Computational Cognitive Neuroscience (CLPS1492)

Tue/Thur 2:30pm - 3:50, Fall 2021

Class Web Site: `http://ski.clps.brown.edu/cogsim.html`

Salomon 202

	Professor	**Teaching Assistants**
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Lab Sections: Labs on Zoom: **https://brown.zoom.us/j/96450722192**

Section	Time
01	Mon 4pm-6pm
02	Thurs 4pm-6pm

Goals: This course introduces you to the field of computational cognitive neuroscience, which considers how neural mechanisms inform the workings of the mind, and reciprocally, how cognitive and computational constraints afford a richer understanding of the problems these mechanisms evolved to solve. We focus on simulations of cognitive and perceptual processes using neural network models that bridge the gap between biology and behavior. We first consider the basic biological and computational properties of individual neurons and networks of neurons. We then discuss learning (plasticity) mechanisms that allow networks of neurons to be adaptive and which are required to perform any reasonably complex task. We consider how different brain systems (visual cortex, hippocampus, parietal cortex, frontal cortex, basal ganglia) interact to solve difficult computational tradeoffs. We examine a range of cognitive phenomena within this framework, including visual object recognition, attention, various forms of learning and memory, language and cognitive control. We will see how damage to different aspects of biological networks can lead to cognitive deficits akin to those observed in neurological conditions. The class includes a lab component in which students get hands on experience with graphical neural network software, allowing deeper, more intuitive appreciation for how these systems work.

Prerequisites: Students who have a sincere interest and additional background in cognitive psychology, neuroscience, and/or computers (or their relationships) will find this course more engaging. While the models we will be using are mathematically based, only algebra and some simple calculus-level concepts are involved. The focus will be on intuitive and practical applications (i.e., applying models to psychological and neuroscience data), but students are expected to engage with the core mathematical equations that we will cover in the readings and lectures. For most of the simulation assigments, students will make use of a graphical user interface but some basic programming skills willl be useful for completing the midterm and final projects. (As of 2020, the course will exclusively use the *Go / Python* version of the software. You are not expected to know these specific languages but some familiarity with programming concepts will be helpful).

Text: O'Reilly, R. C., Munakata, Y., Frank, M.J., Hazy, T.E. and Contributors (2012). *Computational Cognitive Neuroscience*. Wiki Book, 4th Edition (2020), URL: `https://github.com/CompCogNeuro/ed4`

Other Texts for supplemental reading (more detailed mathematical treatments of single and multi-neuron dynamics, but far less about cognitive phenomena):

Dayan, P. and Abbott, L.F. (2001) *Theoretical Neuroscience*. MIT Press
Izhikevich, E.M. (2007) *Dynamical Systems in Neuroscience*. MIT Press

Lab: In addition to lecture, there is a weekly 2 hour lab session led by the TA, where students obtain in-depth hands-on experience with the computer simulation explorations. These explorations are the centerpiece of the course, and provide a unique exploratory learning opportunity. You will perform many what-if scenarious to understand what aspects of the brain's biology are important for producing specific cognitive phenomena. You will simulate the effects of brain damage in these models, to understand neuropsychology. The computer models enable complete control and dynamic, colorful visualization of these explorations, providing a unique ability to understand how cognition emerges from the brain. You will document these explorations by answering the simulation exercises questions. You should be able to do much of the required homework during these lab sessions.

Evaluation: Your grade will be based on three components in the following proportions:

Simulation exercises	35%
Reading reactions	10%
Midterm miniproject	10%
Final project	35%
Class participation	10%

Simulation Exercises: The wiki textbook comes with a large number of "pre-built" neural network models that illustrate key principles and phenomena, using the Go/Python code mentioned above. Every week, you will explore these pre-built models, and you will document these explorations by answering questions from the wikibook. You will be responsible for all questions listed in each project, unless I tell you to skip specific questions. You should write up all of the assigned simulation exercises for each chapter and turn them in on Canvas on the date specified on the syllabus. Although you will be working on these exercises in the labs, you must write them up *individually*. We want to see that each person individually understands the material, so this should be evident in your writeup. It is best to write down results and first drafts of answers as you work through the exercises; they can sometimes take a while to run and you don't want to have to run them repeatedly. Exercises turned in late will be penalized 5% for each day after the due date.

Please attempt to provide complete, concise answers. When a question asks why something happens, make sure you provide an account of the mechanisms involved, not a description of the phenomenon in different words. For example, given the question "Why does X make a neuron fire less frequently?", an answer such as "Because the timing between spikes increases" is just a redescription of the question and is not an account of the mechanism by which X impacts spike frequency. To receive full credit on a problem, it should be obvious that you understand the answer from your writing. But this does not mean that you should write an overly long answer: lack of completeness and clarity will result in partial credit, as will answers which mention too many concepts without specifying which subset of them are relevant to the question.

Collaboration: You are allowed to discuss the simulation exercises with other students in the class (indeed, this will be a regular part of the weekly lab sessions). However, you must write them up individually. If you discuss one of the exercises at length with another student, it is always a good idea to list that other student's name in your response (e.g., "I worked with Tom Petty on this question"). This process of listing names protects you from ethics problems, in the following sense: If students X and Y state outright that they worked together on a question, and I think that their answers are too similar, I do not consider this an ethics violation; rather, I will just tell X and Y that they should try harder to come up with different responses (and maybe deduct a few points). However, if X and Y hand in identical, idiosyncratic answers, and they do not list each other as having worked together, this constitutes an ethics violation because they are representing their work to be entirely their own, when in fact it is not.

Reading reactions: For each chapter, you will be asked to post a few sentences about the topic you found most interesting in the chapter and why. These reading reactions are designed to ensure that you are keeping up on the reading and to inform us about your interests. Reading reactions should be posted on canvas under "Discussions" prior to the class meeting when they are due.

Other Discussion/Questions

We will be using Piazza for any discussion and questions other than reading reactions. This can include questions about homework, emergent, course content, or course logistics. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. Find our class page here `https://piazza.com/brown/fall2021/clps1492/home` (feel free to ignore any requests you might get for optional financial contributions).

Final Project: In the final project, you will conduct your own simulations to examine some phenomenon of interest to you (as one example, "the role of oscillations in memory consolidation"). This will involve either adding an extension to an existing model that we covered or building a new one from scratch. *Do not be overly ambitious* — relatively clear and simple but thoughtful work is much preferred to a complicated half-baked mess. Do not be misled by the relative simplicity of running the canned exercises in the book — *simulation projects take a long time to complete!* The TA and professor will consult with you to develop and refine a tractable project. You will also have the opportunity to complete a shorter, directed, midterm project that will help you develop skills with the software that will be useful for the final project.

Undergraduates can work in groups of 2, but each of you will have to contribute independently and each of you will have to write up separate components of the final paper. The following timeline is designed to ensure that you make progress on your project and that you receive feedback on it before turning in the final version.

Deadline	**Assignment**
Oct 22	Midterm mini-project
Oct 28	Project topic
Nov 4	Project proposal (1 page summary and approach to explore thru simulations)
Nov 8 - 12	Meeting w/ TA and instructor about project
Dec 7-9	Presentation of project to class
Dec 14	Final paper

A final paper describing your project is due Dec 14. This paper should be 12-15 pages (double spaced, excluding figures), and should contain a concise introduction to the psychological issue or phenomenon, a justification of your (or others') general approach to modeling it, methods, results, and a concluding discussion (about the significance of your results, what you might do to improve your model, etc.). Network diagrams and graphs of significant results should be included. However, do not include excessive or redundant figures; the text should provide a clear interpretation and justification of all figures. NOTE: For each day that the final paper is late, 5% will be deducted from your final paper grade.

Class Participation: Productive participation in class discussion is encouraged to help you get the most out of this course. You are expected to read the text chapters the week they are assigned and to come to class prepared to actively participate in discussion. Another way to participate is via reading reactions (and interactive discussion by reacting to others' reactions) on Canvas and Piazza.

Class Recording and Distribution of Course Materials For those who cannot attend lecture in person I have made the lectures from Fall 2020 available on Media Library on Canvas. If you have questions or concerns about this protocol, please contact me so that we can talk through those to also ensure your full participation in this course.

Lectures and other course materials are copyrighted. Students are prohibited from reproducing, making copies, publicly displaying, selling, or otherwise distributing the recordings or transcripts of the materials. The only exception is that students with disabilities may have the right to record for their private use if that method is determined to be a reasonable accommodation by Student Accessibility Services. Disregard of the University's copyright policy and federal copyright law is a Student Code of Conduct violation.

Grading Policy: Grades are not curved; they are based on percentages:

85-100	A	75-85	B	65-75	C

I reserve the right to change the schedule as the semester progresses. The most up-to-date version will always be posted on the class web-site.

Schedule

The below table summarizes when we will cover each topic and also contains due dates for assignments. You can access the due dates for all course assignments on Canvas.

Wk	Date	**Tuesday: Lecture**	Ch	Due	Date	**Thursday**	Ch	Due	Due Fri
1	7 Sep 21				9 Sep 21	**Introduction**	**1**		
2	14 Sep 21	**Neurons**	**2**	RR1	16 Sep 21	Neurons	2	RR2	
3	21 Sep 21	**Networks**	**3**	HW2	23 Sep 21	Networks	3	RR3	
4	28 Sep 21	Networks	3		30 Sep 21	**Plasticity / Learning**	**4**		HW3
5	5 Oct 21	Model / statistical learning	4	RR4	7 Oct 21	Task (“error-driven”) Learn	4		
6	12 Oct 21	Task multilayer Learning	4		14 Oct 21	combo and Temporal context learning	4	HW4	
7	19 Oct 21	**Temporal reinforcement learning**	**7**	RR5	21 Oct 21	**Large Scale Org**	**5**		**MidProj**
8	26 Oct 21	**Perception: early vision**	**6**		28 Oct 21	Perception: object recognition	6	**Top**	**HW6**
9	2 Nov 21	Perception: attention	6		4 Nov 21	**Motor / BG /RL**	**7**	**RR7, Prop**	
10	9 Nov 21	**Memory: interference**	**8**		11 Nov 21	Memory: Hippocampus		RR8	HW7
				Meet				Meet	
11	16 Nov 21	Theta, memory retrieval, sleep			18 Nov 21	**Working Memory (BG/PFC)**	**10**		RR10
12	23 Nov 21	Working Memory (BG/PFC)	10	HW8	25 Nov 21	no class			
13	30 Nov 21	**Executive Function**	10		2 Dec 21	**Language**	**9**		HW10
14	7 Dec 21	Student Presentations			9 Dec 21	Student Presentations		HW9	
15	14 Dec 20			**Paper**	16 Dec 21				

Ch = Chapter in text to read, **Due** = Materials due in class (**HW** = homework, **RR** = reading reaction), **MidProj** = Mid-term mini project, **Top** = Paper topic, **Prop** = Final project proposal, **Meet** = Meet with instructor this week to discuss proposals. **Paper** = Final papers due by 5:00pm via email.

Diversity Statement

In this class, we strive to create a learning environment that supports a diversity of thought, perspectives, and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc.). This means acknowledging biases and the diversity of all of us. To help accomplish these goals, please come speak with us (either directly or by submitting anonymous feedback):

- If anything in the readings or anything said in class (by anyone) makes you feel uncomfortable
- If you feel that your performance in class is being impacted by your experiences outside of class
- If you have any suggestions for improving the course materials to better include diverse perspectives

We appreciate you letting us know your preferred name and pronouns. We look forward to getting to know everyone in the class.

The CLPS Department statement on Diversity and Inclusion can be found here: `www.brown.edu/academics/cognitive-linguistic-psychological-sciences/diversity`

Please also be aware of these resources: Dean Bhattacharyya, Associate Dean of the College for Diversity Programs Contact: (401) 863-3488, Maitrayee_Bhattacharyya@brown.edu

Students in need of short-term academic advice or support can contact one of the deans in the Dean of the College office.

To empower students whose first language is not English, an array of ELL support is available on campus including language and culture workshops and individual appointments. Contact: ellwriting@brown.edu or (401) 863-5672

Support for Writing at Brown: `www.brown.edu/academics/college/support/writing-center/`

If you might require accommodations or modification of any course procedures, contact Student and Employee Accessibility Services at 401-863-9588 or SEAS@brown.edu

Students with concerns about any non-tuition cost(s) of a course may apply to the Dean of the College Academic Emergency Fund to determine options for financing these costs, while ensuring their privacy. The fund can be found in the Emergency Funds, Curricular & Co-curricular Gap (E-Gap) Funds in UFunds. Information and procedures are available at `http://brown.edu/go/egap`