NEW YORK UNIVERSITY

Computation & Cognition Lab
Department of Psychology

V89.0300 - Computation and the Mind: An Introduction to Cognitive Science

Meeting Time/Place: Conference room in second floor meyer suit from 6:00-7:45 PM on Mondays and Wednesdays
Instructor: Todd M. Gureckis
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Office Hours: By appointment
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Brief Course Description

What is a mind? How is the operation of the mind related to the operation of the brain? What are the basic principals that underly our ability to think, reason, and learn? In this course, an approach to these questions is presented based on the idea that minds are essentially computational devices, similar in many respects to an everyday computer. In particular, the course provides an introductory survey into what is increasingly known as "computational cognitive science". First, I will aim to convince you that the mind is ultimately a computational device, and that we can make great progress on centuries-old questions by exploring the representations and processes the mind uses to solve real-world problems. This idea is a central component to contemporary thinking in neuroscience and all areas of psychology. Next, we will learn about how the emergent properties of interconnected neurons in the brain may enable these computations. In addition, we will learn how insights from machine learning and artificial intelligence are changing the way we think about the building blocks of the human mind and how the study of the mind has in turn revolutionized the way we interact with computers (think Google, smart spam filters, speech recognition, gesture-based cell phones). The course is organized into a set of lectures and basic readings on the philosophy of cognitive science and basic ideas about thinking, reasoning, memory, learning, perception, computation, and the brain. In addition, there will be a small set of hands-on "labs" were were will develop and interact with simple computer programs which simulate aspects of human learning, memory, and decision making. No prior programming experience is required for any of the assignments (the course will have limited enrollment so the structure of the labs can be tailored based on the interests and background of individual students).

Format of the Course

The course will be organized into a series of lectures and hands-on computer lab sessions. Students will be encouraged to interact with one another to solve problems and to develop a solid understanding of the course material. Occasional short homework assignments will be completed partly in class and partly at home. A final project (worth 30% of the final grade) with be completed in groups on a topic of the student's choosing (with input and guidance from the instructor).

Books:

The textbook for this course is "Computing the Mind: How the Mind Really Works" by Shimon Edelman. The textbook is available here and here Additional readings will be selections from research articles, popular science articles, and online tutorials. Here are a collection of helpful resources:

- How to think like a Computer Scientist - An online textbook for learning python
- Main Python website
- Instant Hacking with Python
- A collection of resources for non-programmers learning python

Prerequisites:

Psychology major, introduction to psychology with a grade of at least C, intro states with a grade of a C, and GPA of at least 3.0 in psychology at the university. upper-division standing.

Grading:

As this is a highly interactive course, attendance and participation is critical contributing 20% of the final grade. Early in the class there will be a number of small homeworks and in-class exercises worth 10% of the total. Ultimately, we will conduct three separate "labs". Labs will be completed in teams, but each student is required to write a individual report on the results of the groups. Each of the three reports will contribute 13.33% each (a total of 40%). The reports must conform to APA standards and be original. A final project worth 30% of the grade will involved working alone or in a small group of 2-3 students to design a novel simulation or experiment, present it to the class, and turn in a written summary.

(Tenative) Class Schedule

DATE	DESCRIPTION	SLIDES	PODCAST
Jan 20, 2010	**Introduction, Course Policies, General Overview, etc...** *IMPORTANT* Please fill out the pre-course survey and email me your responses. Click here to view **Reading for Monday: Chapter 1 and 2 from Edelman ("Brains, Minds, and Numbers" and "Computing Minds")**		
Jan 25, 2010	**Lecture: Computation and the Mind** Objective: Today we will try to answer the question, how are minds like computers (and computers like minds?) This will involve a short and informal overview of some issues in philosophy of mind and computational theory. We will discuss the twin strands of computational-level analysis of behavior (the joint specification of both process and representation). **Lab: Basic introduction to Python and some Post-programming Therapy** Objective: To get python installed on your computer. To get some basic familiarity with how to write and enter a simple program. To start learning python so we can do more interesting things with it later! ***Homework***: Link **Reading for Monday: Chapter 3 from Edelman "Computing Brains"**		
Jan 27, 2010	**Lecture: How do brains given rise to computations?** Objective: While last lecture we examined arguments for thinking of the mind in computational terms, in this lecture we consider the next obvious riddle: if minds are like computers,		

how the heck could a bunch of interconnected neurons make this possible?

Lab: Crunching numbers in Python

Objective: Our next step is to understand how to use Python to compute simple math calculations and to use "control structures" (i.e., automatically following paths and branches in the order of execution)

__Homework #2__ (this one may take a bit longer, due date flexible): Link

Reading for Monday: Chapter 4 from Edelman "The Astonishing Hypothesis"

Additional reading: Marr., D. (1982). Vision (ch. 1).

Feb 1, 2010 **Lecture: How do brains given rise to computations?**

Objective: Today we will culminate our discussion about computation by considering the implications of the view of the mind as a computational device? What does this offer us scientifically? What new insights can we derive about human behavior from such a theory? We will also discuss the idea of "levels of analysis" (in the Marr-ian sense) which helps us understand what kinds of explanations we might expect this new science of the mind to encompass.

Lab: More Python basics and "Flipping coins: Harnessing randomness and basic sampling processes"

Today's class we'll spend some more time going over homework #2 and fine-tuning some more basic python including introducing programs that include a random element (so they are different each time they run)

__Homework 3__: Link

Reading for Monday: Chapter 5 (pg. 86-105) from Edelman "Perception"

Feb. 3, 2010 **Lecture: Perception I**

Objective: This is first lecture putting the principals from the last few readings into motion (in this case to understand human perception). We will discuss how the visual system constructs representations of the visual world, how the visual system solves incredible problems such as color constancy.

Lab: Perceiving Randomness: Does your iPod know what kind of music you like?

Why do people perceive structure in randomness? Today we will attempt to answer (scientifically) a critical question facing modern science: Does your iPod (or other digital music player) know what kind of music you like? Have you ever been listening to your iPod on shuffle and had a feeling that the song were being

selected to "go together"? Sometimes it really feels like iTunes or the iPod are choosing songs to go together well. In lecture will examine psychological research into the perception of randomness including studies of the hot-hand in basketball, the gambler's fallacy, and other "cognitive illusions". Then in the lab we will see if we can test (statistically) the idea that iTunes is "smart" by testing exactly how random is the iTunes/iPod shuffle feature.

Reading for Monday: Chapter 5 (pg. 106-129) from Edelman "Perception"

Feb. 8, 2010 **Lecture Perception II: Perceptual Learning**

Objective: Despite the common assumption, perceptual systems are not hard-wired to response in particular ways, but instead our perecptual abilities are often augmented through learning. Today we will discuss a range of topics dealing with perceptual learning, the nature of the primatives the underlying human perception, and the "truthiness" of perception (how close is our perception to the actual state of the world). A key computational idea we will introduce is that idea of "units" which are automatically recruited online during learning to represent important aspects of the environment.

Lab Perceiving Randomness (continued) Today, we'll continue to develop our programming experience with the issue of randomness (or lack of randomness)

Reading for Monday: Chapter 5 (pg. 129-148) from Edelman "Perception"

Feb. 10, 2010 **Lecture Perception III**

Objective: Concluding issues in perception. Following Edelman we'll have a discussion of what it means to "see", the nature of beauty, and other miscellaneous topics.

Lab: Continue perception of randomness lab

Reading for Monday: Chapter 6 (pg. 155-178) from Edelman "Memory"

Feb. 15, 2010 **Lecture Memory I**

Objective: Now we move onto the second "domain" in which we will explore computational principles. First, we will go over an introduction to memory. There are many types of memory, each with different properties, and perhaps even neural substrates. We'll discuss how the representation of memory influences how easy or hard it is to solve certain kinds of problems. This will lay the foundation for a lab exploring neural networks of memory.

Lab: Simple forms of memory

Reading for Monday: Chapter 6 (pg. 178-202) from Edelman "Memory"

Feb. 17, 2010 **Lecture: Concepts**

Objective: Memory forms the basic ingredient for much of what we know about the world. In the follow set of three lectures we will explore structured memory representations and concepts. This will take us through semantic memory, conceptual representation, category learning, and will expose new and interesting computational ideas.

Lab: Simple forms of memory

Reading for Monday: Chapter 6 (pg. 202-228) from Edelman "Memory"

Feb. 22, 2010 **Lecture: Concepts II**

Objective: Structured memory representations and concepts (cont.)

Lab: Simple forms of memory

Feb. 24, 2010 **Lecture: Concepts III**

Objective: Structured memory representations and concepts (cont.)

Lab: Simple forms of memory (extensions to concept learning)

Mar. 1, 2010 **Lecture: Memory II**

Objective: We will wrap up our discussion of memory and concepts with a deeper look at the underlying neurobiology of memory and concepts.

Lab: Simple forms of memory (extensions to concept learning)

Reading: Chapter 8 (pg. 315-334) from Edelman "Thinking"

Mar. 3, 2010 **Lab: Learning in Humans and Machines**

Learning is the processes of changing behavior in response to the environment in a way that is adaptive for the behavior of the agent or individual. In this course we will explore learning from both a psychological and computational perspective. The questions we will face are how do people and machines learn, what are the basic processes that underlying learning in people, how can these be understood through mathematics and computational methods, and how may they inform the creation of automated learning methods.

Lab 2 Specification: here

In addition, the following chapter might be useful for you: Reinforcement Learning: Sutton & Barto (Chapter 2)

Reading: Chapter 8 (pg. 353-364) from Edelman "Thinking"

Mar. 8, 2010 **Lab: Learning in Humans and Machines (cont)**
Reading: Chapter 8 (pg. 353-364) from Edelman "Thinking"

Mar. 10, 2010 **Lab: Learning in Humans and Machines (cont)**

Over break: Chapter 8 (pg. 334-353 and 364-387) from Edelman "Thinking"

Mar. 15, 2010 Spring Break, No Class

Mar. 17, 2010 Spring Break, No Class

Mar. 22, 2010 **Lecture: Thinking, Problem Solving, and Induction**

Objective: Today we will return from break with a lecture integrating various work on topics in thinking, problem solving, and induction. In particular we will discuss the idea of "inductive constraints" and how computational models may help us identify and analyze the constraints under which the mind/brain operates to solve computational problems.

Lab: Complex Systems and Emergence

Reading: Chapter 7 (pg. 235-247) from Edelman "Language"

Mar. 24, 2010 **Lecture: Introduction to the Computational Challenge of Language**

Objective: We now begin a multi-week exploration into the nature of language. We will be looking at language from a number of perspectives ranging from how language is represented in the mind, the degree to which learning influences language (or if it is innate), and a very birds-eye survey of computational approaches to language processing. Sounds scary, but isn't!

Lab: Complex Systems and Emergence

Reading: Chapter 7 (pg. 247-275) from Edelman "Language"

Mar. 29, 2010 **Lecture: Learning and Language**

Objective: Today, we will discuss the role of learning in language acquistion. Some of the most surprising insights from cognitive science have been analyses showing how much of language actually could be learned (in contrast to the classic poverty of the stimulus idea). We'll evaluate both sides of this issue in some depth.

Lab: Complex Systems and Emergence

Reading: Chapter 7 (pg. 276-306) from Edelman "Language"

Mar 31, 2010 **Lecture: The neurocomputational basis of language**

Objective: Today we'll cover a multidue of issue in language use, production, communication, and what is known about the neurobiological basis of language.

Lab: ?

Apr 5, 2010 **Lecture: The neurocomputational basis of language (part II)**

Objective: Today we'll cover a multidue of issue in language use, production, communication, and what is known about the

neurobiological basis of language.

Lab: ?

Apr 7, 2010 **Lecture: What kind of models do we want?**

Objective: An important debate in cognitive science is about the appropriate form for our theories to take. We discussed many week ago the idea of "levels of analysis" as advocated by Marr. Today researchers work at all three levels of analysis. However, there are criticism about how each group uses data to support and refine their theories. We'll take an in-depth look at this idea (how exactly does data constrain our ideas of cognitive function)?

Lab: ?

Apr 12, 2010 **Lecture: Clean up date**

Objective: We'll leave this open in case there are topics we want to explore that we didn't get to.

Lab: ?

Apr 14, 2010 **Work on Final Projects**

Apr 19, 2010 **Work on Final Projects**

Apr 21, 2010 **Work on Final Projects**

Apr 26, 2010 **Work on Final Projects**

Apr 28, 2010 **Work on Final Projects**

Reading: Chapter 11 from Edelman "Thinking"

May 3, 2010 **Final Presentations**