Attention!

This is a *representative* syllabus.

The syllabus for the course when you enroll may be **different**.

Use the syllabus provided **by your instructor** for the most up-to-date information. Please refer to your instructor for more information for the specific requirements for a given quarter.

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Psychology 618

Introduction to Computational Cognitive Neuroscience

Semester-length Course Syllabus

Course:	PSYCH 618
Credits:	3
Dates:	TBA
Times:	Tuesdays and Thursdays, 9:00 – 10:30 a.m.
Room:	TBA
Prerequisites:	Graduate standing or permission by instructor. (Psych 612 recommended.)
Websites:	https://carmen.osu.edu
Textbook:	Randall O'Reilly & Yuko Munakata (2000). *Computational Explorations in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain.* Cambridge, MA: MIT Press.

Course Overview

How does cognition emerge from the brain? This course introduces you to the new and exciting field of Computational Cognitive Neuroscience (CCN) that provides important pieces of the answer to this question. We focus on simulations of cognitive and perceptual processes using neural network models that bridge the gap between biology and behavior. The first half of the course surveys some classic connectionist models and algorithms such as pattern associators, backpropagation nets, Hopfield nets, Kohonen's self-organizing maps, and Grossberg's Adaptive Resonance Theory (ART). The second half of the course focuses on the *Leabra* framework of Randy O'Reilly and Yuko Munakata. Their 2000 book is the main text for the course and their *Emergent* neural network simulator is used for all demos, explorations, and homework assignments. Throughout the course, special attention is given to the neurological plausibility of the models. We consider briefly the basic biological and computational properties of individual neurons and networks of neurons, as well as their idealized counterparts. We discuss basic processing mechanisms such as spreading activation, inhibition, constraint satisfaction, and various forms of learning. Models illustrating these ideas are demonstrated in class and explored in homework assignments. These include case studies of full-blown models of various aspects of perception, language, and memory. Finally, we turn to big-picture issues and present (an outline of) a comprehensive connectionist proposal of a cognitive architecture. We discuss how different brain systems (posterior cortex, hippocampus, prefrontal cortex) specialize to solve difficult computational tradeoffs.

Textbook

The main textbook is *Computational Explorations in Cognitive Neuroscience* (O'Reilly & Munakata, 2000, henceforth abbreviated OR&M00), MIT Press, http://grey.colorado.edu/CompCogNeuro/index.php/CECN
Additional readings are listed in the lecture plan below.

Prerequisites

There are no formal prerequisites for graduate students. Advanced undergraduate students need permission by the instructor. Psych 612 (*Introduction to Cognitive Science*) is recommended but not required. Obviously, prior exposure to mathematical models (e.g., Psych 609), linear algebra (e.g., Math 571), and/or neuroscience (e.g., Psych 313) will be extremely useful, although the present course overlaps little with these courses. While the models we will be studying are mathematically based, only algebra and some simple calculus-level concepts are involved. We rely primarily on computer simulations to explore the models and develop intuitions about how they work. Computer programming experience is not required because the models are accessible via a graphical interface. Still, you will be expected to install the *Emergent* simulator on your own and be able to run about two dozen "canned" exercises with selected models.

Teaching Method

Classes will consist of lectures, tutorials, and discussions. There will be many in-class demonstrations. The course will require preparation prior to each class: reading chapters from the textbook, additional readings, and hands-on explorations with *Emergent*.

Emergent Software

Each student should have access to the *Emergent* simulator. It is the successor of PDP++ (the software that came with the book). *Emergent* is open-source and available on all major platforms: Linux, Mac OS X (preferred), and Windows. Precompiled binaries (and C sources) are available for download from http://grey.colorado.edu/emergent/ It is assumed that all students have access to a personal computer and are willing to install the software. Be sure to get version 5.0.1 or later.

Hands-on experience with actual running models is an important part of the course. It is a unique exploratory learning opportunity. The difficulty level will be matched to the average ability of the students in the class. We will begin with very simple exercises and progress to more complex ones depending on your interest and skill. The simulator gives complete control over all aspects of the network and its training environment. It also provides dynamic, colorful visualizations that are an indispensable tool for developing intuitions about how complex cognition can emerge from a network of neurons. To access the simulation exercises, go to
http://grey.colorado.edu/CompCogNeuro/index.php/CECN1_Projects

Accommodations for Students with Special Needs

The policy of The Ohio State University is to provide every reasonable, appropriate, and necessary accommodation to qualified disabled students. The University's colleges and

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academic centers evaluate and judge applications on an individual basis and no categories of disabled individuals are automatically barred from admission. The privacy rights of each disabled person are honored to the fullest extent possible. The University's interest in a students disabilities are only for the purpose of accommodating his/her specific disability, thereby providing an academically qualified disabled student access to programs and activities accorded all other qualified students. Whenever generally accessible facilities do not adequately accommodate a specific disability, the University makes every reasonable accommodation and program or facility adjustment to assure individual access. These policies are fully supported and practiced in this class.

Students with disabilities that have been certified by the Office of Disability Services will be appropriately accommodated, and should inform the instructor as soon as possible of their needs. The Office for Disability Services is located in 150 Pomerene Hall, 1760 Neil Avenue; telephone 292-3307, TDD 292-0901; http://www.ods.ohio-state.edu/ . Contact Dr. Petrov privately: email petrov.11@osu.edu, telephone 614-247-2734; office in 200B Lazenby Hall.

Evaluation

Your grade will depend on four components in the following proportions:

Model explorations	30%
Class participation	10%
Midterm exam	30%
Final exam	30%

Grades are based on absolute cutoffs: A=90-100%, B=80-89%, C=70-79%, D=60-69%.

Model explorations: 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 document your explorations by answering questions from the textbook. The Course Calendar lists which exercises to do for each chapter. You should write up all assigned simulation exercises for each chapter and upload them to the corresponding Carmen dropbox. The acceptable formats are MS Word (.doc or .docx), plain text (.txt), PDF, HTML, or RTF. Note that the model exploration report for each chapter must be in a separate file and dropped in a separate dropbox, prior to the date specified in the Calendar section of the syllabus. Late submissions will be penalized 1% for each day after the due date. Reports submitted by email, slipped under the door, etc. will not be graded and do not bring any points. Teamwork on these explorations is encouraged, but you must write your reports *individually*. We want to see that each individual person understands the material, and so this should be evident in your writing. It is best to write down results and first drafts of answers as you work through the simulations; they can sometimes take a while and you do not want to have to run them repeatedly.

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 discuss the issues and answer questions. Attendance is required.

Exams: There will be one Midterm Exam during the semester and one Final Exam during the final week. All are closed-book and consist of short- and long-answer questions. Sample questions will be given in class. No make-up exams will be given, except in the case of documented illness or emergency. All make-up exams will be oral. In the event of a last-minute emergency, you **must** call the instructor or the office associate for the cognitive area **on the same day as the exam**, preferably before the exam begins. Acceptable excuses for missing an exam are a death in your family, personal illness or the illness of your child or spouse, and unforeseen accidents like your car breaking down or getting stuck in an elevator. Please obtain documented proof of these events should they occur. If you are late for an exam, you will be allowed to take it but you will have to submit your answers by the closing time like everybody else.

Academic Ethics

All students enrolled in OSU courses are bound by the *Code of Student Conduct* (http://studentaffairs.osu.edu/resource_csc.asp). The instructor is committed to maintaining a fair assessment of student performance in this course. Suspected violations of the *Code* will be dealt with according to the procedures detailed in the *Code*. Specifically, any alleged cases of misconduct will be referred to the Committee on Academic Misconduct. It is the responsibility of the Committee on Academic Misconduct to investigate or establish procedures for the investigation of all reported cases of student academic misconduct. The term "academic misconduct" includes all forms of student academic misconduct wherever committed; illustrated by, but not limited to, cases of plagiarism and dishonest practices in connection with examinations. Instructors shall report all instances of alleged academic misconduct to the committee (Faculty Rule 3335-5-487). For additional information, see the *Code of Student Conduct*.

Course Calendar

1. Getting started. The appeal of PDP. History of connectionism. Overview of the course. Overview of the *Emergent* simulator.
2. Neurophysiology. Membrane potential. Ion channels. Integrate-and-fire model neuron.
3. Rate codes. Point-neuron approximation to integrate-and-fire. Population codes. Local and distributed representations. Feedforward networks. Linear associator network. Review of vector and matrix algebra. Linear and non-linear transformations.
4. Biological basis of learning. Synaptic plasticity. LTP/LTD. Introduction to Hebbian learning. Learning in the linear associator network.

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5. Perceptron. Error-correcting (task) learning. Delta rule. XOR problem. Multi-layer feedforward networks as universal function approximators. Backpropagation (part 1).
6. Backpropagation continued. Gradient descent. Local minima. Momentum. Simulated annealing. Overfitting and cross-validation.
7. Backpropagation applications. NetTALK. NavLab. English past-tense model (Rumelhart & McClelland, 1986, and the multiple follow-ups).
8. Winner-takes-all inhibition. Competitive learning. Self-organizing maps (Kohonen).
9. Grossberg's (1978) Adaptive Resonance Theory (ART). Fuzzy ARTMAP (Carpenter & Grossberg, 1992). The complementary brain (Grossberg, 2000, *TiCS*).
10. Hebbian learning (continued). Model learning. Conditional Principal-Component Analysis (CPCA). Weight normalization (Oja's rule, BCM rule).
11. Hebbian applications. Orientation columns in primary visual cortex (OR&M00, Sect.8.3). Lexical semantics and network analogs to Latent Semantic Analysis (LSA; OR&M00, Sect.10.6).
12. Interactive activation and inhibition (IAC). Constraint satisfaction. Schema theory (Rumelhart, Smolensky, McClelland, & Hinton, 1986, PDP2, Chap 14, pp. 7-38).
13. Hopfield networks. Introduction to dynamic-system theory. Phase portraits. Attractors. Pattern completion and content-addressable memory.
14. Boltzmann machines (Hinton). Contrastive Hebbian learning (CHL).
15. **Midterm Exam:** Same time and place. Short- and long-answer questions.
16. Is error-correcting learning biologically plausible? Delta learning in the cerebellum. Generalized Recirculation (GeneRec, O'Reilly & Munakata, 2000).
17. Combined Hebbian + GeneRec learning. *Leabra* (O'Reilly, 1998; OR&M00)
18. Invariant object recognition (part 1). Binding problem. Static (conjunctive) binding vs. dynamic binding. Synchrony.
19. Invariant object recognition (part 2; OR&M00, Sect.8.4).
20. Selective attention. Simple model (OR&M00, Sect.8.5), integrated model (OR&M00, Sect.8.6).
21. Complementary learning systems (part 1). Catastrophic interference. Sparseness. Interleaved learning.
22. Complementary learning systems (part 2; OR&M00, Sect.9.2 & 9.3).
23. Simple recurrent networks (Elman, 1990). Sentence Gestalt model (St. John & McClelland, 1990; OR&M00, Sect. 10.7)
24. Activation-based memory in the pre-frontal cortex (OR&M00, Sect.9.4).
25. Reinforcement learning. Actor-critic architecture.

26. Executive control. Stroop model (OR&M00, Sect. 11.3). Gating in the basal ganglia. PFC/BG working-memory model (PBWM).
27. Tripartite Cognitive Architecture (OR&M00, Chapter 7; Jilk et al, 2009).
28. Advanced Topics. Conclusions.
29. **Final Exam**. Short- and long-answer questions.

The above calendar is subject to change at the discretion of the instructor, depending on the rate of progress through the material, student interest in alternative topics, and/or scheduling constraints.

Finally, welcome to the course. I hope that you will enjoy the class and learn valuable information and skills. I look forward to seeing you on ?/??.

Alex Petrov

psy618-semester-syllabus1.doc, last updated 21 April 2010