

BEP-330 Computational Methods in Cognitive Neuroscience

Spring 2025, College of Education, The University of Alabama

Instructor: Firat Soyly (fsoyly@ua.edu)

Room: Autherine Lucy Hall 3

Meeting Time: Mondays, 12:00 PM – 2:50 PM

Office hours: Fridays 11am-1pm (click to reserve a slot) or Email to make an appointment

Office: Capital Hall 1617

Course Description

Cognitive and educational neuroscience research methods (e.g., EEG/ERP, fMRI) heavily rely on use of computational tools. Students who are interested in conducting neuroimaging research often have difficulty with deciding which tools to use, managing the technical difficulties involved with creating an analysis pipeline, and debugging & documenting the analysis process. The purpose of this course is to introduce signal processing methods and computational tools, skills, and heuristics that are essential for conducting cognitive and educational neuroscience research.

Course Objectives

The students will learn about:

- foundational concepts and skills in coding & scripting
- signal processing methods used in neuroscience research
- different free and open source software (FOSS) for neuroimaging research
- preparing and formatting data for analysis
- developing batch files and writing scripts to automatize analysis steps
- Open science principles and practices

Prerequisites

Some previous experience with and/or coursework on neuroimaging (e.g., fMRI) or electrophysiological (e.g., EEG) research is preferred but not required for this course.

Software & Textbook

- **MATLAB:** You will need to have MATLAB on your laptop to be able to do in-class activities and assignments. UA has a MATLAB site license, meaning that all students and faculty have free access to MATLAB and all its toolboxes. Visit <https://oit.ua.edu/software/matlab/> for more info & to download MATLAB.
 - When installing MATLAB, please ensure that you include the following toolboxes in the installation (see here for help). You can also install these toolboxes after you install MATLAB (see here for help).
 - * Signal Processing Toolbox
 - * Statistics and Machine Learning Toolbox

- As an alternative to installing MATLAB on your laptop, you can use MATLAB online: <https://www.mathworks.com/online.html>. MATLAB Online is not fully equivalent to the MATLAB version installed on a computer and you are recommended to install Matlab on your computer. However, if you are having issues with your computer, you can use MATLAB online.
- **MBCS:** We will read chapters and do exercises from “Cohen, M. X. (2017). **MATLAB for Brain and Cognitive Scientists**. MIT Press.” This book is available as a hardcopy from the UA Library.
- All additional reading materials are linked on this syllabus (under the schedule section).

Summary of Course Activities

This course will have two main components:

1) **Scripting in MATLAB & foundational knowledge of signal processing methods used in neuroscience research.** We will start the semester with an introduction to coding and programming structures. Even though we will be using Matlab, the general knowledge and heuristics you acquire will be equally applicable to other programming environments (e.g., Python). After covering the basics of programming in Matlab, we will focus on most prevalently used signal processing methods in neuroscience research and how they are implemented in Matlab.

Each week you will read select chapters from the textbook. Students are expected to read the assigned chapters and complete the coding exercises before class. After reading the chapters, you will post at least one question on the question board for the week (linked under the Schedule section). These questions can be on topics you could not understand or want to further discuss. We will discuss answers for the questions posted in each class. You will also submit your solutions to the coding exercises for the week through the Matlab Grader website for the class (linked below).

2) **Learning about heuristics, best practices, and free and open software for data analysis.** You will learn about available sources for conducting research, will acquire practical skills in analyzing data, documentation, and building a pipeline, and discuss current approaches to neuroscience research (e.g., open science, replicability, data sharing).

Class Structure

Each class starts with an overview of the content presented in the readings by the instructor, followed by a discussion of the questions posted by the students prior to the class. In the second half of the class we will conduct hands-on exercises and activities that target understanding practical applications of computational tools used in research.

Weekly Tasks

- **Readings.** Students will cover all assigned weekly readings before the class.
- **Discussion question.** Students will post at least one discussion question on the discussion board for the week. The discussion question should be about the content discussed in the book. We will discuss these questions during the class. Each week’s discussion board is linked in the schedule below.
- **Coding exercises.** Students will submit solutions to the coding problems for the week, through the Matlab Grader website, linked here

Due Dates for Weekly Tasks

- The discussion questions are due 8:00 AM on the day of the class (Tuesday).
- The coding exercises are due 11:59 PM on the day of the class (Tuesday). However, it is advisable to submit the coding exercises before the class, so that you can ask questions on the scripting problems you are struggling with. You can resubmit the solutions until the deadline.

Weekly Class Activities

Over the semester we will conduct practical, hands-on activities with:

- Matlab scripting for data analysis and visualization

- Linux/Mac OS X Terminal Commands & Bash scripts
- Data exploration (PivotTables & Graphs)
- EEG & ERP data analysis (e.g., EEGLAB/ERPLAB)
- Structural & functional MRI analysis (e.g., SPM 12)

Quizzes

- There will be three quizzes to evaluate students' understanding of the content presented in class. The quizzes will target both theoretical concepts as well as scripting skills. The quizzes will be posted on the Matlab Grader site on the dates indicated in the schedule (Tuesdays, after class). Students will have four days to complete the quizzes and the responses will be submitted by the Friday (5pm) of the same week.

Use of Generative AI

You can use generative AI tools, such as ChatGPT, Perplexity AI, Microsoft Copilot etc., when working on the weekly coding exercises or the quizzes. However, beware that generative AI tools can (and often will) produce erroneous code. If you decide to use generative AI tools, it is completely your responsibility to understand and mitigate these errors. Always double-check the code generated by generative AI.

An alternative approach to general purpose generative AI is the Matlab Playground. This is an AI system specifically designed to help you with Matlab problems. You are encouraged to use this system for both coding exercises and quizzes. Here is the link: <https://www.mathworks.com/matlabcentral/playground/new>

Schedule & Weekly Themes

1. Introduction

2. Principles of Data Analysis, Open Science and Replicability (Jan 21)

- MBCS Chapters 1-3 (pgs. 1-30)
- Discussion Board

3. MATLAB Environment & Variables (Jan 28)

- MBCS Chapters 4-5 (pgs. 31-62)
- Discussion board

4. Functions & Control Statements (Feb 4)

- MBCS Chapters 6-7 (pgs. 67-99)
- Discussion board

5. Input-Output (Feb 11)

- MBCS Chapter 8 (pgs. 103-114)
- Discussion board
- **Quiz I**

6. Plotting (Feb 18)

- MBCS Chapter 9 (pgs. 117-141)
- Discussion board

7. Matrix Algebra 1 (Feb 25)

- MBCS Chapter 10 (pgs. 147-164)
- Discussion board

8. Matrix Algebra 2 (Mar 4)

- MBCS Chapter 10 (pgs. 147-164)
- Discussion board

—————**March 7 - 16 Spring Break**—————

9. Fourier Transform 1 (Mar 18)

- MBCS Chapter 11 (pgs. 167-188)
- Discussion Board
- **Quiz II**

10. Fourier Transform 2 (Mar 25)

- MBCS Chapter 11 (pgs. 167-188)
- Discussion Board

11. Convolution (April 1)

- MBCS Chapter 12 (pgs. 193-201)
- Discussion board

12. Frequency Analyses (April 8)

- MBCS Chapter 18 (pgs. 287-306)
- Discussion board

13. Time-Frequency Analysis (April 15)

- MBCS Chapter 19 (pgs. 311-331)
- Discussion board

14. Review of Content (Apr 22)

- Discussion board
- We will review the entire course content
- **Quiz III**

Grading

Weekly readings, questions & class participation (3 pt) (Highest 11 of the 12 weeks will be counted towards the grade)	11x3 = 33 pts
Weekly coding exercises (2 pt)	11x2 = 22
Quizzes (x3)	15x3 = 45 pts
Total	100 pts

Grading scale: A: 90 - 100, B: 80 - 89, C: 70 - 79, D: 60 - 69, F: 0 - 59

Additional Resources

Free and Open Source Matlab Alternative

Octave Online

Neuroimaging Software

- EEGLAB, ERPLAB, SPM12, FSL, AFNI

Statistics Software

- JASP, JAMOVI, R, Rstudio

Image & Media Editing

- Adobe Suite (free to UA members), GIMP

Books

Linear Algebra Interactive Linear Algebra by Dan Margalit, Joseph Rabinoff (online interactive book)

Neuroscience Methods

- Luck, S. J. (2014). An introduction to the event-related potential technique. MIT press.
- Poldrack, R. A., Mumford, J. A., & Nichols, T. E. (2011). Handbook of functional MRI data analysis. Cambridge University Press
- Cohen, M. X. (2014). Analyzing neural time series data: theory and practice. MIT press.

Data Analysis & Coding

- Cohen, M. X. (2017). MATLAB for brain and cognitive scientists. MIT Press.

Open Data

- NIMH Data Archive (<https://nda.nih.gov/>)
- Open fMRI (<https://openfmri.org/>)
- OpenNeuro (<https://openneuro.org/>)
- Harvard Dataverse (<https://dataverse.harvard.edu/>)
- OSF (<https://osf.io/>)
- Human Connectome Project (<https://humanconnectome.org/>)
- ABCD Study (abcdstudy.org/; <https://nda.nih.gov/abcd>)
- Brain Imaging Data Structure (<https://bids.neuroimaging.io/>)
- ABIDE (Autism Brain Imaging Data Exchange; https://fcon_1000.projects.nitrc.org/indi/abide/)
- Max Planck Institut Leipzig Mind-Brain-Body LEMON dataset ([Link](#))

Policy Statements

Policy on Missed Exams and Coursework

It is important that students turn in all assignments on time and attend classes. Each week, students are required to submit discussion questions and responses to coding exercises, in addition to attending class. You will not receive any points for weekly participation, even when you post a discussion question, if you don't show up for class. Except in the case of documented severe illness, funeral of a family member, or a personal, catastrophic or religious event (as defined by the University policies), assignments submitted late are not accepted. For excused absences, documentation (e.g., doctor's note) for the absence needs to be sent within a week of the absence. There will not be any exceptions to the policy stated here.

Attendance Policy

Class attendance is necessary and required. It is expected that you undertake appropriate prior preparation for each class period and actively participate during class. Attendance will be taken. You can miss up to two classes if you have an excused absence. In the case of an excused absence (documented severe illness, funeral of a family member, or a personal, catastrophic or religious event, as defined by the University policies), please contact me by email in advance of the absence.

Notification of Changes

The instructor will make every effort to follow the guidelines of this syllabus as listed; however, the instructor reserves the right to amend this document as the need arises. In such instances, the instructor will notify students in class and/or via email and will endeavor to provide reasonable time for students to adjust to any changes.

Mission of the College of Education

Our mission in the College of Education is to be a leader in Alabama and across the nation in teaching, scholarship, advocacy, and service by developing professionals with pedagogic and disciplinary expertise who advance the intellectual and social conditions of all learners in a globalized society.

Conceptual Framework Summary

The vision of the College of Education (COE) at The University of Alabama is to develop effective, ethical, and reflective professionals who advance the theme of the COE: Unite, Act, and Lead (UA Leads). By engaging in theoretically informed and intellectually advanced effective practice our graduates will

UNITE with the larger community to collaboratively nurture cultural competence, empathy, and a vision of equity and justice for all learners;

ACT to develop the full potential of all learners to be excellent professionals in their fields; and

LEAD through continuous research-based critical inquiry of policy and reflective practice to enable transformative change in our diverse local and global communities.

Dispositions

We strive to create programs that emphasize Fairness and Equity, Reflective Stance for Professional Practice, a Commitment to Diversity, and a Culture of Collaboration.

Statement on Academic Misconduct

Students are expected to be familiar with and adhere to the official Code of Academic Conduct provided in the Online Catalog (<https://catalog.ua.edu>).

Statement on Disability Accommodations

- Contact the Office of Disability Services (ODS) as detailed in the Online Catalog.
- The Office of Disability Services (ODS) is the central contact point for UA students with disabilities. The goal of ODS is to ensure that University programs and services are accessible to qualified students with disabilities. For student who may require their services more information is available at <http://ods.ua.edu>. ODS is located at 1000 Houser Hall and their phone number is 348-4285 (voice) or 348-3081 (TTY).

Severe Weather Protocol

Please see the latest Severe Weather Guidelines in the Online Catalog. The link for the Severe Weather Guidelines is <https://ready.ua.edu/severe-weather-guidelines/>

Statement on Pregnant and Parenting Students

Title IX is a federal law that prohibits discrimination on the basis of sex in an education program. Among the types of gender discrimination covered by this statute, Title IX protects against discrimination related to pregnancy or parental status. Protection extends to students who are pregnant or who have either had a false pregnancy, termination of pregnancy, have gone through childbirth, or are recovering from any of those conditions. Title IX regulations also prohibit a school from applying any rule related to a student's parental, family or marital status that treats students differently based on their sex. For more information, please visit http://provost.ua.edu/uploads/3/9/7/6/39760652/student_pregnancy_faq_final_8_11_17.pdf

Statement on Religious Observances

The University of Alabama respects the religious diversity of our academic community and recognizes the importance of religious holy days and observances in the lives of our community members. For more information, please go to <http://provost.ua.edu/religious-observances.html>

Statement on Academic Work Duplication

Any submission of academic work designed to meet the requirements of a particular credit-bearing course is assumed to be work completed for that course and only that course; the same material submission, or material that is substantially similar, may not be used to meet the requirements of another course. Any violation of this rule may result in a referral to the Associate Dean for Student Services and Certification for disciplinary action.

UAct Statement

The UAct website provides an overview of The University's expectations regarding respect and civility. The website link is <https://www.ua.edu/campuslife/uact/>