

Course ID and Title: [BME 599 Human Neuroimaging Methods]

Units: 4.0

Term—Day—Time: [Spring 2025] — Monday-Wednesday 12:00-1:50pm

Location: TBD

Instructor: Vasileios Christopoulos

Office: Denney Research Center (DRB), Room 208

Office Hours: Monday-Wednesday 2:30-3:30pm

Contact Info: vchristo@usc.edu

Catalogue Description

Introduction to neuroimaging with magnetic resonance imaging (MRI): Principles of MRI physics, image acquisition techniques, functional MRI (fMRI) and blood oxygenation level dependent (BOLD) contrast, diffusion tensor imaging (DTI), preprocessing and analysis of neuroimaging data, design of experiment, statistical analysis of BOLD signal, machine learning techniques, applications in cognitive neuroscience and clinical diagnostics.

Course Description

How do we grasp a glass of water? What mental processes are involved in recalling memories? Do we have free will? What causes mental illness? For centuries, scientists and philosophers have sought to unravel the mysteries of the human brain by exploring these questions. Until recently, the brain was considered nearly incomprehensible, largely due to a lack of technology for non-invasive monitoring of brain activity during various behavioral tasks. However, recent advancements in neuroimaging have begun to reveal its secrets, providing powerful tools to assess the brain's functional architecture in health, disease, and development. This course introduces the fundamentals of MR instrumentation, including magnets, gradients, RF coils, and key signals (T1, T2, T2*). We will explore MR image formation and the acquisition, and analysis of common neuroimaging measurements, such as anatomical, diffusion, and functional signals. Additionally, we will cover experiment design using fMRI and statistical and functional connectivity analyses. Students will also learn about other neuroimaging modalities, including electroencephalography, magnetoencephalography and functional ultrasound imaging (fUSI).

Learning Objectives

- Acquire basic knowledge of MRI, including techniques for structural imaging, functional imaging, and diffusion imaging.
- Learn to apply fundamental techniques for analyzing data from these modalities.
- Acquire the essential skills to interpret literature and conduct research effectively in the field.
- Be able to design experiments, test hypotheses, and perform statistical analyses.
- Learn advanced statistical and machine learning methods for application to functional neuroimaging data.

Prerequisite(s):**Co-Requisite(s):****Concurrent Enrollment:**

Recommended Preparation: Basic principles of neuroscience (brain structure and function), physics (basic of NMR properties, electromagnetism), statistics (descriptive, testing hypothesis, regression analysis, ANOVA, correlation analysis).

Course Notes

Copies of lecture slides and other class information will be posted on Brightspace.

Technological Proficiency and Hardware/Software Required

Previous experience with Python, MATLAB, or another programming language would be valuable for the class project.

Required Readings and Supplementary Materials

Functional Magnetic Resonance Imaging, third Edition 3'd Edition, by Scott A. Huettel, Allen W. Song, and Gregory McCarthy. Sinauer Associations, Inc., 2014. ISBN: 978-0- 87893-627-4.

Optional Readings and Supplementary Materials

Class notes and handouts provided by instructor.

Discussion – Homework assignment

During the second hour of the second lecture each week, students will present and discuss research articles related to that week's topics. All students should provide a summary report (1-2) pages (homework assignment) at the beginning of class on their due date (see syllabus for due dates). Homework assignments are to be typed and printed. Use Arial font, size 12, single spaced, 1" margins. One of the students will present the research article and lead the discussion, whereas 2 other students will be assigned as "discussants". Discussants will prepare questions for the paper presenter, to help the group get to the core issues of each research article.

Description of Assignments and How They Will Be Assessed

- 2 midterm exams, homework assignments, paper presentations, final project report and final presentation of your project.
- Midterm exams: They will be administered during the lecture period. Students will have the full lecture period to complete the exam. Each exam will focus on material covered in the lectures, text, and discussion sections since the previous exam (not cumulative).
- Homework assignments: They will involve writing a review (summary and critique) of the articles that are assigned for the discussion section. All students (including the "presenter" and the "discussants") have to submit the assignment.
- Project: Students need to propose a research project related to the topics of the course, such as Brain Connectivity, Resting-State Brain Networks, Dynamical Causal Modeling, Granger Causality, etc. The instructor will review the proposal and will provide feedback to the students. The students have to submit final report at the end of the semester (see project description).

Grading Breakdown

Assessment Tool (assignments)	% of Grade
Midterm 1	25%
Midterm 2	25%
Homework Assignment	15%
Discussion (presentation, participation)	5%
Project proposal	5%

Assessment Tool (assignments)	% of Grade
Project report	20%
Project presentation	5%
TOTAL	100%

Grading Scale

98 – 100%	A+
93 – 97%	A
90 – 92%	A-
87 – 89%	B+
83 – 86%	B
80 – 82%	B-
77 – 79%	C+
73 – 76%	C
70 – 72%	C-
67 – 69%	D+
63 – 66%	D
60 – 62%	D-
< 60%	F

Letter grades decided by rounding floating point grades up to the nearest whole number (e.g., 92.2 -> A; 59.8 -> D-

Assignment Submission Policy

- Exam and homework dates will only be moved if the instructor is 1) notified ahead of time and 2) if it is a university accepted excuse. Only doctor's note and police report are accepted. No other excuses will be considered to get an extension of a homework assignment, project proposal, final report and exams. I understand circumstances arise unexpectedly, so please do your best to inform me ahead of time (details are not necessary). Assignments will be graded within two weeks after the due date, mostly.
- Any assignment submitted late will **lose credit at a rate of 20% per day** until the assignment has been submitted. This includes all deadlines associated with review of the papers.
- Late research proposal/report submission or absence from final presentation (including others' final presentation) will lead to no credit for the final project.

Course-Specific Policies

Once a grade has been posted on brightspace, students have one week to discuss the grade and request either a re-grade of the whole exam/assignment or discuss points they missed. After that period the grade is final and will not be adjusted.

Attendance

Active participation in the course is strongly encouraged and may influence the overall assessment of final grades. Participation can take various forms, including arriving on time and prepared, actively engaging in the lectures, especially in the discussion section, interacting with classmates and the instructor, and asking relevant questions.

Academic Integrity

Unless otherwise noted, this course will follow the expectations for academic integrity as stated in the [USC Student Handbook](#). The general USC guidelines on Academic Integrity and Course Content Distribution are provided in the subsequent “Statement on Academic Conduct and Support Systems” section.

For this class:

- Collaboration: In this class, you are expected to submit work that demonstrates your individual mastery of the course concepts. While you are encouraged to discuss homework assignments with fellow students, please remember that the final report must reflect your own understanding and insights. Failure to do so will constitute plagiarism for which there is a zero-tolerance policy in this course.
- Group work: Except the project, all assignments (i.e., homework and midterm exams) are expected to be completed individually.
- Computer programs: Plagiarism includes the submission of code written by, or otherwise obtained from someone else.

Cheating and/or plagiarism of any kind will not be tolerated. On the first offence you will receive a zero for the assignment/exam and I will file a report with the Office of Academic Integrity. A second offense will result in failure of the course and a second report to the Office of Academic Integrity. If you are unsure at any point whether or not you are citing information correctly discuss it with the instructor.

Lectures are not recorded unless noted. You may not record this class without the express permission of the instructor and all other students in the class. Distribution of any notes, recordings, exams, or other materials from a university class or lectures — other than for individual or class group study — is prohibited without the express permission of the instructor.

Use of Generative AI in this Course

Generative AI is not permitted: Since creating, analytical, and critical thinking skills are part of the learning outcomes of this course, all assignments should be prepared by the student working individually or in groups as described on each assignment. Students may not have another person or entity complete any portion of the assignment. Developing strong competencies in these areas will prepare you for a competitive workplace. Therefore, using AI-generated tools is prohibited in this course, will be identified as plagiarism, and will be reported to the Office of Academic Integrity.

Course Evaluations

Course evaluation occurs at the end of the semester university-wide. It is an important review of students’ experience in the class. The process and intent of the end-of-semester evaluation should be provided.

Course Schedule

	Topics/Daily Activities	Readings/ Preparation	Deliverables
Week 1	Introduction to MRI and Neuroimaging - A brief introduction to neuroscience - History of MRI/fMRI - MRI scanners, MRI safety		
Week 2	NMR Signal generation and detection - MR signal generation - Physics underlying MR signal formation - Proton and NMR properties - Excitation and relaxation mechanisms - T1-weighted and T2-weighted images	Presentation of paper 1	Submission of review for paper 1
Week 3	MRI Image formation and instrumentation - Gradient coils, slice selection, frequency/phase encoding - K-space analysis	Presentation of paper 2	Submission of review for paper 2 Project proposal Due
Week 4	MRI Image contrast and pulse sequences - Static contrast vs. motion contrast - MR Angiogram - Diffusion weighted imaging (DWI) - Arterial spin labeling (ASL) perfusion - Tensor Imaging (DTI)	Presentation of paper 3	Submission of review for paper 3
Week 5	Physiology of Brain Activity - Neurons and Synaptic Transmission - Neurotransmitters and Neuromodulators - Neuroanatomy - Techniques for Measuring Brain Activity	Presentation of paper 4	Submission of review for paper 4
Week 6	BOLD fMRI: Origins and properties - BOLD signal in fMRI - Hemodynamic response (HDR) function - Spatial and temporal properties of BOLD fMRI - Linearity of HDR - fMRI adaptation		Midterm exam 1
Week 7	Basic fMRI Acquisition; data pre-processing - Noise in the signal - Sources of noise in fMRI - Noise vs. variability - Techniques for reducing noise (improve SNR) - Distortion, normalization, spatial-temporal smoothing	Presentation of paper 5	Submission of review for paper 5
Week 8	Design of experiment - Testing hypothesis - Variables, contrasts, confounding factors - Randomization and blinding - Design type (block vs. event-related)	Presentation of paper 6	Submission of review for paper 6
Week 9	Data analysis: Basic Analyses and the GLM model - Descriptive statistics - Statistical Parametric Mapping - t-test, ANOVA, type 1-typ2 errors - GLM model - Multiple comparison analysis/correction	Presentation of paper 7	Submission of review for paper 7

Week 10	Neural prediction and advanced imaging techniques - Advanced functional MRI data analysis - Principal Component Analysis (PCA) - Independent component analysis (ICA) - Support vector machine (SVM, classification, regression)	Presentation of paper 8	Submission of review for paper 8
Week 11	Functional connectivity analysis - Time-series analysis (prewhitened) - Resting-state connectivity - Overview of major resting-state networks - Dynamic functional connectivity - Functional connectivity alterations in neurological disorders	Presentation of paper 9	Submission of review for paper 9
Week 12	Combining fMRI with other techniques - EEG, MEG, TMS, tDSC, pharmacological perturbations		Midterm exam 2
Week 13	The future of fMRI: Practical and ethical issues - Ethics and Regulatory Considerations (IRB, informed consent) - Applying fMRI to controversial topics (Free will, lie detection, neuromarketing, neural correlates of morality, etc)	Presentation of paper 10	Submission of review for paper 10
Week 14	Beyond fMRI: Functional ultrasound imaging (fUSI) - Basic principles of fUSI technology - Application in preclinical research - Functional connectivity with fUSI - Application in disease models - Clinical applications	Presentation of paper 11	Submission of review for paper 11
Week 15	Presentations of the final project		
FINAL			Final research project submission

Academic Integrity

The University of Southern California is foremost a learning community committed to fostering successful scholars and researchers dedicated to the pursuit of knowledge and the transmission of ideas. Academic misconduct — which includes any act of dishonesty in the production or submission of academic work (either in draft or final form) — is in contrast to the university’s mission to educate students through a broad array of academic, professional, and extracurricular programs.

This course will follow the expectations for academic integrity as stated in the [USC Student Handbook](#). All students are expected to submit assignments that are their own original work and prepared specifically for this course and section in this academic term. You may not submit work written by others or “recycle” work prepared for other courses without obtaining written permission from the instructor(s). Students suspected of engaging in academic misconduct will be reported to the Office of Academic Integrity.

Other violations of academic misconduct include, but are not limited to, cheating, plagiarism, fabrication (e.g., falsifying data), knowingly assisting others in acts of academic dishonesty, and any act that gains or is intended to gain an unfair academic advantage.

Academic dishonesty has a far-reaching impact and is considered a serious offense against the university. Violations will result in a grade penalty, such as a failing grade on the assignment or in the course, and disciplinary action from the university itself, such as suspension or even expulsion.

For more information about academic integrity see the [student handbook](#) or the [Office of Academic Integrity’s website](#), and university policies on [Research and Scholarship Misconduct](#).

Please ask your instructor if you are unsure what constitutes unauthorized assistance on an exam or assignment or what information requires citation and/or attribution.

Course Content Distribution and Synchronous Session Recordings Policies

USC has policies that prohibit recording and distribution of any synchronous and asynchronous course content outside of the learning environment.

Recording a university class without the express permission of the instructor and announcement to the class, or unless conducted pursuant to an Office of Student Accessibility Services (OSAS) accommodation. Recording can inhibit free discussion in the future, and thus infringe on the academic freedom of other students as well as the instructor. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Distribution or use of notes, recordings, exams, or other intellectual property, based on university classes or lectures without the express permission of the instructor for purposes other than individual or group study. This includes but is not limited to providing materials for distribution by services publishing course materials. This restriction on unauthorized use also applies to all information, which had been distributed to students or in any way had been displayed for use in relation to the class, whether obtained in class, via email, on the internet, or via any other media. Distributing course material without the instructor’s permission will be presumed to be an intentional act to facilitate or enable academic dishonesty and is strictly prohibited. ([Living our Unifying Values: The USC Student Handbook](#), page 13).

Statement on University Academic and Support Systems

Students and Disability Accommodations:

USC welcomes students with disabilities into all of the University's educational programs. [The Office of Student Accessibility Services](#) (OSAS) is responsible for the determination of appropriate accommodations for students who encounter disability-related barriers. Once a student has completed the OSAS process (registration, initial appointment, and submitted documentation) and accommodations are determined to be reasonable and appropriate, a Letter of Accommodation (LOA) will be available to generate for each course. The LOA must be given to each course instructor by the student and followed up with a discussion. This should be done as early in the semester as possible as accommodations are not retroactive. More information can be found at osas.usc.edu. You may contact OSAS at (213) 740-0776 or via email at osasfrontdesk@usc.edu.

Student Financial Aid and Satisfactory Academic Progress:

To be eligible for certain kinds of financial aid, students are required to maintain Satisfactory Academic Progress (SAP) toward their degree objectives. Visit the [Financial Aid Office webpage](#) for [undergraduate-](#) and [graduate-level](#) SAP eligibility requirements and the appeals process.

Support Systems:

[Counseling and Mental Health](#) - (213) 740-9355 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

[988 Suicide and Crisis Lifeline](#) - 988 for both calls and text messages – 24/7 on call

The 988 Suicide and Crisis Lifeline (formerly known as the National Suicide Prevention Lifeline) provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week, across the United States. The Lifeline consists of a national network of over 200 local crisis centers, combining custom local care and resources with national standards and best practices. The new, shorter phone number makes it easier for people to remember and access mental health crisis services (though the previous 1 (800) 273-8255 number will continue to function indefinitely) and represents a continued commitment to those in crisis.

[Relationship and Sexual Violence Prevention Services \(RSVP\)](#) - (213) 740-9355(WELL) – 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender- and power-based harm (including sexual assault, intimate partner violence, and stalking).

[Office for Equity, Equal Opportunity, and Title IX \(EEO-TIX\)](#) - (213) 740-5086

Information about how to get help or help someone affected by harassment or discrimination, rights of protected classes, reporting options, and additional resources for students, faculty, staff, visitors, and applicants.

[Reporting Incidents of Bias or Harassment](#) - (213) 740-2500

Avenue to report incidents of bias, hate crimes, and microaggressions to the Office for Equity, Equal Opportunity, and Title for appropriate investigation, supportive measures, and response.

[The Office of Student Accessibility Services \(OSAS\)](#) - (213) 740-0776

OSAS ensures equal access for students with disabilities through providing academic accommodations and auxiliary aids in accordance with federal laws and university policy.

[USC Campus Support and Intervention](#) - (213) 740-0411

Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.

[Diversity, Equity and Inclusion](#) - (213) 740-2101

Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

[USC Emergency](#) - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call

Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

[USC Department of Public Safety](#) - UPC: (213) 740-6000, HSC: (323) 442-1200 – 24/7 on call

Non-emergency assistance or information.

[Office of the Ombuds](#) - (213) 821-9556 (UPC) / (323-442-0382 (HSC)

A safe and confidential place to share your USC-related issues with a University Ombuds who will work with you to explore options or paths to manage your concern.

[Occupational Therapy Faculty Practice](#) - (323) 442-2850 or otfp@med.usc.edu

Confidential Lifestyle Redesign services for USC students to support health-promoting habits and routines that enhance quality of life and academic performance.