

CGSC 4605 / 5605 **Hyperdimensional Cognitive Models**

Prerequisites (CGSC 4605): 4th year standing in CGSC Honours required.

Instructor: Mary Kelly, Ph.D. (she/her; mary.kelly4@carleton.ca)

- **Office:** 2213 Dunton Tower; <https://carleton-ca.zoom.us/my/animus.lab>
- **Office Hours:** By appointment (**in person or online**)

- I. **Course description:** An introduction to the fundamentals of hyperdimensional computing (HDC), also known as vector-symbolic architectures (VSAs), and their application to computational cognitive modelling and artificial intelligence.
By the end of the course, you will be able to:
 - Describe the linear algebra of vector-symbolic architectures
 - Implement vector-symbolic architectures in Python
 - Construct a cognitive model or simple agent using a vector-symbolic architecture
- II. **Brightspace:** All materials, including readings, slides, code, rubrics, and term model submission portal, will be here: <https://brightspace.carleton.ca/d2l/home/292904>
- III. **Textbook:** No textbook is required for the course. Readings will be provided online.
- IV. **Software:** All students taking are required to either own or have daily access to a computer which can use Brightspace, Zoom, Python, and a word processor.
- V. **Hybrid:** In the interest of accommodating disabled, sick, immunocompromised, or COVID-cautious students, all seminars may be attended either online or in person.
- VI. **Email:** I try to respond to e-mails within 48 hours (excluding weekends and holidays).
- VII. **Evaluation:** The coursework consists of math and programming exercises, a topic statement for the term model/paper, and the term model or term paper.

<i>Evaluation</i>	<i>Value</i>	<i>Due Date</i>
Exercises	60% (6 exercises, 10%/ea)	Sept. 19; Oct. 3, 10, 17; Nov. 7, 14
Topic Statement	10%	Oct. 31
Model/Paper	30%	Dec. 21

VIII. Exercises: Exercises are due by **11:59pm Wednesday** as per the schedule.

- Exercise 1 is to be completed **individually**.
- Exercises 2 to 6 are to be completed in **pairs**. A group of three or individual work is permitted only with permission from the instructor.
- Using generative AI / Large Language Models (LLMs) to generate *first draft code* solutions to programming problems is **permitted** but the use of an LLM must be noted in your submission. However, use of an LLM to *generate text* to answer exercise questions is **not permitted**. Trust in your own writing skills!
- Time will be given in class to work on exercises in pairs and ask for help if you need it, and as such, regular class attendance is strongly advised, as the exercises may be challenging.

IX. Term Model/Paper:

- **Option 1:** Provide code for a model you have created or modified and a write-up detailing the model. Please consult with the grading rubric found on the Model assignment submission portal. 50% of the grade will be the model and 50% of the grade will be the write-up.
- **Option 2:** For those who would prefer not to write code for this project: Write a standard research proposal where you outline a computational model you could create. This is expected to be a longer write-up than for Option 1. 100% of your grade will be the proposal. Consult the rubric for the Proposal assignment submission portal.
- This project can be completed either individually or in pairs. If completed as a pair, both students' names must be on the final submission and each student must have contributed to part of the project (coding and/or writing).
- As in the exercises, use of an LLM to generate code is permitted with attribution, but use of an LLM to generate the text of the paper is not permitted.

X. Course Schedule: *This schedule is to be regarded as tentative.*

Date	Topic	Readings
Sept. 5	Systematicity Critique	course syllabus; Fodor & Pylyshyn (1988)
Sept. 12	Linear Algebra <i>Exercise 1 assigned</i>	Garrity (2001) <i>All the Math You Missed But Need to Know for Graduate School</i> , ch. 1, Linear Algebra
Sept. 19	Hopfield Networks <i>Exercise 1 due</i>	Layerwise Lectures, https://youtu.be/piF6D6CQxUw Hopfield (1982) Neural networks and physical systems... Krotov (2023) A New Frontier for Hopfield Networks
Sept. 26	Holographic Vectors <i>Exercise 2 assigned</i>	Plate (1995) Holographic reduced representations Gayler (2003) Vector symbolic architectures Kelly, Blostein, & Mewhort (2013) Encoding structure
Oct. 3	Rule Induction <i>Ex.2 due; Ex.3 assn.</i>	Rasmussen & Eliasmith (2011) A Neural Model of Rule Generation in Inductive Reasoning

Oct. 10	Neural Engineering <i>Ex. 3 due; Ex. 4 assn.</i>	Eliasmith, Tang, & DeWolf (2013) <i>How to build a brain</i> , ch.3, Biological Cognition: Semantics
Oct. 17	Memory & Learning <i>Ex. 4 due; Ex. 5 assn.</i>	Franklin & Mewhort (2015) Memory as a hologram Jamieson & Hauri (2012) An Exemplar Model of...
Oct. 21-25	Fall Break	No classes
Oct. 31	Memory Tesseract <i>Topic Statement due</i>	Levy & Gayler (2009) "Lateral Inhibition" Kelly, Mewhort, & West (2017) The Memory Tesseract
Nov. 7	Semantic Space <i>Ex. 5 due; Ex. 6 assn.</i>	Landauer & Dumais (1997) A Solution to Plato's Problem Jones & Mewhort (2007) Representing Word Meaning
Nov. 14	Indirect associations <i>Exercise 6 due</i>	Kelly et al. (2020) Indirect associations in learning...
Nov. 15		Last day for academic withdrawal
Nov. 21	Declarative Memory	Kelly et al. (2020) Holographic Declarative Memory: Distributional Semantics as the Architecture of Memory
Nov. 28	Catastrophic Interference	Mannering & Jones (2021) Catastrophic Interference in Predictive Neural Network Models ... Cheung et al. (2019) Superposition of many models into one
Dec. 5	Transformers	Vaswani et al. (2017) Attention is all you need
Dec. 21	Exam Period	Term Model/Paper (take-home exam) due by 11:59pm

XI. Copyright: Classroom teaching and learning activities, including lectures, discussions, presentations, etc., by both instructors and students, are copyright protected and remain the intellectual property of their respective author(s). All course materials, including presentations, outlines, and other materials, are also protected by copyright and remain the intellectual property of their respective author(s).

Students registered in the course may take notes and make copies of course materials for their own educational use only. Students are not permitted to reproduce or distribute lecture notes and course materials publicly for commercial or non-commercial purposes without express written consent from the copyright holder(s).

XII. Addressing Human Rights Concerns: The University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities at equity@carleton.ca.

XIII. Grades: In accordance with the Carleton University Undergraduate Calendar (p. 34), the letter grades assigned in course will have the following percentage equivalents:

A+ = 90-100	B+ = 77-79	C+ = 67-69	D+ = 57-59
A = 85-89	B = 73-76	C = 63-66	D = 53-56
A- = 80-84	B- = 70-72	C- = 60-62	D- = 50-52
F = Below 50	WDN = Withdrawn from the course		DEF = Deferred

Standing in a course is determined by the course instructor subject to the approval of the Faculty Dean. This means that grades submitted by the instructor may be subject to revision. No grades are final until they have been approved by the Dean

XIV. Plagiarism: The University Academic Integrity Policy defines plagiarism as “presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one’s own.” This includes reproducing or paraphrasing portions of someone else’s published or unpublished material, regardless of the source, and presenting these as one’s own without proper citation or reference to the original source. Examples of sources from which the ideas, expressions of ideas or works of others may be drawn from include but are not limited to: books, articles, papers, literary compositions and phrases, performance compositions, chemical compounds, artworks, laboratory reports, research results, calculations and the results of calculations, diagrams, constructions, computer reports, computer code/software, material on the internet and/or conversations.

Plagiarism is a serious offence that cannot be resolved directly by the course’s instructor. The Associate Dean of the Faculty conducts a rigorous investigation, including an interview with the student, when an instructor suspects a piece of work has been plagiarized. Penalties are not trivial. They can include a final grade of “F” for the course.

Examples of plagiarism include, but are not limited to:

- any submission prepared in whole or in part, by someone else, including the unauthorized use of generative AI tools (e.g., ChatGPT);
- using ideas or direct, verbatim quotations, paraphrased material, algorithms, formulae, scientific or mathematical concepts, or ideas without appropriate acknowledgment in any academic assignment;
- using another’s data or research findings without appropriate acknowledgement;
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one’s own; and

- failing to acknowledge sources through the use of proper citations when using another's work and/or failing to use quotations marks.

XV. Statement on Student Mental Health: As a University student you may experience a range of mental health challenges that significantly impact your academic success and overall well-being. If you need help, please speak to someone. There are numerous resources available both on- and off-campus to support you. Here is a list that may be helpful:

- a. **Emergency Resources (on and off campus):** <https://carleton.ca/health/emergency-numbers/>
- b. **Carleton Resources:**
 - i. Mental Health and Wellbeing: <https://carleton.ca/wellness/>
 - ii. Health & Counselling Services: <https://carleton.ca/health/>
 - iii. Paul Menton Centre: <https://carleton.ca/pmc/>
 - iv. Academic Advising Centre (AAC): <https://carleton.ca/academicadvising/>
 - v. Centre for Student Academic Support (CSAS): <https://carleton.ca/csas/> •
 - vi. Equity & Inclusivity Communities: <https://carleton.ca/equity/>
- c. **Off Campus Resources:**
 - i. Distress Centre of Ottawa and Region: (613) 238-3311 or TEXT: 343-306-5550, <https://www.dcottawa.on.ca/>
 - ii. Mental Health Crisis Service: (613) 722-6914, 1-866-996-0991, <http://www.crisisline.ca/>
 - iii. Empower Me: 1-844-741-6389, <https://students.carleton.ca/services/empower-me-counselling-services/>
 - iv. Good2Talk: 1-866-925-5454, <https://good2talk.ca/>
 - v. The Walk-In Counselling Clinic: <https://walkincounselling.com>

XVI. Academic Accommodations: Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes, including information about the Academic Consideration Policy for Students in Medical and Other Extenuating Circumstances, are outlined on the Academic Accommodations website: <https://students.carleton.ca/course-outline/>

XVII. Important Information:

- Students must always retain a hard copy of all work that is submitted.
- For us to respond to your emails, we need to see your full name, CU ID, and the email must be written from your valid CARLETON address. Therefore, in order to respond to your inquiries, please send all email from your Carleton CMail account. If you do not have or have yet to activate this account, you may wish to do so by visiting <http://carleton.ca/ccs/students/>