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, allowing deeper, more intuitive appreciation for how these systems work.

Prerequisites: Students who have a sincere interest and 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 on intuitive and practical applications (i.e., applying models to psychological and neuroscience data), but students are expected to engage with the core mathematical equations that we will cover in the readings and lectures. For most of the simulation assignments, students will make use of a graphical user interface but some basic programming skills will be useful for completing the midterm and final projects. (As of 2020, the course will exclusively use the Go / Python version of the software. You are not expected to know these specific languages but some familiarity with programming concepts will be helpful).

Other Texts for supplemental reading (more detailed mathematical treatments of single and multi-neuron
dynamics, but far less about cognitive phenomena):


**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 center-
piece 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 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. You should be able to do much 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 wiki textbook comes with a large number of “pre-built” neural network
models that illustrate key principles and phenomena, using the Go/Python code mentioned above. Every
week, you will explore these pre-built models, and you will document these explorations by answering
questions from the wikibook. You will be responsible for all questions listed in each project, unless I tell
you to skip specific questions. You should write up all of the assigned simulation exercises for each chapter
and turn them in on Canvas 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.

Please attempt to provide complete, concise answers. When a question asks why something happens,
make sure you provide an account of the mechanisms involved, not a description of the phenomenon in
different words. For example, given the question “Why does X make a neuron fire less frequently?”, an
answer such as “Because the timing between spikes increases” is just a redescription of the question and is
not an account of the mechanism by which X impacts spike frequency. To receive full credit on a problem, it
should be obvious that you understand the answer from your writing. But this does not mean that you should
write an overly long answer: lack of completeness and clarity will result in partial credit, as will answers
which mention too many concepts without specifying which subset of them are relevant to the question.

**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 post 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 posted on canvas under “Discussions” prior to the class meeting when they are due.

**Other Discussion/Questions**

We will be using Piazza for any discussion and questions other than reading reactions. This can include questions about homework, emergent, course content, or course logistics. The system is highly catered to getting you help fast and efficiently from classmates, the TA, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza. Find our class page here https://piazza.com/brown/fall2021/clps1492/home (feel free to ignore any requests you might get for optional financial contributions).

**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.

<table>
<thead>
<tr>
<th>Deadline</th>
<th>Assignment</th>
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<tbody>
<tr>
<td>Oct 22</td>
<td>Midterm mini-project</td>
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<tr>
<td>Oct 28</td>
<td>Project topic</td>
</tr>
<tr>
<td>Nov 4</td>
<td>Project proposal (1 page summary and approach to explore thru simulations)</td>
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<tr>
<td>Nov 8 - 12</td>
<td>Meeting w/ TA and instructor about project</td>
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<tr>
<td>Dec 7-9</td>
<td>Presentation of project to class</td>
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<tr>
<td>Dec 14</td>
<td>Final paper</td>
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</tbody>
</table>

A final paper describing your project is due Dec 14. This paper should be 12-15 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. Another way to participate is via reading reactions (and interactive discussion by reacting to others’ reactions) on Canvas and Piazza.

**Class Recording and Distribution of Course Materials** For those who cannot attend lecture in person I have made the lectures from Fall 2020 available on Media Library on Canvas. If you have questions or concerns about this protocol, please contact me so that we can talk through those to also ensure your full participation in this course.

Lectures and other course materials are copyrighted. Students are prohibited from reproducing, making copies, publicly displaying, selling, or otherwise distributing the recordings or transcripts of the materials. The only exception is that students with disabilities may have the right to record for their private use if that method is determined to be a reasonable accommodation by Student Accessibility Services. Disregard of the University’s copyright policy and federal copyright law is a Student Code of Conduct violation.

**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

The below table summarizes when we will cover each topic and also contains due dates for assignments. You can access the due dates for all course assignments on Canvas.

<table>
<thead>
<tr>
<th>Wk</th>
<th>Date</th>
<th>Tuesday: Lecture</th>
<th>Ch</th>
<th>Due</th>
<th>Date</th>
<th>Thursday</th>
<th>Ch</th>
<th>Due</th>
<th>Due Fri</th>
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<tbody>
<tr>
<td>1</td>
<td>7 Sep 21</td>
<td></td>
<td></td>
<td></td>
<td>9 Sep 21</td>
<td>Introduction</td>
<td>1</td>
<td></td>
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<tr>
<td>2</td>
<td>14 Sep 21</td>
<td>Neurons</td>
<td>2</td>
<td>RR1</td>
<td>16 Sep 21</td>
<td>Neurons</td>
<td>2</td>
<td>RR2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>21 Sep 21</td>
<td>Networks</td>
<td>3</td>
<td>HW2</td>
<td>23 Sep 21</td>
<td>Networks</td>
<td>3</td>
<td>RR3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>28 Sep 21</td>
<td>Networks</td>
<td>3</td>
<td></td>
<td>30 Sep 21</td>
<td>Plasticity/Learning</td>
<td>4</td>
<td>HW3</td>
<td></td>
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<tr>
<td>5</td>
<td>5 Oct 21</td>
<td>Model/statistical learning</td>
<td>4</td>
<td>RR4</td>
<td>7 Oct 21</td>
<td>Task (error-driven)Learn</td>
<td>4</td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td>12 Oct 21</td>
<td>Task/multilayer Learning</td>
<td>4</td>
<td></td>
<td>14 Oct 21</td>
<td>combo and Temporal context learning</td>
<td>4</td>
<td>HW4</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>19 Oct 21</td>
<td>Temporal reinforcement learning</td>
<td>7</td>
<td>RR6</td>
<td>21 Oct 21</td>
<td>Large Scale Org</td>
<td>5</td>
<td>MidProj</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2 Nov 21</td>
<td>Perception: attention</td>
<td>6</td>
<td></td>
<td>4 Nov 21</td>
<td>Motor/BG/RL</td>
<td>7</td>
<td>RR7, Prop</td>
<td></td>
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<tr>
<td>10</td>
<td>9 Nov 21</td>
<td>Memory: interference</td>
<td>8</td>
<td></td>
<td>11 Nov 21</td>
<td>Memory: Hippocampus</td>
<td>RR8</td>
<td>HW7</td>
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<td></td>
<td></td>
<td>Meet</td>
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<tr>
<td>11</td>
<td>16 Nov 21</td>
<td>Theta, memory retrieval, sleep</td>
<td>11</td>
<td></td>
<td>18 Nov 21</td>
<td>Working Memory (BG/PFC)</td>
<td>10</td>
<td>RR10</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>23 Nov 21</td>
<td>Working Memory (BG/PFC)</td>
<td>10</td>
<td>HW8</td>
<td>25 Nov 21</td>
<td>no class</td>
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<tr>
<td>13</td>
<td>30 Nov 21</td>
<td>Executive Function</td>
<td>10</td>
<td></td>
<td>2 Dec 21</td>
<td>Language</td>
<td>9</td>
<td>HW10</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>7 Dec 21</td>
<td>Student Presentations</td>
<td>10</td>
<td></td>
<td>9 Dec 21</td>
<td>Student Presentations</td>
<td>HW9</td>
<td></td>
<td></td>
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<tr>
<td>15</td>
<td>14 Dec 20</td>
<td>Paper</td>
<td></td>
<td></td>
<td>16 Dec 21</td>
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</tbody>
</table>

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.

Diversity Statement

In this class, we strive to create a learning environment that supports a diversity of thought, perspectives, and experiences, and honors your identities (including race, gender, class, sexuality, religion, ability, etc.). This means acknowledging biases and the diversity of all of us. To help accomplish these goals, please come speak with us (either directly or by submitting anonymous feedback):

- If anything in the readings or anything said in class (by anyone) makes you feel uncomfortable
- If you feel that your performance in class is being impacted by your experiences outside of class
- If you have any suggestions for improving the course materials to better include diverse perspectives

We appreciate you letting us know your preferred name and pronouns. We look forward to getting to know everyone in the class.

The CLPS Department statement on Diversity and Inclusion can be found here: www.brown.edu/academics/cognitive-linguistic-psychological-sciences/diversity
Please also be aware of these resources: Dean Bhattacharyya, Associate Dean of the College for Diversity Programs Contact: (401) 863-3488, Maitrayee.Bhattacharyya@brown.edu

Students in need of short-term academic advice or support can contact one of the deans in the Dean of the College office.

To empower students whose first language is not English, an array of ELL support is available on campus including language and culture workshops and individual appointments. Contact: ellwriting@brown.edu or (401) 863-5672

Support for Writing at Brown: www.brown.edu/academics/college/support/writing-center/

If you might require accommodations or modification of any course procedures, contact Student and Employee Accessibility Services at 401-863-9588 or SEAS@brown.edu

Students with concerns about any non-tuition cost(s) of a course may apply to the Dean of the College Academic Emergency Fund to determine options for financing these costs, while ensuring their privacy. The fund can be found in the Emergency Funds, Curricular & Co-curricular Gap (E-Gap) Funds in U Funds. Information and procedures are available at http://brown.edu/go/egap