# COG260(**F21**): Data, Computation, and The Mind

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Lecture+Lab: **Tuesday 1-4pm ET** (see Quercus course page for details)

Office Hour: **Thursday 10-11am ET** (see Quercus course page for details)

*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; **Corequisite** COG250.

**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 for the labs and the project write-ups should be submitted via Quercus. 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.

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|---|---|
| Labs 1-6 | 60% (10% each) |
| Critical summary | 10% |
| Project proposal | 5% |
| Project presentation | 10% |
| Project report | 15% |

**Grading Scale**

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|---|---|---|---|---|---|---|---|
| 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**

- Students should work individually for the labs but collaborate in pairs for the final projects. 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 expected from every student; project reporting styles should follow the guidelines provided at http://advice.writing.utoronto.ca/types-of-writing/lab-report/.

- Late assignments will be discredited at 1 point per delayed hour based on the submission time. Delays should be explained in writing at least 2 days before due date.

- Write a critical summary (500-600 words) on 1 selected Required reading by summarizing the study, discussing at least 2 related papers (via Google/Semantic Scholar) and referencing the papers found, suggesting the limitations and proposing ways to extend the study.

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

- **Sep 14 (Tue)** Introduction + Lab 0 (Juypter Notebook)

  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.

- **Sep 21 (Tue)** Numerical cognition + Lab 1 (data exploration)

  Required reading:

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

  Technical reference:

  - Chapters 1-3 in *Stats*.

  *Optional readings:*

  - Wynn, K. (1992). Addition and subtraction by human infants. *Nature*, 358(6389), 749–750.
  - Gordon, P. (2004). Numerical cognition without words: Evidence from Amazonia. *Science*, 306(5695), 496–499.
  - Feigenson, L., Dehaene, S., and Spelke, E. (2004). Core systems of number. *Trends in Cognitive Sciences*, 8(7), 307–314.
  - 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.
  - Carey, S., and Barner, D. (2019). Ontogenetic origins of human integer representations. *Trends in Cognitive Sciences*, 23(10), 823–835.

- **Sep 28 (Tue)** Object recognition + Lab 2 (number estimation) (Lab 1 due)

  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.

- **Oct 5 (Tue)** Spatial cognition + Lab 3 (mental rotation) (Lab 2 due)

  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.

- **Oct 12 (Tue)** Categories + Lab 4 (prototypicality) (Lab 3 due)

  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.

- **Oct 19 (Tue)** Categorization + Lab 5 (categorization) (Lab 4 due)

  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.

- **Oct 26 (Tue)** Words + Lab 6 (word frequency) (Lab 5 due)

  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.
  - Brown, R. (1958). How shall a thing be called? *Psychological Review*, 65(1), 14–21.

 

- 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.
- Blasi, D. E., Wichmann, S., Hammarström, H., Stadler, P. F., and Christiansen, M. H. (2016). Sound-meaning association biases evidenced across thousands of languages. Proceedings of the National Academy of Sciences, 113(39), 10818–10823.

- **Nov 2 (Tue)** Languages + Lab 7: Project orientation (Lab 6 due)

  Readings relevant to the project:

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

- **Nov 16 (Tue)** Judgment and decision making + Lab 8: Project analysis (Project proposal due)

  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.

- **Nov 23 (Tue)** Human and machine biases + Lab 9: Project analysis (Critical summary due)

*Optional readings:*

- Bolukbasi, T., Chang, K. W., Zou, J. Y., Saligrama, V., and Kalai, A. T. (2016) Man is to computer programmer as woman is to homemaker? Debiasing word embeddings. In *Advances in neural information processing systems.*
- Caliskan, A., Bryson, J. J., and Narayanan, A. (2017). Semantics derived automatically from language corpora contain human-like biases. *Science*, 356(6334), 183–186.
- Ellemers, N. (2018). Gender stereotypes. *Annual Review of Psychology*, 69, 275–298.

- **Nov 30 (Tue)** Lab 10: Project walk-in clinics
- **Dec 7 (Tue)** Data blitz (project final presentation)
- **Dec 13 (Mon)** No class (project final report due)