.
27-Nov-26	No Class (Thanksgiving Holiday)		None
4-Dec-26	Forking Paths & Decision-Making	**Introduction:** Software-induced variation in fMRI results, multiverse analysis **Activity:** Deciding on an analysis pipeline	Practical #9: Resting-State Functional Connectivity Matrices Reading: • Marek, S., Tervo-Clemmens, B., Calabro, F.J. et al. Reproducible brain-wide association studies require thousands of individuals.

			Nature 603, 654–660 (2022). https://doi.org/10.1038/s41586-022-04492-9 • Botvinik-Nezer, R., Holzmeister, F., Camerer, C. F., Dreber, A., Huber, J., Johannesson, M., ... & Rieck, J. R. (2020). Variability in the analysis of a single neuroimaging dataset by many teams. *Nature*, *582*(7810), 84-88.
11-Dec-26	Final Project Presentations	**Activity:** Brief Final Project Presentations	Project Stage 4 Due: Final Report Project Stage 5 Due: Class Presentation