PSY 596L, *Analyzing Neural Time-series Data*
Spring, 2020, Mondays, 1^{00}-3^{45} P.M.
Room 323 Psychology

INSTRUCTOR

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Office Hours: Tu 5^{00}-6^{00} starting Feb 4, or by appointment

COURSE DESCRIPTION AND OBJECTIVES

This goal of this course is to provide you with a conceptual, mathematical, and pragmatic understanding of time-, time-frequency-, and synchronization-based analyses of neural time series data, especially electroencephalographic (EEG) signals. Stated differently, the course has three main objectives:

a) To provide students with the tools to process and analyze EEG data using standard (e.g., ERP, topography) methods in Matlab
b) To provide students with the tools to process and analyze EEG data using advanced (e.g., frequency and time-frequency decomposition, directional coupling) methodologies in Matlab.
c) To prepare students to analyze an EEG study independently, including generating plots and computing statistics.

These principles and programming approaches will be relevant for other neural time series data such as magnetoencephalographic (MEG) signals and local field potentials (LFP). The focus of the course is on the pragmatic implementation of signal processing approaches, and will be run in a collaborative workshop format. This format will be a flipped class[1] where we will read and watch lectures outside of class; our time in class will be devoted to short presentations and working through programming exercises using Matlab to be sure we all understand how to process neural timeseries data.

Our roadmap for the course will be the wonderfully detailed yet highly accessible and sometimes entertaining book by Mike X Cohen (2014): *Analyzing neural time series data: Theory and practice*, Cambridge, MA: MIT Press. This book is available on the Amazon.com website, as well as the University of Arizona library as an electronic resource. We will work through chapters of the book, including chapter exercises that include Matlab code provided by Mike Cohen.

EXPECTED LEARNING OUTCOMES

By the end of the course, you should:

a) Have gained an understanding of how and why specific analyses are performed;
b) Be able to interpret results conducted with these approaches;
c) Demonstrate that you understand the methodological and practical issues involved with these analyses;
d) Be able to perform single-subject and group-level statistical analyses of neural time-series data.

COURSE WEBPAGE

Please visit the course webpage (jallen.faculty.arizona.edu, courses) for links to:

- Purchase the text or access the electronic version via the library
- Obtain a copy of the syllabus and the current up-to-date schedule of topics and assignments
- Download Matlab code and data that accompany the book
- Access video lectures that accompany some topics in the book
- Access coding assignments and other class resources.

Any changes to the course content or schedule will be reflected on the course webpage.

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[1] The flipped classroom is a pedagogical model in which the typical lecture and homework elements of a course are reversed. Short video lectures are viewed by students at home before the class session, while in-class time is devoted to exercises, projects, or discussions. (From https://net.educause.edu/ir/library/pdf/eli7081.pdf)

Course Structure

The course will follow a workshop format. Each class session may involve some lecture/demonstration and will involve active practice with coding in Matlab. For a 3-credit course, we should have 150 minutes of class each week; our class is scheduled for 175 minutes, so this allows for one or two short breaks totaling 15 minutes.

You should read the assigned readings and view any assigned lectures before class. You should bring your laptop with you to each class and be prepared to work on the homework I'll provide the day of class. We will work collaboratively, and take turns projecting our screens to the big screen as we discuss strategies for solving the problems.

Readings

All readings will be from the sole book (and roadmap) for the course:

Cohen, MX. (2014): *Analyzing neural time series data: Theory and practice*, Cambridge, MA: MIT Press.

Other Materials You Will Need

You will need to install Matlab on your computer if you have not done this already. You should go to softwarelicense.arizona.edu and under types of licenses click on your designation (student for almost all of you) and find Matlab. If given an option for what to install, you can omit any of the "Simulink" packages that are part of Matlab/Simulink. Only install Matlab and its toolboxes. This takes quite a while. Once complete, launch Matlab and be sure it does not give you any license errors. If you are having trouble, let me know.

Evaluation

- ***In-class homework and class participation (60%):*** I intend for everyone to be able to achieve all these points by showing up having read the chapters, having viewed the videos, and being ready to code and collaborate. Because attendance is required for participating and coding, it is important that you attend class. Knowing that quotidian exigencies, unanticipated entanglements, and unforeseen clandestine government missions are a part of life, you can miss one class with no penalty whatsoever. You may also attend a class virtually (via Zoom) if you cannot be in town, and this can count for attending with prior permission of the instructor. If you need to miss more than one class, then for any absence after that excused absence you will need to produce incontrovertible evidence before the next class period that you have completed the homework for the missed class period.

- ***Function project (40%)***: By the end of the class, you should be able to write a well-documented function in Matlab that does something useful with EEG data. The function could graph waveforms in a new way. The function could calculate a summary value given an input. The function could transform the data in some way. The function could calculate statistics for a group of input datasets. The function should work and be something you can demonstrate to the class. You will demonstrate your function during a 15-minute demonstration in one of the final two class periods. In that 15-minute presentation, you should explain why your function is needed (what makes it useful), demonstrate its use, and show highlights of your code. You should email your completed function (m file) and any necessary data (mat file) to the instructor by noon of the day you will be presenting your function. Your grade on this function will be determined by: 1) the instructor's evaluation of the code's accuracy and readability (50%); 2) Class ratings of your presentation and function by class members using a grading rubric (50%) that will be distributed at least 4 weeks before the function presentations begin.

Incompletes

Short of major medical illness or global catastrophe, there is virtually no reason I will award an incomplete grade for this course. Incompletes merely move a crisis from one time to another.

D2L

I don't much like D2L I'm not kidding. It aggravates me. D2L will host a copy of the syllabus, and a link to the class webpage. The calendar will remind you when class meets. That's all. And that's sufficient to meet the University mandate to use D2L.

Absences

See above under "Evaluation."

Students with Special Needs

If you anticipate barriers related to the format or requirements of this course, please meet with me so that we can discuss ways to enssure your full participation in the course. If you determine that disability-related accommodations are necessary, please register with Disability Resources (621-3268; drc.arizona.edu) and notify me of your eligibility for reasonable accommodations. We can then plan how best to coordinate your accommodations.

Academic Integrity

Students are expected to adhere to the UA Code of Academic Integrity as described in the UA the Academic Integrity policy: https://deanofstudents.arizona.edu/policies-and-codes/code-academic-integrity . Cheating or plagiarism on the exam or the paper will result in a failing grade for the course, a notice will be sent to the Dean's office, and expulsion from the University of Arizona can result. Plagiarism is defined as any case where one person tries to take credit for the ideas or work of another, including fellow students, or published authors (please see: http://www.library.arizona.edu/help/tutorials/plagiarism).

Use of Electronic Gizmos

You will be using computers for working on data. These devices are essential for the class, but alas, they can also be a potent distraction. Please do not use them for other purposes (e.g. social media, e-chatting/texting, shopping, catching up on email, organizing a flash mob, plotting mass insurrection) or you will be asked to leave the classroom, and will suffer the loss of attendance for that day. Please turn your phones to silent mode.

Changes in Course Content, Schedule, Requirements

The information contained in this syllabus, other than the grade and absence policies, may be subject to change with reasonable advance notice, as deemed appropriate by the instructor. I

Mike Cohen's Trinity of EEG Data Analysis Equations

If Mike were teaching this class, you'd need to learn these three equations by heart, and recite them on command when asked to do so at any time. These three equations form the mathematical bases of most advanced EEG data analyses. Although I won't ask you to be able to recite these equations at any time of day, in any mood, and in any state of consciousness (as Mike would), consider it a grand idea if you memorize them. It is a well-known fact that knowing these equations increases your market value, professionally, financially, and socially. It's true.

Sine wave: $A\sin(2\pi\mathrm{ft}+\theta)$

"Aey sine two pie eff tee plus theta"

Euler's formula: $Me^{ik}=M(\cos(k)+i\sin(k))$

"Em ee to the eye kay equals em cosine kay plus eye sine kay"

Gaussian: $e^{-t^2/2s^2}$

"ee to the minus tee squared over two ess squared"

Tentative Schedule of Topics & Readings

Date	Topics	Chapters	Videos
27-Jan	Lecture Overview topics and chapters; Introduction to Matlab		
3-Feb	Matlab Tutorial	1,2,3,4,5	
10-Feb	Practicalities of EEG measurement and experimental design Preprocessing steps necessary and useful for advanced data analysis EEG artifacts: their detection, influence, and removal Overview of time-domain EEG analyses	6 7 8 9	
17-Feb	The dot product and convolution The discrete time Fourier transform, the FFT, and the convolution theorem Morlet wavelets and wavelet convolution	10 11 12	
24-Feb	Complex wavelets and extracting power and phase Band-pass filtering and the Hilbert transform Short-time FFT	13 14 15	
2-Mar	Multi-taper Less commonly used time-frequency decomposition methods Time-frequency power, and baseline corrections	16 17 18	
9-Mar	**Spring Recess!!!!!!!!!!**		
16-Mar	Inter-trial phase clustering Total, phase-locked, and non-phase locked power, and phase clustering Interpretations and limitations of time-frequency power and phase analyses Surface Laplacian	19 20 21 22	
23-Mar	Principal components analysis Basics of single dipole and distributed source imaging Introduction to the various connectivity analyses Phase-based connectivity	23 24 25 26	
30-Mar	Power-based connectivity Granger prediction Mutual information	27 28 29	
6-Apr	Cross-frequency coupling Graph theory Advantages and limitations of different statistical procedures	30 31 32	
13-Apr	No formal class: hack-a-thon day to work on your functions		
20-Apr	Non-parametric permutation testing Within-subject statistical analyses Group-level analyses and appropriate data analysis strategies	33 34 35	
27-Apr	Recommendations for reporting results in figures, tables, and text Recurring themes in this book, and some personal advice The future of cognitive electrophysiology Class presentation of personally-written functions (First Group from class)	36 37 38 None	
4-May	Class presentation of personally-written functions (Second Group from class)	None	

Other recommended sources for the seriously inclined:
Lyons, R. G. (2012). *Understanding Digital Signal Processing* (3rd Ed.). Boston, MA: Prentice Hall.
Rosenbaum, D.A., Vaughan, J., & Wyble, B. (2014). *Matlab for Behavioral Scientists* (2nd Ed.). New York: Routledge.
Ingle, V.K., & Proakis, J.G. (2017). *Digital Signal Processing Using MATLAB* (3rd Ed.). Stamford, CT: Cengage Learning
Steve Smith's online (free) Digital Signal Processing Book: http://www.dspguide.com/
Mike X Cohen's complete set of Lecturelets: http://mikexcohen.com/lectures.html