COG260(**F19**): Data, Computation, and The Mind

Yang Xu

Lecture+Lab: **Wednesday 10am-13pm @ BA 2200**

Office Hours and Contact Details: See Quercus (http://q.utoronto.ca/).

Syllabus might be adjusted as the course progresses.

Description

This entry-level course takes an integrated approach to the study of the mind, drawing ideas from cognitive science, computer science, and data science. Why is this integration important? From a scientific perspective, there has been extensive confluence between the fields of cognitive science and computational intelligence over the past 70 years. Many successful approaches to computational intelligence have been inspired by human cognition, but machines have yet to acquire core human cognitive abilities such as how people reason about objects, categories, and relations, or how people learn and communicate. On the other hand, theories of cognition have often drawn on computational ideas and methodologies. The understanding of this confluence requires students to develop a broad vocabulary across the relevant disciplines, so that they may translate fluently between these fields. From a pragmatic perspective, the rise of "big data" has made it almost imperative for students in cognitive science and related disciplines to acquire basic skills in data manipulation, analysis, and modelling.

Central to this course is the theme of *uncertainty*. We will explore how uncertainty might arise and concern cognitive functions such as object recognition, numerical and spatial cognition, categorization, language and communication. In doing so, we will also discuss basic tools for handling uncertainty by drawing topics from exploratory data analysis, probability theory, and statistics.

This course will involve a combination of lectures, labs, and an open-ended project. Each lecture will typically cover one topic of importance in cognitive science. Each lab session will typically involve the analysis of a cognitive dataset, along with discussion of relevant computational concepts and methods. Towards the end of the term, students will work on a project where they will formulate and test their own hypotheses based on an extensive public dataset. There will be no written exam in this course.

Prerequisite CSC108 - Introduction to Computer Programming

Objectives

1. Develop a basic understanding of the relations between uncertainty and cognition.
2. Acquire basic knowledge for characterizing uncertainty computationally.
3. Develop practical skills in scientific exploration and data analytics.

Textbook

We will read a combination of published papers and book chapters. We will use *Stats* as a reference textbook for elementary statistics and data analytics: De Veaux, R. D., Velleman, P. F., & Bock, D. E. (2012) *Stats: Data and models, 3rd edition*. Pearson. In addition, we will use the reference booklet *An introduction to Python for data science applications* (Salas, 2016) for programming and data analysis with Python.

Deliverables and Assessments

Python Notebooks or code for the labs and the project should be submitted via Google Forms. Readings will be assessed through the labs. Required reading materials, data, starter Python Notebooks, and submission links for the labs and the project will be posted on Quercus.

Participation in labs	10%
Labs 1-6	60% (10% each)
Project proposal	5%
Project presentation	10%
Project report	15%

Grading Scale

90 - 100%	A+	77 - 79%	B+	67 - 69%	C+	57 - 59%	D+
85 - 89%	A	73 - 76%	B	63 - 66%	C	53 - 56%	D
80 - 84%	A-	70 - 72%	B-	60 - 62%	C-	50 - 52%	D-
						0 - 49%	Fail

Policies and guidelines

- Attendances to labs and lectures are assumed.
- Students should work individually for the labs but collaborate in pairs for the final projects. Collaborators should be acknowledged (e.g., full names and student UIDs) in the front page of any assignment write-up. Plagiarism is strictly forbidden and any such case if identified will be reported according to the university guidelines (see http://www.governingcouncil.utoronto.ca/Assets/Governing+Council+Digital+Assets/Policies/PDF/ppjun011995.pdf).
- Project presentation is required from every student; project reporting styles should follow the guidelines provided at http://advice.writing.utoronto.ca/types-of-writing/lab-report/.
- Late written assignments will be discredited at 1 point per delayed hour based on the time stamps of submission. Exceptional circumstances should be explained in writing to the course instructor, at least two days prior to the due date.

Lab + Lecture Schedules and Readings (due/required items are highlighted)

- **Sep 11 (Wed)** Lab 0 (Juypter Notebook) + Introduction

  Required reading:

  – Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63(2), 81–97.

  Optional readings:

  – Turing, A. M. (1950) Computing machinery and intelligence. *Mind*, 49, 433–460.

  – Chomsky, N. (1959). Review of B. F. Skinner, *Verbal Behavior*. *Language*, 35(1), 26–58.

  – Miller, G. A. (2003). The cognitive revolution: A historical perspective. *Trends in Cognitive Sciences*, 7(3), 141–144.

  Recommended book:

  – Skinner, B. F. (1957). *Verbal behavior*. Prentice-Hall.

- **Sep 18 (Wed)** Lab 1 (data exploration) + Numerical cognition

  Required reading:

  – Feigenson, L., Dehaene, S., and Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, 8(7), 307–314.

  Technical reference:

  – Chapters 1-3 in *Stats*.

  Optional readings:

  – Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, 358(6389), 749–750.

  – Pica, P., Lemer, C., Izard, V., and Dehaene, S. (2004). Exact and approximate arithmetic in an Amazonian indigene group. *Science*, 306(5695), 499–503.

  – Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science*, 306(5695), 496–499.

  – Frank, M. C., Everett, D. L., Fedorenko, E., and Gibson, E. (2008). Number as a cognitive technology: Evidence from Pirahã language and cognition. *Cognition*, 108, 819–824.

  – Halberda, J., Mazzocco, M. M., and Feigenson, L. (2008). Individual differences in non-verbal number acuity correlate with maths achievement. *Nature*, 455(7213), 665–668.

  Recommended book:

  – Dehaene, S. (2011). The number sense: How the mind creates mathematics. Oxford University Press.

- **Sep 25 (Wed)** Lab 2 (number estimation) (Lab 1 due) + Object recognition

Required reading:

- Shepard, R. N., and Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, 171(3972), 701–703.

Technical reference:

- Chapter 4 in *Stats*.

Optional readings:

- Hubel, D. H., and Wiesel, T. N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *The Journal of Physiology*, 160(1), 106–154.
- Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. *Psychological Review*, 94(2), 115–147.
- Logothetis, N. K., and Sheinberg, D. L. (1996). Visual object recognition. *Annual Review of Neuroscience*, 19(1), 577–621.
- Riesenhuber, M., and Poggio, T. (1999). Hierarchical models of object recognition in cortex. *Nature Neuroscience*, 2(11), 1019–1025.
- DiCarlo, J. J., Zoccolan, D., and Rust, N. C. (2012). How does the brain solve visual object recognition? *Neuron*, 73(3), 415–434.

Recommended book:

- Marr, D. (1982). Vision: A computational investigation into the human representation and processing of visual information. Freeman.

- **Oct 2 (Wed)** Lab 3 (mental rotation) (Lab 2 due) + Spatial cognition

Required reading:

- Levinson, S., Meira, S., and The Language and Cognition Group. (2003). 'Natural concepts' in the spatial topological domain-adpositional meanings in crosslinguistic perspective: An exercise in semantic typology. *Language*, 79(3), 485–516.

Technical reference:

- Chapter 8 in *Stats*.

Optional readings:

- Tolman, E. C. (1948). Cognitive maps in rats and men. *Psychological Review*, 55(4), 189–208.
- Morris, R. G. M., Garrud, P., Rawlins, J. A., and O'Keefe, J. (1982). Place navigation impaired in rats with hippocampal lesions. *Nature*, 297(5868), 681–683.
- Landau, B. and Jackendoff, R. (1993). "What" and "where" in spatial language and spatial cognition. *Behavioral and Brain Sciences*, 16(2), 217–238.
- Majid, A., Bowerman, M., Kita, S., Haun, D. B., and Levinson, S. C. (2004). Can language restructure cognition? The case for space. *Trends in Cognitive Sciences*, 8(3), 108–114.

Recommended book:

- Newcombe, N. S., and Huttenlocher, J. (2003). *Making space: The development of spatial representation and reasoning*. MIT Press.

- **Oct 9 (Wed)** Lab 4 (prototypicality) (Lab 3 due) + Categories

  Required reading:

  - Eleanor, R. (1978) Principles of Categorization, in Rosch, E. and Lloyd, B. B. (eds), *Cognition and Categorization*. Lawrence Erlbaum, 27–48.

  Technical reference:

  - Chapter 7 in *Stats*.

  Optional readings:

  - Rosch, E. (1973). Natural categories. *Cognitive Psychology*, 4(3), 328–350.
  - Rosch, E. (1975). Cognitive representations of semantic categories. *Journal of experimental psychology: General*, 104(3), 192–233.
  - Tversky, A. (1977). Features of similarity. Psychological Review, 84(4), 327–352.
  - Medin, D. L., Goldstone, R. L., and Gentner, D. (1993). Respects for similarity. Psychological Review, 100(2), 254–278.

  Recommended book:

  - Murphy, G. (2004). *The big book of concepts*. MIT Press.

- **Oct 16 (Wed)** Lab 5 (categorization) (Lab 4 due) + Categorization

  Required reading:

  - Nosofsky, R. M. (1986). Attention, similarity, and the identification-categorization relationship. *Journal of Experimental Psychology: General*, 115(1), 39–57.

  Optional readings:

  - Reed, S. K. (1972). Pattern recognition and categorization. Cognitive Psychology, 3, 382–407.
  - Medin, D. L., and Schaffer, M. M. (1978). Context theory of classification learning. *Psychological Review*, 85(3), 207–238.
  - Medin, D. L., and Smith, E. E. (1984). Concepts and concept formation. *Annual Review of Psychology*, 35(1), 113–138.
  - Anderson, J. R. (1991). The adaptive nature of human categorization. *Psychological review*, 98(3), 409–429.
  - Goldstone, R. L., and Kersten, A. (2003). Concepts and categorization, in Healy, A.F. and Proctor, R.W. (eds), *Comprehensive handbook of psychology, Volume 4: Experimental psychology*. Wiley, 599–621.

  Recommended book:

- Lakoff, G. (1987). *Women, fire, and dangerous things: What categories reveal about the mind*. University of Chicago press.

- **Oct 23 (Wed)** Lab 6 (word frequency) (Lab 5 due) + Words

  Required reading:

  - Chapter 2 in Zipf, G. K. (1949). *Human behavior and the principle of least effort*. Addison-Wesley Press.

  Technical reference:

  - Nichols, T. E., and Holmes, A. P. (2002). Nonparametric permutation tests for functional neuroimaging: A primer with examples. *Human Brain Mapping*, 15(1), 1–25.

  Optional readings:

  - Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, 27, 379-423 and 623-656.
  - Shannon, C. E. (1951). Prediction and entropy of printed English. *Bell system technical journal*, 30, 50–64.
  - Piantadosi, S. T., Tily, H., and Gibson, E. (2011). Word lengths are optimized for efficient communication. Proceedings of the National Academy of Sciences, 108(9), 3526–3529.

  Recommended book:

  - Chomsky, N. (1986). *Knowledge of language: Its nature, origin, and use*. Greenwood.

- **Oct 30 (Wed)** Lab 7: Project orientation (Lab 6 due) + Languages

  Required reading:

  - Berlin, B., and Kay, P. (1969). *Basic color terms: Their universality and evolution*. University of California Press.

  Optional readings:

  - Regier, T., Kay, P., and Cook, R. S. (2005). Focal colors are universal after all. *Proceedings of the National Academy of Sciences*, 102(23), 8386–8391.
  - Regier, T., Kay, P., and Khetarpal, N. (2007). Color naming reflects optimal partitions of color space. *Proceedings of the National Academy of Sciences*, 104(4), 1436–1441.
  - Abbott, J. T., Griffiths, T. L,., and Regier, T. (2016). Focal colors across languages are representative members of colors categories. *Proceedings of the National Academy of Sciences*, 113(40), 11178-11183.
  - Gibson, E., Futrell, R., Jara-Ettinger, J., Mahowald, K., Bergen, L., Ratnasingam, S., ... and Conway, B. R. (2017). Color naming across languages reflects color use. *Proceedings of the National Academy of Sciences*, 114(40), 10785–10790.

- Kemp, C., Xu, Y., and Regier, T. (2018). Semantic typology and efficient communication. *Annual Review of Linguistics*, 4, 109–128.
- Zaslavsky, N., Kemp, C., Regier, T., and Tishby, N. (2018). Efficient compression in color naming and its evolution. *Proceedings of the National Academy of Sciences*, 115(31), 7937–7942.

  Recommended book:
- Pinker, S. (2007). *The stuff of thought: Language as a window into human nature*. Penguin.

- **Nov 13 (Wed)** Lab 8: Project analysis (project proposal due) + Judgment and decision making

  Required reading:
  - Tversky, A., and Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science*, 185(4157), 1124–1131.

  Optional readings:
  - Kahneman, D. and Tversky, A. (1979). Prospect Theory: An analysis of decision under risk. *Econometrica*, 47(2), 263–292.
  - Tversky, A., and Kahneman, D. (1981). The framing of decisions and the psychology of choice. *Science*, 211(4481), 453–458.
  - Griffiths, T. L., Kemp, C., and Tenenbaum, J. B. (2008). Bayesian models of cognition. In Ron Sun (ed.), *The Cambridge handbook of computational cognitive modeling*. Cambridge University Press.
  - Chater, N., Oaksford, M., Hahn, U., and Heit, E. (2010). Bayesian models of cognition. *Wiley Interdisciplinary Reviews: Cognitive Science*, 1(6), 811–823.

  Recommended book:
  - Kahneman, D., and Egan, P. (2011). *Thinking, fast and slow*. Farrar, Straus and Giroux.

- **Nov 20 (Wed)** Lab 9: Project analysis + Research talk 1

  Optional readings:
  - TBD

- **Nov 27 (Wed)** Lab 10: Project analysis + Research talk 2

  Optional readings:
  - TBD

- **Dec 4 (Wed)** Data blitz (project final presentation)

- **Dec 8 (Sun)** No class (project final report due)