EEG Methods and Analyses

PSY 407/507 Course Syllabus Spring 2024

When / Where

Wednesday 10:40-12:30 / Thursday 8:50-9:30 FENS G025

Instructor

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Office hours: please reach out via email for questions

TA

Berna Güler <berna.guler@sabanciuniv.edu>
Duygu Yücel <duyguyucel@sabanciuniv.edu>
TAs will hold weekly recitation hours to answer your questions regarding each assignment.

Prerequisites

See the Information System website. A basic understanding of programming in MATLAB, Python, or alike would be beneficial though it is not required.

Description

This project-based course is where students write custom code in MATLAB to perform EEG analyses. We will also cover the basics of EEG experimental design and data collection, though these will take only 2 weeks. This section teaches students how to shape EEG researchers' choices when designing their experiments according to their research questions. The remaining focus will be on data analysis and interpretation of results. Students will learn preprocessing, event-related potentials, and time-frequency power analyses. Depending on the progress, we may also briefly discuss analysis in the multivariate domain (e.g., representational similarity analysis, multivariate pattern analysis, forward encoding models, etc.). Given the hands-on approach of the course, students will acquire not only theoretical knowledge but also practical skills.

Gains and potential extended benefits

This course aims to provide an introductory understanding of what EEG measures and an intermediate understanding of how to perform time-domain and time-frequence domain analyses. This knowledge can later be developed to be applied to the following areas:

1. **Medical Diagnosis and Treatment:**
    a. Neurological Disorders: EEG is crucial in diagnosing and monitoring neurological disorders like epilepsy, sleep disorders, and Alzheimer's disease. Understanding EEG patterns can help in early detection and effective treatment planning.
    b. Brain-Computer Interfaces (BCI): Knowledge of EEG can contribute to developing BCIs for individuals with movement disabilities, enabling them to control prosthetic limbs or communicate through thought.
2. **Cognitive Neuroscience Research:**
    a. Understanding Brain Functions: Researchers can use EEG to study how the brain processes information, makes decisions, or reacts to stimuli, enhancing our understanding of human cognition and behavior.
    b. Impact of Substances: EEG methods can be used to study the effects of pharmaceuticals, recreational drugs, or nutrition on brain activity and cognitive functions.

3. **Mental Health:**
    a. Mood and Anxiety Disorders: EEG patterns can provide insights into various mental health conditions, leading to better diagnosis and personalized treatment strategies.
    b. Biofeedback Therapy: Patients can learn to alter their brain activity to improve mental health conditions through EEG-based biofeedback.
4. **Education and Training:**
    a. Optimizing Learning Methods: Understanding brain waves during different learning states can help in designing better educational tools and environments.
    b. Professional Training: Pilots, athletes, and other professionals can use EEG feedback to improve performance and focus.
5. **Consumer Research:**
    a. Neuromarketing: Businesses use EEG to understand consumer reactions to products, advertisements, or brands, providing insights into consumer preferences and behavior.
    b. Product Testing: EEG can be used to test the usability and user experience of various products, including virtual reality environments and video games.
6. **Forensic Science:**
    a. Lie Detection: Some approaches attempt to use EEG for lie detection by observing brain responses that indicate deception.
7. **Art and Creativity:**
    a. Interactive Art: Artists and designers use EEG to create interactive art that responds to the viewer's brainwaves, creating personalized and dynamic experiences.

Moreover, the analysis and data visualization skills developed during this course can constitute the basis for further advancement that can be applied to signal processing in engineering and physics, quantitative analysis in finance, genomics and chemometric analysis in biotechnology and chemistry, predictive modeling imaging analysis in healthcare and epidemiology, climate modeling in environmental science, and machine learning and AI in information technology.

Course website

Please regularly check the course website because the syllabus is subject to change depending on your progress. The latest updates will be posted on the website.

Materials

Textbook: We will mostly follow Mike X Cohen's Analyzing Neural Time Series Data: Theory and Practice. However, you are not expected to own the book. Instead, I will go over all the important bits and provide the necessary MATLAB code.

Course schedule

Note that the schedule below is tentative; depending on the questions asked during classes and the subjective difficulty of the topics for students we may cover fewer or more topics than shown here. Please check the course website for the latest updates on the syllabus.

W1: What does EEG measure?

What is the brain signal that the EEG picks up?
What is EEG good for, and not so good for?
Comparison of EEG to other cognitive neuroscience methods.
Also: An introduction to MATLAB

W2: How to design an EEG experiment?

What to watch out for to make the most of your data? (trial numbers, electrode number, and positioning, timing, sampling rate, etc.)

The importance and implementation of jittering

How to provide communication between EEG and experiment presentation computers? (event markers)

Also: More on MATLAB

W3 PART I: How to collect data?

How to prepare a participant for the session?

How to set up the electrodes?

How to maximize the cleanliness of data in terms of physical preparations and instructions?

W3 PART II: Preprocessing of EEG data,

Filtering, referencing, epoching

Interpolating bad electrodes

Also: More on MATLAB and an introduction to EEGLAB

W3 PART III: Removing or correcting for EEG artifacts

Types of artifacts (blinks, oculomotor activity, muscle movements, etc)

Removal of noisy data and ocular artifacts

Correction of noisy data and ocular artifacts

Detecting bad electrodes

Ws 4&5: Event-related potentials (ERPs)

How to calculate ERPs [involves basic MATLAB coding which will be described]?

How to perform statistical analysis of ERPs?

How to plot ERPs and their standard deviations?

Ws 6, 7, 9, & 10: Time-frequency analyses (*note*: *W8 is Spring Break*)

What is a time-frequency analysis?

Fourier transform and convolution

Computing time-frequency decompositions

Baseline corrections

Differences between total vs phase-locked vs non-phase-locked power

Plotting time-frequency data

W11: Statistics

How to perform parametric tests on EEG data

How to perform non-parametric tests on EEG data

W12: Visualization

Preparing nice-looking ERP and TF power plots

Showing the outcome of the permutation test on figures

Preparing violin plots for data averaged across time

W13: Going over your analyses, plots, and interpretations

We will use this week to finalize your preparations for the presentations. This will involve a separate meeting with each group to answer your questions and help you understand the theory and practice behind the analyses you have been performing.

Also: During this week, groups will finalize their analyses and prepare for their presentations that will take place next week.

W14: Presentations, conclusions, and future directions

This week, we will go over each group's analyses and outcomes across short presentations. It will allow sharing all semester's work with others, getting feedback, and also experience presenting an EEG study.

We will conclude the class by going over important issues and mistakes encountered during the semester

If we go faster than planned:
Multivariate analyses

Introduction to multivariate analyses; what they are, what they are for, and how to use them in EEG
Types of multivariate analyses

Grading

Assignment	Date	% of the final grade (for 407)	% of the final grade (for 507)
Presentation	In the last week, every group (of a few students depending on the total size of the class), will present the outcomes of their analyses and their interpretations to their classmates.	70%	70%
Thought paper*	You will write a thought paper regarding a paper that uses EEG to answer a cognitive neuroscience question. * Graduate students who take 507 will write two thought papers.	20%	25%
Participation	You are expected to demonstrate your progress through the questions you ask AND answer.	10%	5%
Extra credit*		Up to 3%	

A	A-	B+	B-	C+	C-	D+	D-	F
>90	85-89.99	80-84.99	75-79.99	70-74.99	65-69.99	60-64.99	55-59.99	<55

Class Presentations:
Each student is expected to form groups of two to four people depending on the class size. As a group, each student will work on different analyses we covered during the semester and give a presentation at the end of the semester. The presentations should be given using a slide presentation to lead the class through the paper. Each presentation is expected to last about 30 minutes with an additional 5-10 minutes of discussions. To facilitate discussions, presenters are expected to come up with discussion questions. See the 'Presentation grading' section below for more details. Going over the 30-minute limit will cost points for your presentation grading.

Presentation Content:
Describe the research question of the data (which will be previously acquired as part of an existing experiment – but will be unpublished), the method, the results, and the conclusions, and then bring up points for discussion. Since this is an EEG course, you will be expected to focus much more on the details of methods and analyses than you would normally do in a project presentation. Also, the plots should be clear, the stats should be accurate and properly explained.

Presentation grading:
Your class presentation is worth 70% of your grade and is graded out of 100 points.
Describing the research question = 5 points,
Describing the experimental method = 10 points,
Describing the preprocessing steps = 5 points
Describing the artifact removal steps = 5 points
Describing the data analysis steps = 25 points
Describing the results = 25 points
Describing the conclusions reached = 10 points,
Bringing up points for discussion = 5 points.
Clarity of presentation (speaking and slides) = 10 points.

Thought paper:
You will summarize and criticize a paper that uses EEG to answer a cognitive neuroscience topic. It will be a 1-1.5 page paper. Below are the basic guidelines:

- Start with a summary of the main goal and findings of the paper (4-6 sentences).
- Describe the aspect you want to focus on (e.g., methodological flaw, theoretical gap, follow-up research idea, etc.; about 1 page).
- Briefly summarize and conclude the paper (2-4 sentences).
- Try to focus on just one, maybe two main points/issues. Use the rest of the text to support your arguments by referring to what we learned in class and/or information you learned from other papers in the area of the paper you cover.

Extra credit:
By participating in psychology experiments, you can receive extra points on top of your final grade, with a maximum of 3 points. I recommend you to volunteer in experiment participation to (i) receive extra

course credits, (ii) contribute to the scientific advancement performed at Sabancı University, and (iii) experience how psychology and cognitive neuroscience experiments are performed.

For this course, you will be able to earn up to 3 bonus points (1 research point equals ~ 30 minutes of research participation). Six research points (6RPs) will be converted to 3 bonus points and added to your overall total at the end of the semester. More information on the available research projects will be provided during the semester. You will be able to sign up for the experiments and get your research participation points through the online Sona system at http://sabanciuniv.sona-systems.com. Please, carefully read the Guide for Students: Sabancı University Experiment Credits System (Sona). Note that this option is subject to availability: There may be not enough experiments available to complete 3 bonus points.

Attendance:
I recommend attending classes and if possible participating in the classes. If you don't understand something, please ask. If you don't agree with something, please raise your concern. Participation will enhance the learning of the whole classroom, will make the classes more fun for you, and also will make teaching more fun for me (instructors are also human ☺). Also, participation will make up 10% of your grade.

Plagiarism (Extremely critical. Make sure you read this part):
If you use someone else's thoughts, sentences, figures, slides, etc. without mentioning that these are not yours, then you are conducting plagiarism. Do not use someone else's idea as if it is yours. That means, no copy-pasting, no stealing of ideas without acknowledging that they are someone else's. For more information on plagiarism, check out this link. If you plagiarize you can get zero points for your quizzes or take-home exams. Please, never plagiarize!