CGSC 4900 B / 5901 X Hyperdimensional Cognitive Models
Prerequisites (CGSC 4900 B): 4th year standing in CGSC Honours required.

Lectures: 5:35 p.m. to 6:55 p.m. on Mondays and Wednesdays **(in person and online)**

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 fundmentals of hyperdimensional computing (HDC), also know 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/224834

III. **Textbook:** No textbook is required for the course. Readings and slides will be provided through the course website.

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 attendance and participation, programming exercises based on readings and seminar discussions, a term model and a presentation on the term model. All course materials will be available through Brightspace.

Evaluation	Value	Due Date
Participation	20% (0.8%/seminar)	Every seminar, in person or online
Exercises	40% (12 exercises, 3.3%/ea)	Wednesday of the following week
Term Model	40%	April 25

VIII. **Participation**: To earn full marks for participation, you need to
  (a) Attend all classes, either in person or online, except when unable to do so due to life circumstances communicated to me;
  (b) Be prepared for class (as evidenced by having done the readings);
  (c) Participate in class discussions: ask thoughtful questions, find ways to link issues from one topic to another, and/or come up with new ways to examine issues;

IX. **Exercises:** Some readings and seminars will have corresponding programing exercises due by **11:59pm Wednesday on the following week**. Exercises may be completed individually or in pairs. Class time may be allocated to completing exercises, schedule permitting.

X. **Term Model**: A running model of a task of your choice in the programming language of your choice. Recommended: Python and a model that uses my HDM architecture (guidance on how to build this will be given in class). The model should be accompanied by a short write-up explaining the code and task. Model can be created individually or in pairs. Grading rubric will be posted on Brightspace. The term model is the **take-home exam** for the course.

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

Date	Topic	Readings
Jan. 8	Introduction	course syllabus
Jan. 10	Systematicity Critique	Fodor & Pylyshyn (1988) Connectionism and cognitive arch
Jan. 15	Linear Algebra	Garrity (2001) *All the Math You Missed*, ch. 1
Jan. 17	Holographic Vectors	Plate (1995) Holographic reduced representations
Jan. 22	Vector Symbols	Gayler (2003) Vector symbolic architectures…
Jan. 24	Semantic Pointers	Eliasmith (2015) *How to build a brain*, ch. 4

Jan. 29	Interference	Cheung et al. (2019) Superposition of many models into one
Jan. 31	Working Memory	Franklin & Mewhort (2015) Memory as a hologram
Feb. 5	Episodic Memory	Jamieson & Hauri (2012) An exemplar model…
Feb. 7	Semantic Memory	Jones & Mewhort (2007) Representing word meaning…
Feb. 12	Catastropic Interference	Mannering & Jones (2021) Catastrophic Interference in Predictive Neural Network Models …
Feb. 14	**Colloquium Talk & Guest Lecture**	Colloquium talk at 3:00 pm DT 2203 by Furlong Furlong & Eliasmith (2023) Modelling neural probabilistic computation using vector symbolic architectures
Feb. 19-23	Winter Break	No classes
Feb. 26	**Guest Lecture**	**(online only)** T.B.A.
Feb. 28	**Guest Lecture**	**(online only)** T.B.A.
March 4	Abstract Associations	Kelly et al. (2020) Indirect associations…
March 6	Quantum Probability	Busemeyer et al. (2011) A quantum theoretical…
March 11	Declarative Memory	Kelly et al. (2020) Holographic Declarative Memory
March 13	Transformers	Vaswani et al. (2017) Attention is all you need
March 15		Last day for academic withdrawal
March 18	HRRformers	Alam et al. (2023) Recasting Self-Attention with HRRs
March 20	Hopfield Networks	Ramsauer et al. (2020) Hopfield networks is all you need
March 25	Predictive coding	Friston (2010) The free energy principle
March 27	Architectures	Ororbia & Kelly (2023) A neuro-mimetic realization…
April 1	Overview	Kleyko et al. (2023) A survey on HDC aka VSA, part I
April 3	Overview	Kleyko et al. (2023) A survey on HDC aka VSA, part II
April 8	Free Space	T.B.A.
April 10	Friday Schedule	**No class**
April 25	Exam Period	Term Model (take-home exam) due by 11:59pm

XII.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).

XIII. 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.

In accordance with the Carleton University Undergraduate Calendar (p 34), the letter grades assigned in this 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			

Grades entered by Registrar:
WDN = Withdrawn from the course
DEF = Deferred

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.

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.
  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.

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:

Emergency Resources (on and off campus): https://carleton.ca/health/emergencies-and-crisis/emergency-numbers/

Carleton Resources:
• Mental Health and Wellbeing: https://carleton.ca/wellness/
• Health & Counselling Services: https://carleton.ca/health/
• Paul Menton Centre: https://carleton.ca/pmc/
• Academic Advising Centre (AAC): https://carleton.ca/academicadvising/
• Centre for Student Academic Support (CSAS): https://carleton.ca/csas/
• Equity & Inclusivity Communities: https://carleton.ca/equity/

Off Campus Resources:
• Distress Centre of Ottawa and Region: (613) 238-3311 or TEXT: 343-306-5550, https://www.dcottawa.on.ca/
• Mental Health Crisis Service: (613) 722-6914, 1-866-996-0991, http://www.crisisline.ca/
• Empower Me: 1-844-741-6389, https://students.carleton.ca/services/empower-me-counselling-services/
• Good2Talk: 1-866-925-5454, https://good2talk.ca/
• The Walk-In Counselling Clinic: https://walkincounselling.com

Requests for Academic Accommodations
ACADEMIC ACCOMMODATION
You may need special arrangements to meet your academic obligations during the term. For an accommodation request the processes are as follows:
Pregnancy obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form (click here).
Religious obligation: write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details click here.
Academic Accommodations for Students with Disabilities: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, please request your accommodations for this course through

the Ventus Student Portal at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (*if applicable*). Requests made within two weeks will be reviewed on a case-by-case basis. For final exams, the deadlines to request accommodations are published in the University Academic Calendars. After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website for the deadline to request accommodations for the formally-scheduled exam (if applicable).

Survivors of Sexual Violence
As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/equity/sexual-assault-support-services

Accommodation for Student Activities
Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation will be provided to students who compete or perform at the national or international level. Write to me with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf

Important Information

- Students must always retain a hard copy of all work that is submitted.

-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

- 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/

-November 23, 2023: Last day for academic withdrawal from full fall and late fall classes

-March 15, 2024: Last day for academic withdrawal from full winter, late winter and fall/winter courses.

For a list of dates and deadlines, including holidays and exam dates, please visit:

https://calendar.carleton.ca/academicyear/