Introduction to Neural Computation

BIO 347 3 Credits, SBC: STEM+	NEU 547 3 Credits

	Professor	Professor	TA
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COURSE DESCRIPTION

A broad introduction to neural computation. This course will discuss what counts as "computation" and in what sense the brain computes, how it computes, and whether those computations look anything like those performed by digital computers. These ideas and concepts will be introduced through examples of computation in the brain, including the neural bases of sensory perception, decision making, learning and memory, and motor control. Students will learn through in-class demonstrations and activities, as well as homework assignments that give students the opportunity to analyze real neural recordings relevant to each of the topic modules.

Course Pre/co-requisites

MAT 126, MAT 132, or higher; BIO 211, AMS 110, or AMS 310; any one of BIO 202, BIO 203, CHE 132, CHE 331, PHY 127 or PHY 132. It is recommended that students take MAT 127.

Synchronous lectures will take place via Zoom, TuTh 3:00-4:20 pm ET

TECHNOLOGY REQUIREMENTS

Students will need a device capable of attending these meetings with voice capabilities; use of webcam will be ideal but not mandatory. Lectures will be recorded and posted to Blackboard for students to review after lectures. Note that the recordings will not include the breakout sessions.

In-class activities may make use of online web-applications such as Google forms and docs. In-class polls may require a modern web browser.

MATLAB: Homework will require access to MATLAB, available from Stony Brook's IT Division of Information Technology. If you do not have a computer that can support MATLAB, you can use the virtual SINC site or MATLAB online. MATLAB is also available in several computer labs on campus; students interested in using these facilities should contact these labs to verify whether they will be open this fall. Students who do not have a personal computer or laptop should contact the student support team to request a laptop loan. Students requiring IT support should contact the IT service portal. When setting up MATLAB, students should also install the Statistics and Machine Learning Toolbox and Signal Processing Toolbox, both available from MathWorks.

Blackboard (http://blackboard.stonybrook.edu) will be used as the primary means of distribution for readings from the primary literature and/or lecture notes and/or submission of assignments. It is your responsibility to regularly consult the Blackboard listing for this course.

Please let the instructors know if you are having issues using these technologies.

COURSE LEARNING OBJECTIVES

Students will be able to

- analyze neural activity data using statistics and mathematical modeling.
- articulate their conclusions about how the results explain how neural circuits perform computations and produce behavior.
- explain the function of several brain areas, and which computations those areas are hypothesized to perform.
- describe and analyze mathematical models of these systems.

This course will satisfy the STEM+ learning objectives. Students will hone skills learned in their Versatility courses and practice them in greater depth, with further study applied to quantitative approaches to understanding functions of the nervous system.

COURSE REQUIREMENTS

Attendance and Make Up Policy

- Lectures will take place online in a synchronous manner to facilitate active student learning. Asynchronous attendance is not permitted except in exceptional circumstances or prior permission.
- All work should be submitted by the deadlines given on each assignment; students anticipating that they will be unable to complete work by these deadlines due to extenuating circumstances should contact instructors ahead of the deadline to make arrangements. Late work may not otherwise be accepted.
- Midterm exams will be conducted in a hybrid synchronous+take-home format in which the exam will begin during the scheduled lecture but students will have up to 24 hours to complete the exam.
- In the case of 1) verifiable illness, 2) verifiable family emergency, 3) University-sanctioned religious holiday, or 4) participation in official University-sponsored events (for documented student athletes only), the excuse must be documented on official letterhead (as appropriate) and students should contact the Student Support Team in the Dean of Students Office. The professional staff in this office will determine the validity of the excuse and contact the faculty to confirm that the absence should be excused.

Textbook

There is no official textbook for this course. Lecture notes will be made available to the students. As background or reserve materials on Neuroscience, the students can consult the following books:

- P. Dayan and L. Abbott, Theoretical Neuroscience, MIT Press. ISBN-13: 978-0262541855 (for Computational Neuroscience)
- J. Nicholls et al, From Neuron to Brain, 5th Ed, Sinauer. ISBN-13: 978-0878936090 (for General Neuroscience)
- G. Lindsay, Models of the Mind: How Physics, Engineering and Mathematics Have Shaped Our Understanding of the Brain. ISBN-13: 978-1472966421 (popular science overview of computational neuroscience)

Assignments

- Students will be required to complete several homework assignments and in-class activities. Homework assignments primarily involve using MATLAB to analyze real neural data; code and online tutorials will often be provided to assist students without strong programming backgrounds.
- In-class activities will involve mathematical calculations or other exercises related to models discussed in class; if the activities are not finished in class they may be completed outside of class and turned in by the beginning of the next lecture.
- Three in-class (synchronous) quizzes will be given to test students' conceptual understanding of the material. Asynchronous make-up quizzes will not be given except in exceptional circumstances.
- Lectures will be recorded and posted on Blackboard.
- Students taking NEU 547 will also complete a MATLAB project based on published research and write a report on their results.

Exams

- There will be two midterm exams.
- Exams will be conducted in a hybrid synchronous+take-home format in which the exam will begin during the scheduled class time, during which instructors will be available to answer clarification questions, but students will have up to 24 hours to complete the exam outside of the scheduled time.
- The exam will be open-book.
- There is no final exam.

GRADING

BIO 347: 30% in-class worksheets, 25% homework assignments, 25% exams, 20% conceptual quizzes.

NEU 547: 25% in-class worksheets, 20% homework assignments, 20% exams, 15% conceptual quizzes, 20% final paper.

Percentages will be assigned to grades as follows: A: 91-100, A-: 87-90, B+: 83-86, B: 80-82, B-: 77-79, C+: 73-76, C: 70-72, C-: 61-69, F: Below 60.

MEETING SCHEDULE (subject to change)

L	Date	Topic	Learning objective	Activity or quiz	Assignments
1	8/24/2021 (B, P)	What is Computation?	Define what it means to compute and how machines perform computation	Ice breaker; Designing a finite state machine.	HW0: Install Matlab and run test scripts (not graded)
2	8/26/2021 (P)	What is Neural Computation?	Apply the 3-level analysis to recognize neural computations at multiple levels and scales. Understand McCulloch-Pitts model.	Draw McCulloch-Pitts model for eXclusive OR (XOR) computation.	
3	8/31/2021 (B)	Neural simulations in MATLAB	Get used to the MATLAB environment		HW1: Simulate leaky integrate-and-fire neurons in MATLAB
4	9/2/2021 (P)	MATLAB, the language	Grasp the MATLAB language basics	Write MATLAB simple scripts and plot graphs	
5	9/7/2021 (B)	Sensory perception	Understand basic relationships between neural activity and sensory perception	Analyze & discuss some optical & auditory illusions	**HW1 due**
6	9/9/2021 (B)	Receptive fields	Understand what a receptive field is and how it allows a neuron to respond to particular stimulus features	Based on a neuron's receptive field, predict what stimulus features it might respond to	HW2: Compute spike-triggered averages to estimate receptive fields
7	9/14/2021 (P)	Visual motion representation and its computation	Tuning properties of MT neurons in response to visual motion	Compare MT tuning measured curves and Reichardt detector's tuning curves.	
8	9/16/2021 (B)	Sparse coding in vision (part 1)	State the assumptions and principles underlying the sparse coding hypothesis	Optimizing cost functions.	**HW2 due**
9	9/21/2021 (B)	Sparse coding in vision (part 2)	State the assumptions and principles underlying the sparse coding hypothesis	**Quiz 1: vision concepts**	HW3: "Train" a model of visual cortex
10	9/23/2021 (P)	Variability in neural codes (part 1)	Understand how noise can impact experimental measurements and neural dynamics	Estimating signals from "noisy" data. Compute mean firing rate.	
11	9/28/2021 (P)	Variability in neural codes (part 2): tuning curve and the Poisson neuron model	Get a feel for the basic properties of the Poisson model of neural activity	Explore the statistics of Poisson distribution as a neuron model	**HW3 due**
12	9/30/2021 (P)	Variability in neural codes (part 3): LNP and temporal code		Interaural time difference perception and the Jeffress model.	HW4: Simulate Poisson neurons with tuning curves
13	10/5/2021 (P)	Decision-making #1: neurophysiology	Analyze neural correlates of decision formation from event-aligned spike trains	Develop an ad-hoc evidence accumulation model	
14	10/7/2021 (P)	Decision-making #2: accumulator model	Use drift-diffusion model for perceptual decision-making	In-class audio-visual psychophysics.	**HW4 due**

	10/12/2021	Fall Break			
15	10/14/2021 (P)	Decision-making #3: optimality	Derive the ideal observer model given various sources of "noise"	**Quiz 2: neural variability, code & decision-making concepts**	
	10/19/2021	**Midterm #1**			
16	10/21/2021 (B)	Learning and memory	Differentiate various forms of memory and recognize them in tasks	Memory games	
17	10/26/2021 (B)	Working memory (part 1)	Identify stable and unstable fixed points in recurrent dynamics	Use multiple stable fixed points to encode information	HW5: Analyze data recorded from prefrontal cortex
18	10/28/2021 (B)	Working memory (part 2)	Articulate the difference between discrete attractors and continuous attractors	Derive the "bump attractor" state of a neural activity model	
19	11/2/2021 (B)	Long-term memory & synaptic plasticity	Understand current evidence for synaptic models of memory storage	TBD	
20	11/4/2021 (B)	Associative memory: Hopfield network model #1	Understand how the Hopfield network stores "memories"	Associative memory matrices	**HW5 due**
21	11/9/2021 (B)	Associative memory: Hopfield network model #2	Storing multiple patterns with Hopfield networks	Hopfield network capacity	HW6: Hopfield network
22	11/11/2021 (B)	Learning in Artificial Neural Networks	Explain the differences between how artificial neural networks "learn" compared to biological networks	Discuss biological vs. artificial intelligence	
23	11/16/2021 (P)	Brain-machine interfaces	Articulate the challenges involved in implementing brain-machine communication	**Quiz 3: associative memory concepts+motor learning**	
24	11/18/2021 (P)	Motor planning	Understand basic aspects of how neural activity encodes motor plans	Debate prep & Midterm prep	**HW6 due** **HW7 (debate prep) assigned**
	11/23/2021	**Midterm #2**			
	11/25/2021	Thanksgiving			
25	11/30/2021 (P)	Neuromorphic computing	Recognize application potentials of neuromorphic systems	Discussion of ethics of artificial intelligence and neuromorphic machines	**HW7 part 1 due**
26	12/2/2021 (B,P)	Theories of consciousness	Critically evaluate formulations of consciousness and their neural correlates	Debate whether machines can be "conscious"!	**HW7 part 2 due**

CLASS PROTOCOL

Please try to be punctual and arrive in class within 5 minutes of the beginning of class. Students who will be later than 15 minutes may be asked not to enter class. In the case of conflict with other classes please contact the instructor.

EMAIL AND COMMUNICATIONS POLICY

Email and especially email sent via Blackboard (http://blackboard.stonybrook.edu) is one of the ways we will officially communicate with you for this course. It is your responsibility to make sure that you read your email in your official University email account. For most students that is Google Apps for Education (http://www.stonybrook.edu/mycloud) but you may verify your official Electronic Post Office (EPO) address at: http://it.stonybrook.edu/help/kb/checking-or-changing-your-mail-forwarding-address-in-the-epo If you choose to forward your official University email to another off campus account, we are not responsible for any undeliverable messages to your alternative personal accounts. You can set up email forwarding using these DoIT-provided instructions found at: http://it.stonybrook.edu/help/kb/setting-up-mail-forwarding-in-google-mail If you need technical assistance, please contact Client Support at (631) 632-9800 or supportteam@stonybrook.edu

STUDENT ACCESSIBILITY SUPPORT CENTER (SASC) STATEMENT

If you have a physical, psychological, medical or learning disability that may impact your course work, please contact the Student Accessibility Support Center, ECC (Educational Communications Center) Building, Room 128, (631) 632-6748. They will determine with you what accommodations, if any, are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information go to the following website: https://ehs.stonybrook.edu//programs/fire-safety/emergency-evacuation/evacuation-guide-disabilities.

ACADEMIC INTEGRITY STATEMENT:

Each student must pursue his or her academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty are required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Technology & Management, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the academic judiciary website at http://www.stonybrook.edu/commcms/academic_integrity/index.html

CRITICAL INCIDENT MANAGEMENT:

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of University Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Until/unless the latest COVID guidance is explicitly amended by SBU, during Fall 2021 "disruptive behavior" will include refusal to wear a mask during classes. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

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