

Computational Cognitive Neuroscience (Psyc 444A/544A)

M/W 9:00 - 10:15, Spring 2008

Room: PSYCH 317B (Labs in PSYCH 128)

Class Web Site: <http://www.u.arizona.edu/~mfrank/cogsim.html>

	Professor	Teaching Assistant
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Lab Sections: Labs in Psych 128

<u>Section</u>	<u>Time</u>
01	Tues 11-1
02	Fri 11-1

Goals: How does the brain secrete the mind? This course introduces you to the field of computational cognitive neuroscience that have been applied toward answering this question. 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, which give rise to basic processing mechanisms like spreading activation, inhibition, and multiple constraint satisfaction. We then discuss learning mechanisms that allow networks of neurons to be adaptive and which are required to perform any reasonably complex task. We examine a range of cognitive phenomena within this framework, including attention, memory, language and higher-level cognition, and how different brain systems (eg., hippocampus, parietal cortex, frontal cortex) are specialized to solve difficult computational tradeoffs. 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: PSYC 101 (intro), 325 (cognitive), 302 (biopsych), which provide basic background in cognitive psychology and neurobiology that will be useful for the course. In addition to these formal prerequisites, 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). Computer programming experience is not required, because the models are accessible via a graphical interface.

Text: O'Reilly, R. C. and Munakata, Y. (2000). *Computational Explorations in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain*. Cambridge, MA: MIT Press.

Lab: There is a weekly 2 hour lab session, 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 scenarios 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 study of brain-damaged patients). 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 (hopefully all) of the required homework during these lab sessions.

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

Simulation exercises	40%
Reading reactions	15%
Final project	30%
Class participation	15%

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 mfrank@u.arizona.edu and bdoll@email.arizona.edu, prior to the class meeting when they are due.

Final Project: In the final project, you can either (a) use simulations to examine some psychological phenomenon of interest to you; or (b) do a literature search and write a review of how recent computational models have addressed a particular topic, including successes and shortcomings yet to be addressed.

Choice (a) will of course take more computer time, where you will explore manipulations of one of the models in the text and write up results and conclusions. Graduate students could add extensions to these

models or build a new one from scratch. If you choose (a), *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!*

Choice (b) will require more reading and integration of scientific articles. While this does not involve you actually simulating anything, it will require more in depth understanding of publishable research modeling. You will also have to compare and contrast at least two models in the literature and how they differentially account for your phenomenon of interest, and comment on which you think is a more realistic account, supported by data, and why.

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 (5 of the 30 points for the project will come from simply making each of the 5 deadlines before the final due date) and that you receive feedback on it before turning in the final version.

Deadline	Assignment
Mar 12	Project topic
Mar 24	Project proposal (1 page summary of your question of interest and proposed approach to explore this question through simulations or literature review)
Mar 31- Apr 4	Meeting w/instructor about project
Apr 28-30	Presentation of project to class
May 9	Final paper

A final paper describing your project is due May 9. 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. Also, undergrads will be responsible for fewer of the homework questions.

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

90-100	A	80-89	B	70-79	C	60-69	D
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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

Date	Monday: Lecture	Ch Due	Date	Wednesday	Ch Due	Due Fri
14 Jan 08			16 Jan 08	Introduction	1	
21 Jan 08	No class (MLK day)	RR1	23 Jan 08	Neurons	2 RR2	
28 Jan 08	Neurons	2 HW2	30 Jan 08	Networks	3 RR3a	
4 Feb 08	Networks	3	6 Feb 08	Networks	RR3b	HW3
11 Feb 08	Model ("Hebbian") Learning	4	13 Feb 08	Model Learning	4 RR4	HW4
18 Feb 08	Task ("error-driven") Learning	5	20 Feb 08	Task Learning	5 RR5	
25 Feb 08	Combo Learning	6	27 Feb 08	Temporal Learning	6 RR6	HW5
3 Mar 08	Temporal/Reinforcement Learning	6	5 Mar 08	Large Scale Org	7 RR7	HW6
10 Mar 08	Perception: early vision	8 RR8	12 Mar 08	Perception: object recognition	8 Top	
17 Mar 08	No class (spring break)	8	19 Mar 08	No class (spring break)	8	
24 Mar 08	Attention	8 Prop	26 Mar 08	Memory: priming	9	HW8
31 Mar 08	Memory: Hippocampus	9 RR9 Meet	2 Apr 08	Memory: Working memory	9 Meet	
7 Apr 08	Memory: Working Memory (BG/ PFC)	9	9 Apr 08	Language	10 RR10	HW9
14 Apr 08	No class (CNS conference)	10	16 Apr 08	Language	10	HW10
21 Apr 08	Higher Level Cognition	11 RR11	23 Apr 08	Higher Level Cognition		
28 Apr 08	Student Presentations	11 HW11	30 Apr 08	Student Presentations		
5 May 08	Misc / Theta Oscillation Learning Rule		7 May 08	Grand Finale	12 RR12	Paper

Ch = Chapter in text to read, **Due** = Materials due in class (**HW** = homework, **RR** = reading reaction), **Top** = Paper topic, **Prop** = Final project proposal, **Meet** = Meet with instructor this week to discuss proposals. **Paper** = Final papers due by 5:00pm in professor's office or mailbox or via email.

The below table shows the questions that can be skipped in your write-ups of lab exercises. You should still step through these exercises as you go through the chapter. (In some cases, this will be useful for subsequent questions.)

Ch	Undergrads Skip	Grads Skip	Ch	Undergrads Skip	Grads Skip
2	2b, 3c, 4, 5, 8b	–	3	3b, 4, 7, 11d,e, 13, 14	4, 14
4	4, 5, 7c,d	–	5	5b	5b
6	3, 4, 5b,c	4	8	5, 7c, 8, 13	13
9	3, 8, 12, 15, 16	3, 12, 15, 16	10	2b, 8, 9	–
11	5,6,7,8	5,6,7,8			