Introduction to Computational Modelling for Neuroscience and Psychology

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Contents

1 Instructor Information

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2 Course Description

This course is intended for students, undergraduate and graduate, who wish to learn more about computational methods and their application to neuroscience and psychological topics.

Student Type A: knows psychology, but little to no math and would like to learn how to combine the two.

Student Type B: knows maths (or engineering, computer science, etc), but little psychology and would like to learn how the two can be combined.

For the psychologist, whose last math course may have been grade 11, don't despair. This course is meant for you. If you have the skills to be an honors psych student than you have all the brain power needed to master this material. As long as you are willing to work hard you will succeed, and you will get a grade that you are happy with.

However, saying that you will earn a good grade is not the same as saying the course is easy. The course may require you to push yourself into areas where you are not confident or comfortable, and it may take a lot of time. The trade off is that I will not be an unmerciful grader. I take into account your effort and your skill level when I grade. I want to make the classroom a "safe place" for intellectual exploration.

For students from a computational background, I ask the same effort and make the same offer: make an effort to stretch and expand your skill set, e.g. use a new programming language that you have never used before, and I won't penalize you if it crashes.

2.1 Learning Goals

- Become better consumers of cognitive neuroscience research.

  By exploring how computational techniques are used in cognitive neuroscience research you will become a more knowledgeable and critical reader of research papers. No more should the words: model, computation, or equation, lead you to skip from introduction to discussion.

- Develop a computational vocabulary.

  I want you to know what some of those squiggly symbols mean and what a programmer actually does. This will help with the first goal of

being a critical consumer of computational research, and it will also help you to be an effective collaborator in computational research. Even if you don't go on to do any programming on your own, you should have a better understanding of what a programmer does, how she does it, and to propose suggestions that are sensible.

Also part of this goal is for you to become somewhat familiar with some of the tools of the trade. What is version control? What is an IDE? How do you download/install a piece of software. These techniques can be valuable for a person who *never* does any computational modelling, but only uses statistical tools in writing their own papers.

- Dispel the notion that computational approaches require some special cognitive ability.

  You will learn some elements of programming in this course. Programming does **not** require months spent learning some arcane language. Anyone who has ever summed a column of numbers in a spreadsheet has the skills to program a computer, because telling Excel to sum a column of numbers *is programming*. For this reason, while the course allows for using spreadsheets in the very early exercises it is expected the student will progress to using either R, Python (e.g students already competent in those two languages it is suggested that they try a new language. I recommend Haskell). It is strongly suggested that students new to programming in either of these languages use the Jupyter Notebook as the space for developing and testing their code. Class time will be devoted to getting this set up and to exploring tooling for computational research and collaboration.

2.2 Learning Content

Table 1: The list of mathematical topics and their companion psychological or neuroscience application.

Installing Software/Version Control/IDEs	tools for computational work
Build your own neuron	differential equations
Neural networks	linear algebra and neural networks
Reaction Time Modeling	probability
Production Systems	logic
Social Interactions	agents

The basic format is that I pick a topic from the table based on the mix of students, and we work through it. First, we establish some context and goals. Often there will be a little primer on the maths involved. Then I will guide you through a series of exercises. In a change from past offerings I am going to work much more to classtime as a workshop time. I will assign homework that should help you prepare, and then we can use the class time to explore and collaborate, and build on the tools you are learning to use.

3 Textbook

Early versions of this class became a textbook. Much of what I teach is almost verbatim from this book. If you like having text available, buy the book, but you should be able to get all the material you need from class.

There are other sources that supplement the goals of this course. I will try to keep a list of links up to date on our github page. You can add to that directly (we will discuss how). Or you can send links to me and I will update. Two excellent books, which cover a lot of the same material in more depth as well as additional topics, are *Theoretical Neuroscience* by Dayan and Abbott (this one is fairly deep) and *Fundamentals of Computational Neuroscience* by Trappenberg (a bit more basic, but reliant on MATLAB). An additional one I like, and that is available on line is: Spiking Neuron Models.

4 Course Requirements, Expectations, and Grading

4.1 Requirements

There really are no mathematical pre-requisites beyond an interest in the material and a willingness to work. Any prior calculus, linear algebra, or programming experience will be convenient, but it is not necessary. The course is intended to be self-contained. If you want to get anything out of this course you will probably have to work pretty hard, but the pressure to do so, will have to be self-applied. Just because the course is classed as a "seminar" does not mean it is a talking course. You will have to do things to learn anything.

From the psychology standpoint, the material of PSYCH 261, Physiological Psychology is the basic building block.

4.2 Expectations

- I expect you to attend every class or send me advance notice indicating why you cannot.
- You will need a computer you can bring to class to hack away on. It will not need to be powerful, but it does need to be functional.
- There will be periodic assignments during the course. Each week I will try and provide you with something concrete to work on before you come to class, and when we are in class.
- Complete all assignments. This means do something, and turn it in. I am less concerned with "right" answers than effort and progress. You know and I know that you can get a pretty good sense of how hard someone worked on something by how they talk about it, and how they list what they tried and worked (or didn't). My promise is that if you demonstrate effort then you will pass and I won't torpedo your GPA. Admittedly then, my grading scheme is subjective. Because there are a relatively small number of students I will learn each of your names and I will become a pretty good judge of your capabilities. I will judge whether you are making an effort and I will adjust my evaluation for what I understand to be your level of computational expertise. A computer science major and a psychology major might not get the same grade for the same assignment.

4.3 Grading

There are three graded components:

- Classroom assignments and homework 50% aggregated
- Classroom Participation 20%
- Final Presentation or Project 30%

The class room assignments and homework are assignments that you do alone, or in collaboration (just make sure that I know in advance who is collaborating with whom and that if I question you later you are able to demonstrate an understanding of the work submitted). They are announced in class, distributed on *Learn* and returned in electronic drop boxes on *Learn*.

To meet the major goal of making you informed consumers of computational approaches the course builds towards a final project. This can differ

depending on your interests and background, but it has to be approved by me. I hope to be able to use the last few classroom sessions for sharing this work with each other by having you present it. I am open to students collaboration, especially where it combines expertise. For example, a psychologist collaborating with a neuroscientist might provide a synergy that neither working alone could do.

Graduate students have to meet all the obligations of the undergraduates and in addition will have to deliver a more extensive presentation (both in duration and in content).

No midterms or finals are projected at this time.

5 The Official Version of the Course Outline

The outline posted on *Learn* will be deemed the official version. Outlines on *Learn* may change as instructors develop a course, but they become final as of the first class meeting for the term.

6 Students with Disabilities

The AccessAbility Services (AS) Office, located in Needles Hall, Room 1132, collaborates with all academic departments to arrange appropriate accommodations for students with disabilities without compromising the academic integrity of the curriculum. If you require academic accommodations to lessen the impact of your disability, please register with the AS Office at the beginning of each academic term.

7 Concerns About the Course or Instructor

7.1 Informal Stage

We in the Psychology Department take great pride in the high quality of our program and our instructors. Though infrequent, we know that students occasionally find themselves in situations of conflict with their instructors over course policies or grade assessments. If such a conflict arises, the Associate Chair for Undergraduate Affairs is available for consultation and to mediate a resolution between the student and instructor.

7.2 Formal Stage

A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. See Policy 70 and 71 below for further details.

8 Academic Integrity, Academic Offenses, Grievance, and Appeals

Academic Integrity: in order to maintain a culture of academic integrity, members of the University of Waterloo community are expected to promote honesty, trust, fairness, respect and responsibility.

Discipline: A student is expected to know what constitutes academic integrity, to avoid committing academic offenses, and to take responsibility for his/her actions. A student who is unsure whether an action constitutes an offense, or who needs help in learning how to avoid offenses (e.g., plagiarism, cheating) or about 'rules' for group work/collaboration should seek guidance from the course professor, academic advisor, or the Undergraduate Associate Dean. When misconduct has been found to have occurred, disciplinary penalties will be imposed under Policy 71 - Student Discipline. For information on categories of offenses and types of penalties, students should refer to Policy 71 - Student Discipline, `https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71`

Grievance: A student who believes that a decision affecting some aspect of his/her university life has been unfair or unreasonable may have grounds for initiating a grievance. Read Policy 70 - Student Petitions and Grievances, Section 4, `http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm`. In addition, consult: `http://www.adm.uwaterloo.ca/infosec/Policies/policy70.htm` for the Faculty of Arts greivance processes.

Appeals: A student may appeal the finding and/or penalty in a decision made under Policy 70 - Student Petitions and Grievances (other than regarding a petition) or Policy 71 - Student Discipline if a ground for an appeal can be established. Read Policy 72 - Student Appeals, `http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm`

Academic Integrity website (Arts): :: `http://www.adm.uwaterloo.ca/infosec/Policies/policy72.htm`

Academic Integrity Office (UW): :: `http://arts.uwaterloo.ca/arts/ugrad/academic_responsibility.html`