

PSYD52: Neural Network Models of Cognition Laboratory

University of Toronto Scarborough
Fall Term, 2020

Introduction

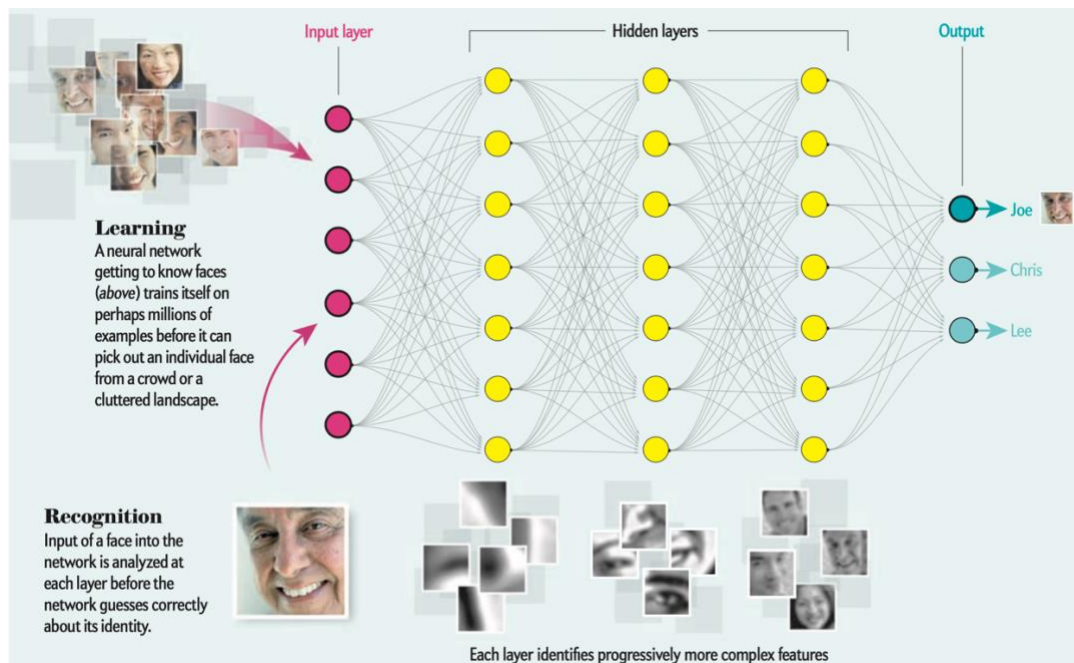
Instructor: Prof. George S. Cree
email: george.cree@utoronto.ca

About Your Instructor

Dr. George Cree is an Associate Professor in the Department of Psychology at UTSC. He joined the department in 2003, and was Chair of the department from 2012-2018. He studies semantic memory with expertise in neural network models of word meaning computation. More generally, he is interested in knowledge representation, neural network modeling of cognition, cognitive science, and artificial intelligence.

Learning Goals & Course Content

In this course you will learn how to build a neural network that can learn to perform tasks like this (taken from Bengio, 2016, Scientific American):



There are two main goals for this course, one content based, and the other focused on developing practical, hands-on skills: (1) learning about how neural network models have been used in psychology to help us understand cognition, and (2) learning how to implement a neural network model from scratch.

Neural network models have played an important role in psychology in helping us develop a better understanding of how the brain, which is a complex biological neural network, can give rise to the mind. We will survey how neural network models have been used in psychology, and what we've learned from them. This is a very big topic, beyond the scope of a single course, so we will focus on the work of one particular group of researchers that can be directly linked to the pioneering work of the PDP Research Group, who in 1986 published what is sometimes referred to as the "bible of connectionist modeling", the two part PDP Volumes (Rumelhart, McClelland & PDP Research Group 1986). We will closely examine models of vision, memory, language, and cognitive control, and how the modeling work has contributed to cognitive theory. After successful completion of this course you will be able to describe and discuss the main theoretical contributions of major models in each of these areas of cognition.

You can't truly understand how a neural network model works until you've built one yourself, and spent some time digging into *how* it works. The laboratory component of this course will focus on learning *how* to build a neural network model. Specifically, you will learn how to implement a multi-layer perceptron, trained with backpropagation, from scratch, in Python. You will then use the model to explore a phenomenon in cognition of your choosing, and produce a report in which you describe the model and the results of your simulation. After successful completion of this course you will know how to build your own neural network model, and will be well prepared for further study of concepts in contemporary neural network modeling (aka deep learning) using well known computing frameworks such as TensorFlow or PyTorch.

Pre-requisite Knowledge

Ideal preparation for this course includes: (1) introductory experience with Python, such as an intro level programming course, or having worked through an internet tutorial, (2) high school math that has introduced basic concepts in linear algebra such as vectors, matrices, and dot/cross products, and high school calculus that has introduced the idea of derivatives, and (3) advanced study of at least one sub-area of cognition, such as a 3rd year course on vision, language, or memory. None of these are absolutely necessary, however, as long as you have a sincere desire to learn about the topic, and to put in some extra work if needed to get up to speed with any of these concepts with which you're not familiar. The programming will build from the ground up, explaining mathematical concepts as needed. Pointers to supplementary material will be provided throughout the course for those needing to refresh their memory/skills in specific areas. If you have any concerns about any of this then it is important that you discuss them with the instructor early in the course so that we can create an appropriate learning plan.

Textbook

The textbook for this course is:

Kinsley, H. & Kukiela, D. (2020, in prep). Neural Networks from Scratch in Python: Building neural networks in raw python.

The book has not yet appeared in print, but the authors have verified that the text is complete, and the first print edition should be appearing soon, hopefully in October.

You can pre-order the book [here](#). This will give you (relatively) immediate access to the online version of the book in Google Docs.

All other readings will be provided as PDF files, available for download on Quercus.

Plan for Each Week

The lessons each week will comprise a mixture of readings, notes, and online lectures. You will find a full and up-to-date listing of these materials for each week in the weekly modules available on Quercus. The material listed below is to provide an outline of the topics to be covered, and is subject to change based on how the course progresses. Always check Quercus for the most up-to-date information.

Week 01: September 8-12, 2020

- Reading: Rogers, T. T. (2009). Connectionist Models. In: Squire, L. R. [Ed.], *Encyclopedia of Neuroscience*, Volume 3, pp. 75-82. Oxford: Academic Press.
- Reading: Bengio, Y. (2016). Machines Who Learn. *Scientific American*, June 2016, pp. 46-51.
- Video: 3BLUE1BROWN: [But what is a neural network? Deep Learning, Chapter 1](#) (19mins)

Week 02: September 13-19, 2020

- Reading: Rogers, T. T. & McClelland, J. L. (2014). Parallel Distributed Processing at 25: Further explorations in the microstructure of cognition. *Cognitive Science*, 38, 1024-1077. Read to end of page 1046.
- Video: [NNFS Video 1: Units and Layers](#) (16 mins)
- Video: [NNFS Video 2: Coding a Layer](#) (15 mins)
- Reading: NNFS Book Chpt 1: Introducing Neural Networks
- Reading: NNFS Book Chpt 2: Coding our First Neurons

Week 03: September 20-26, 2020

- Reading: Rogers, T. T. & McClelland, J. L. (2014). Parallel Distributed Processing at 25: Further explorations in the microstructure of cognition. *Cognitive Science*, 38, 1024-1077. Read page 1047 to end.
- Video: [NNFS Video 3: The Dot Product](#) (33 mins)
- Video: [NNFS Video 4: Batches, Layers, and Objects](#) (34 mins)
- Video: [NNFS Video 5: Hidden Layer Activation Functions](#) (40 mins)
- Reading: NNFS Chpt 4: Activation Functions

Week 04: September 27 - October 3, 2020

- Reading: Seidenberg, M. S. & Plaut, D. C. (2014). Quasiregularity and its discontents: The legacy of the past tense debate. *Cognitive Science*, 38, 1190-1228.
- Reading: NNFS Chpt 5: Loss

- Reading: NNFS Chpt 6: Optimization
- Video: [3BLUE1BROWN Video 2: Gradient Descent, How Neural Networks I Learn.](#) (21 mins)

Week 05: October 4-10, 2020

- Reading: O'Reilly, R. C., Bhattacharyya, R., Howard, M. D., & Ketz, N. (2014). Complementary learning systems. *Cognitive Science*, *38*, 1229-1248.
- Reading: NNFS Chpt 7: Derivatives
- Reading: NNFS Chpt 8: Gradients, Partial Derivatives, and the Chain Rule
- Video: [3BLUE1BROWN Video 3: What is backpropagation really doing?](#) (14 mins)

— Reading Week (October 11-16) —

Week 06: October 18-24, 2020

- Reading: Botvinick, M. M. & Cohen, J. D. (2014). The computational and neural basis of cognitive control: Charted territory and new frontiers. *Cognitive Science*, *38*, 1249-1285.
- Reading: NNFS Chpt 9: Backpropagation
- Reading: NNFS Chpt 10: Optimizers
- Video: [3BLUE1BROWN Video 4: Backpropagation Calculus](#) (10 mins)

Week 07: October 25-31, 2020

- Reading: McClelland, J. L. & Rogers, T. T. (2003). The parallel distributed processing approach to semantic cognition. *Nature Reviews Neuroscience*, *4*, 310-322.

Week 08: November 1-7, 2020

- Hinton, G. E., Plaut, D. C., & Shallice, T. (1993). Simulating brain damage. *Scientific American*, *October 1993*, pp. 76-82.

Week 09: November 8-14, 2020

- Plaut, D. C., McClelland, J. L., Seidenberg, M. S., & Patternson, K. (1996). Understanding normal and impaired word reading: Computational principles in quasi-regular domains. *Psychological Review*, *103(1)*, 56-115.

Week 10: November 15-21, 2020

- Elman, J. L. (1990). Finding structure in time. *Cognitive Science*, *14*, 179-211.

Week 11: November 22-28, 2020

- Lindsay, G. (2020, in press). Convolutional neural networks as a model of the visual system: Past, present, and future. *Journal of Cognitive Neuroscience*, *X:Y*, 1-14.

Week 12: November 29 - December 5, 2020

- Reading: McClelland, J. L. (2009). The place of modeling in cognitive science. *Topics in Cognitive Science*, *1*, 11-38.

- Reading: McClelland, J. L., Hill, F., Rudolph, M., Baldrige, J. & Schutze, H. (2020). Extending machine language models toward human-level language understanding. arXiv:1912.05877v2 [cs.CL] 4 Jul 2020.

— *Final Exams (December 10-22)* —

Other Important Dates

- Labour Day: Sept 7
- Thanksgiving Day: October 12
- Last day to drop without academic penalty: November 23
- Last day to submit term assignments: December 7

Summary of Homework, Assignments, and Due Dates

Task	Weight	Due Date
Quercus Quiz 1	5%	Friday Sept 25, 1 pm
Mini Research Proposal	5%	Friday Oct 23, 1 pm
Research Proposal	30%	Friday Nov 6, 1 pm
Quercus Quiz 2	15%	Friday Nov 27, 1 pm
Final Research Project Report	45%	Dec 7 at 1 pm

Note: The schedule, due dates, and nature of assignments are subject to change due to extenuating circumstances beyond our control. I would normally say that this is extremely unlikely, but given what we've all been living through the last few months, it is now entirely possible. The University could, for example, mandate that changes are made. Any other changes will be subject to a class vote, where a simple majority of those enrolled in the course must vote in favour of the change.

Course Policies

Time Zone conflicts

If you are physically in a different time zone and a quiz or midterm is scheduled outside of 7:00am to midnight in your local time, you may use the following form to request special arrangements. Note that the form is only for term work. [Final exam conflicts](#) are handled by the Registrar's Office.

The form must be submitted **at least ten (10) business days before the activity**.

Form: <https://uoft.me/PSY-TimeZone>

Submit via email to: Keely Hicks, Departmental Assistant, keely.hicks@utoronto.ca

Missed Term Work due to Medical Illness or Other Emergency

All students citing a documented reason for missed term work must submit their request for accommodations **within three (3) business days** of the deadline for the missed work.

Submit via email to: Keely Hicks, Departmental Assistant, keely.hicks@utoronto.ca

Students must submit **BOTH** of the following:

- (1.) A completed **Request for Missed Term Work Accommodations form** (<http://uoft.me/PSY-MTW>), and
- (2.) **Appropriate documentation** to verify your illness or emergency, as described below.

Appropriate documentation:

For missed **ASSIGNMENTS** or **TERM TESTS** due to **FLU-LIKE SYMPTOMS or SELF-ISOLATION REQUIREMENTS**:

- Email the Request for Missed Term Work Accommodations form (uoft.me/PSY-MTW) to Keely (keely.hicks@utoronto.ca), and
- **Declare** your absence on **ACORN** (Profile & Settings > Absence Declaration)

For missed **ASSIGNMENTS** due to **OTHER ILLNESS**:

- Email the Request for Missed Term Work Accommodations form (uoft.me/PSY-MTW) to Keely (keely.hicks@utoronto.ca), along with the Self-Declaration of Student Illness Form (uoft.me/PSY-self-declare-form).

For missed **TERM TESTS** due to **OTHER ILLNESS**:

- Email the Request for Missed Term Work Accommodations form (uoft.me/PSY-MTW) to Keely (keely.hicks@utoronto.ca), along with a scan/photo of the **original** copy of the official UTSC Verification of Illness Form (uoft.me/UTSC-Verification-Of-Illness-Form) or an **original** copy of the record of visitation to a hospital ER.
- Forms are to be completed in full, clearly indicating the start date, anticipated end date, and severity of illness. The physician's registration # and business stamp are required.
- *Note: If an end date of "ongoing" is specified, the medical note will be assumed to cover a period of **two weeks**. If no end date / an "unknown" end date is specified, the note will be assumed to cover a period of **three business days** (starting from illness start date.)*

For missed **TERM TESTS** due to **ACCESSABILITY REASONS**:

- Meet with your **AccessAbility consultant** and have them email Keely (keely.hicks@utoronto.ca) detailing accommodations required.

For missed **ASSIGNMENTS** due to **ACCESSABILITY REASONS**:

- If your desired accommodation is **within the scope** of your Accommodation Letter (ex. your letter includes "extensions of up to 7 days" and you need 1-7 more days), email the Request for Missed Term Work Accommodations form (uoft.me/PSY-MTW) to Keely

(keely.hicks@utoronto.ca), and attach a **copy of your letter**. Specify how many days extension you are requesting in your email.

- If your desired accommodation is **outside the scope** of your Accommodation Letter (ex. your letter includes “extensions of up to 7 days” but you need more time than that) you will need to meet with your **AccessAbility consultant** and have them email Keely (keely.hicks@utoronto.ca) detailing the accommodations required.

For missed **ASSIGNMENTS** or **TERM TESTS** in **OTHER CIRCUMSTANCES**:

Email the Request for Missed Term Work Accommodations form (<http://uoft.me/PSY-MTW>) form to Keely (keely.hicks@utoronto.ca), along with:

- For the **death of a family member/friend**, provide a copy of the death certificate.
- For U of T varsity-level or professional **athletic commitments**, an email from your coach or varsity administrator should be sent directly to Keely (keely.hicks@utoronto.ca) **well in advance** of the missed work, detailing the dates and nature of the commitment.
- For **religious accommodations**, please email Keely (keely.hicks@utoronto.ca) **well in advance** of the missed work.
- For circumstances **outside of these guidelines**, please email Keely (keely.hicks@utoronto.ca) **on or before the date of the test / assignment deadline** to describe your circumstances and determine appropriate documentation.

Documents covering the following situations are NOT acceptable: medical prescriptions, personal travel, weddings, personal/work commitments.

As stated above, your documents must be submitted **within three (3) business days** of the deadline for the missed work.

After submitting your documentation:

Within approximately one to five business days, you will receive a response from your instructor detailing the accommodations to be made (if any).

You are responsible for checking your official U of T email and Quercus course announcements daily, as accommodations may be time-critical.

You should continue to work on your assignments to the best of your ability, as extension accommodations may be as short as one business day, depending on the nature of the illness/emergency.

If an accommodation has been granted but you are unable to meet the conditions of the accommodation (ex. you need a longer extension, or you missed a make-up test), you will need to repeat the missed term work procedure and submit additional forms to request further accommodation. Note that in the case of a missed make-up test, an opportunity to write a second make-up test may not be provided.

Completion of this form does NOT guarantee that accommodations will be made. The course instructor reserves the right to decide what accommodations (if any) will be made. Failure to adhere to any aspect of this policy may result in a denial of your request for accommodation.

Missed Accommodations

If an accommodation is granted but a continued illness/emergency prevents you from meeting the requirements of your accommodation, you must **repeat** the missed term work procedure to request additional accommodations.

(E.g.) If you miss a make-up midterm, you would need to submit **another** Request for Missed Term Work Accommodations form. If your original medical note / documentation included the date of the make-up midterm, then only the Request form is required. If the date of the make-up midterm fell outside of the dates indicated on your original medical note/other documentation, then a new medical note/other appropriate documentation must also be submitted.

Importance of Three Business Day window:

If you are unable to submit your documents within the three business day window, **you must email Keely** (keely.hicks@utoronto.ca) **within the three business day window** to explain the nature of the delay, and when you will be able to provide your documents. Exceptions to the documentation deadline will only be made under exceptional circumstances.

NOTE: Assignments due at end of term

Instructors cannot accept term work any later than five business days after the last day of class. Beyond this date, you would need to file a petition with the Registrar's Office (<https://www.utsc.utoronto.ca/registrar/term-work>).

NOTE: Final Exams

This policy applies only to missed assignments and term tests. Missed final exams are handled by the Registrar's Office (<http://www.utsc.utoronto.ca/registrar/missing-examination>).

Late Assignments Policy

A penalty of 5% will be deducted from the final grade for every 24 hour period, or part thereof, that an assignment is late. For example, if an assignment is submitted 36 hours after the deadline, and was graded as receiving 75%, 10% would be deducted from the grade, resulting in a grade of 65% for that assignment.

Accommodation for Personal Reasons

There may be times when you are unable to complete coursework, including completing readings, viewing lectures, or completing worksheets, due to non-medical reasons. If this occurs during the term you should contact the course instructor as soon as possible to discuss a strategy for completing or dropping the course. It is also a very good idea to speak to an academic advisor.

Religious Accommodations

The University has a commitment concerning accommodation for religious observances. We will make every reasonable effort to avoid scheduling tests, examinations, or other compulsory activities on religious holy days not captured by statutory holidays. According to University Policy, if you anticipate being absent from class or missing a major course activity due to a religious observance, please let me know as early in the course as possible, and with sufficient notice (at least two weeks), so that we can work together to make alternate arrangements.

Academic Integrity

The University treats cases of cheating and plagiarism very seriously.

The [University of Toronto's Code of Behaviour on Academic Matters](#) outlines the behaviours that constitute academic dishonesty and the processes for addressing academic offences. Potential offences in papers and assignments include using someone else's ideas or words without appropriate acknowledgement, submitting your own work in more than one course without the permission of the instructor, making up sources or facts, and obtaining or providing unauthorized assistance on any assignment. On tests and exams cheating includes using or possessing unauthorized aids, looking at someone else's answers during an exam or test, misrepresenting your identity, or falsifying or altering any documentation required by the University, including (but not limited to) doctor's notes.

Disability-Related Accommodation Request

Students with diverse learning styles and needs are welcome in this course. In particular, if you have a disability/health consideration that may require accommodations, please feel free to approach me and/or the [AccessAbility Services Office](#) as soon as possible. AccessAbility Services staff (located in Rm SW302, Science Wing) are available by appointment to assess specific needs, provide referrals and arrange appropriate accommodations. Please contact 416-287-7560 (tel/TTY) or email: ability@utsc.utoronto.ca for more information. The sooner you let us know your needs the quicker we can assist you in achieving your learning goals in this course.

Course Management System Information: Quercus

This course uses the University of Toronto's learning management system, Quercus, to post information about the course. This includes readings, recorded lectures, worksheets, assignment rubrics, access to tests and exams, and other materials required to complete class activities and course assignments, as well as sharing important announcements and updates. The site is dynamic and new information and resources will be posted regularly as we move through the term, so please make it a habit to log in to the site on a regular, even daily, basis. To access the course website, go to the U of T Quercus log-in page at q.utoronto.ca. Once you have logged in to Quercus using your UTORid and password, you should see the link or "card" for PSYD52. You may need to scroll through other cards to find this. Click on the PSYD52 link to open our course area, view the latest announcements, and access your course resources. There are Quercus help guides for students that you can access by clicking on the "?" icon in the left side column.

Special note about grades posted online: Please note that any grades posted on Quercus are for your information only, so you can view and track your progress through the course. No grades are considered official, including any posted in Quercus at any point in the term, until they have been formally approved and posted on ACORN at the end of the course. Please contact me as soon as possible if you think there is an error in any grade posted on Quercus.

Online Communication Policy

You are required to use your utoronto email address for all course-related communications with the instructor, and are expected to check this email address regularly throughout the course to ensure timely access to important information. I will only respond to emails received from a utoronto account, as this is the only way I can verify who I am talking with.

I reserve the right to remove Discussion Board posts that do not remain on topic. Harassment and bullying will not be tolerated, and will be dealt with swiftly.

Harassment/Discrimination Policy

The University of Toronto is a richly diverse community and as such is committed to providing an environment free of any form of harassment, misconduct, or discrimination. In this course, I seek to foster a civil, respectful, and open-minded climate in which we can all work together to develop a better understanding of key questions and debates through meaningful dialogue. As such, I expect all involved with this course to refrain from actions or behaviours that intimidate, humiliate, or demean persons or groups or that undermine their security or self-esteem based on traits related to race, religion, ancestry, place of origin, colour, ethnic origin, citizenship, creed, sex, sexual orientation, gender identity, gender expression, age, marital status, family status, disability, receipt of public assistance or record of offences.

Privacy/FIPPA Statement

Personal information is collected pursuant to section 2(14) of the University of Toronto Act, 1971 and at all times it will be protected in accordance with the Freedom of Information and Protection of Privacy Act. Please note that this course may require presentations of one's work to the group. For more information, please refer to www.utoronto.ca/privacy.

Copyright of Course Materials

Course materials are provided for the exclusive use of enrolled students. You do not have permission to share them or sell them to anyone outside of the course. The materials should not be posted on websites, uploaded to social media sites, printed and distributed or sold to others, nor sold to companies that intend to package them to sell or distribute to other people in print or via the internet. The University will support me in asserting and pursuing my rights, and my copyrights, in such matters.