Computational Cognitive Neuroscience (CLPS1492)

Tu/Th 10:30 - 11:50, Fall 2012

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

username = cogsim, password = neuro

	Professor	**Teaching Assistant**
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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 (no programming experience needed), allowing deeper, more intuitive appreciation for how these systems work.

Prerequisites: The formal prerequisite courses for this course are: COGS0010 or COGS0420, and PSYC0750 or NEUR0010, which provide basic background in cognitive psychology and neurobiology that will be useful for the course. Students who have a sincere interest and/or 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 more on intuitive and practical applications (i.e., applying models to psychological and neuroscience data) than on theoretical/mathematical derivations (although interested students can certainly engage in more detailed analytical/mathematical approaches). Programming experience is not needed but is helpful for students wishing to pursue advanced projects.

Text: O'Reilly, R. C., Munakata, Y., Frank, M.J., Hazy, T.E. and Contributors (2012). *Computational Cognitive Neuroscience*. Wiki Book, 1st Edition, URL: `http://grey.colorado.edu/CompCogNeuro/index.php/CCNBook/Main`

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 (to be worked on during the lab sessions). You should be able to do most 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 textbook comes with a large number of "pre-built" neural network models that illustrate key principles and phenomena. Every week, you will explore these pre-built models, and you will document these explorations by answering questions from the textbook. For each chapter of the textbook, I will tell you which simulation exercises to do. If you start doing the exercises before you receive this assignment, you risk doing some exercises that are not in the assignment (which is not the worst thing, but you have been warned). You should write up all of the assigned simulation exercises for each chapter and turn them in in class 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.

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 email 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 emailed to michael_frank@brown.edu and jeffrey_cockburn@brown.edu, prior to the class meeting when they are due.

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 19	Midterm mini-project
Nov 1	Project topic
Nov 6	Project proposal (1 page summary and approach to explore thru simulations or lit review)
Nov 6 - 16	Meeting w/ TA and instructor about project
Dec 4/6	Presentation of project to class
Dec 14	Final paper

A final paper describing your project is due Dec 14. This paper should be 10-15 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.

Grads & Undergrads: This course is designed for advanced undergraduates and graduate students. Undergrads need not feel intimidated by the presence of graduate students in the class. More will be expected of the grads than the undergrads, especially when it comes to the final projects.

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

Wk	Date	Tuesday: Lecture	Ch	Due	Date	Thursday	Ch	Due	Due Fri
1	4 Sep 12				6 Sep 12	**Introduction**	**1**		
2	11 Sep 12	**Neurons**	**2**	RR1	13 Sep 12	Neurons	2	RR2	
3	18 Sep 12	**Networks**	**3**	HW2	20 Sep 12	Networks	3	RR3	
4	25 Sep 12	Networks	3		27 Sep 12	**Plasticity / Learning**	**4**		HW3
5	2 Oct 12	Model / statistical learning	4	RR4	4 Oct 12	Task ("error-driven") Learn	4		
6	9 Oct 12	Task Learning	4		11 Oct 12	Temporal Learning	4		HW4
7	16 Oct 12	Temporal/Reinforcement Learn			18 Oct 12	**Large Scale Org**	5		**MidProj**
8	23 Oct 12	**Perception: early vision**	**6**	RR5	25 Oct 12	Perception: object recognition	6		RR6
9	30 Oct 12	Attention	6		1 Nov 12	**Motor / BG /RL**	**7**	**Top, HW6**	RR7
10	6 Nov 12	**Memory: priming**	**8**	**Prop**	8 Nov 12	Memory: Hippocampus	8	HW7	
11	13 Nov 12	Memory: Working memory	8	RR8	15 Nov 12	Working Memory (BG/PFC)	8		HW8
				Meet				Meet	
12	20 Nov 12	**Executive Function**	**10**	RR10	22 Nov 12	Thanksgiving (No Class)			
13	27 Nov 12	**Language**	**9**	HW10	29 Nov 12	Extra exec Function / Theta	10	RR9	
14	4 Dec 12	**Student Presentations**	11	HW9	6 Dec 12	**Student Presentations**	**12**		
15	11 Dec 12				13 Dec 12				**Paper**

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.