Computer Models of Human Perception and Cognition
BCSC/CSC/DSCC 229, DSCC 449

Spring 2026

Tue/Thu 11:05 AM – 12:20 PM in Gavett 312

Instructor
Professor Robert Jacobs
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Teaching Assistant (TA)
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Office Hours

The TA is available to answer students' questions about the course materials. Students may schedule meetings (either in-person or remote via Zoom) with the TA at times of mutual convenience.

The instructor will stay an extra 5-10 minutes at the end of each class to answer questions. Students may schedule meetings (either in-person or remote via Zoom) with the instructor at times of mutual convenience.

Course Objectives

The course aims to teach students about probabilistic methods and their applications to understanding human perception and cognition. From a cognitive science perspective, students will learn about current theories of human perception and cognition, and about experimental studies evaluating those theories. How do our brains perceive, think, and act? Why do our brains use some representations and operations as opposed to others? Are the representations and operations used by our brains "optimal" in some sense? From a computer modeling perspective, students will learn about computational methods and issues (borrowed primarily from the fields of artificial intelligence and machine learning).

Prerequisites

The course prerequisites are MATH 161 (Calculus IA) and MATH 162 (Calculus IIA) (or equivalents), and computer programming experience. MATH 164 (Multidimensional Calculus), MATH 165 (Linear Algebra with Differential Equations), and/or STAT 213 (Elements of Probability and Mathematical Statistics) will be helpful, but are not strictly required. Students will need to complete computer programming assignments using the Python programming language (including libraries such as Numpy, Scipy, Matplotlib, etc.).

Attendance and Participation Policy

Class participation is an essential part of this course. A student's participation credit will be based on both attendance and active involvement in class discussions. If a student must miss a class for a legitimate reason, the student must notify the instructor via email 24 hours in advance and provide documentation to explain the required absence. If a student is unable to attend class due to an unexpected illness or emergency, the student must contact the instructor as soon as possible. Again, the student will need to present appropriate documentation.

Readings
The required textbook for this course is:

Ma, W. J., Körding, K. P., & Goldreich, D. (2023). *Bayesian Models of Perception and Action: An Introduction*. Cambridge, MA: MIT Press.

There are additional required readings for this course which will be made available via Blackboard.

Brief Reports
Certain classes are designated as "Discussion" classes. For these classes, there are one or more assigned readings. For one or more of these readings (as indicated in the Course Schedule; see below), a student should prepare a "brief report" addressing each of the following questions:

- What is the primary research question or issue studied in the reading?
- What do the authors do to address this research question or issue?
- What are the authors' main conclusions?
- Think of two (or more) questions (or comments or discussion points) regarding the reading.

It is recommended that brief reports consist of four paragraphs (one paragraph dedicated to each question). Each paragraph should typically contain 1-3 sentences.

Reports must be submitted (PDF files uploaded using Blackboard) **before the start of the class** on which they are assigned.

Homework Assignments
Two homework assignments will be distributed during the course of the semester. Some homework questions ask students to write short essay-style answers, other questions ask students to solve mathematical problems, and still other questions ask students to write computer code (using Python) implementing solutions to problems or implementing computational models. Homeworks must be submitted (PDF files uploaded using Blackboard) before 11:05am (the start of class) on the due date.

Exams
The course includes two midterm exams and a final exam. Exams will use multiple-choice questions. The first midterm exam focuses on probability problems. The second midterm exam covers all course materials up to the date of the exam. The final exam covers all course materials. Exams are "open note", meaning that a student may look at any of the course materials (e.g., lecture notes, readings) during the exam. However, a student cannot consult any other materials or resources and cannot communicate with anyone while taking an exam.

Final Paper and Presentation
Each student will write a final paper on a topic of their choosing (subject to approval by the instructor). Papers have a maximum length of 1000 words, and should be double-spaced and use a 12-point font. Toward the end of the semester, 7-9 students will give brief (e.g., 5-10 minutes)

presentations based on their papers (see Class 27). (Volunteers will be solicited. "Extra credit" is not available.) Additional instructions will be provided later in the semester.

Due Dates and Exam Dates

All due dates (e.g., brief reports, homework assignments, final paper) are firm. We will be strict about this. If a student needs an extension due to a university-sanctioned emergency, the student must notify the instructor via email 24 hours in advance and provide documentation of the emergency. Similarly, exam dates are firm. There will be **NO MAKE-UP EXAMS** except for university-sanctioned emergencies. Again, formal documentation will be required.

Course Grading

- 15%: Class attendance and participation (including brief reports on readings assigned for discussion classes)
- 10%: Homework I
- 10%: Homework II
- 10%: Final paper
- 10%: Midterm Exam I
- 22.5%: Midterm Exam II
- 22.5%: Final Exam

Collaboration Policy and Academic Honesty

All coursework must be completed by each individual student working alone. Any student suspected of cheating will be referred to the Board on Academic Honest for investigation and possible penalties. Any evidence of collaboration, duplication, or plagiarism (e.g., copying someone else's writing, or failing to cite the work, ideas, or writings of someone else, and presenting it as your own) will be referred to the Board on Academic Honesty. For more information, see: https://www.rochester.edu/college/honesty/.

On the Use of AI Programs

Students may use AI programs (e.g., ChatGPT) to help understand concepts taught in this course. (For example, one might ask an AI program: "I don't understand the concept of "induction". Please provide an example of this concept.".) However, since coding, writing, analytical, and critical thinking skills are part of the learning outcomes of this course, all course exams and assignments must be completed by a student **without** the assistance of AI programs.

Learning Assistance

Students requiring assistance in learning should contact the Learning Center at Dewey 1-154 (phone: 585-275-9049; email: learning@rochester.edu; web: https://www.rochester.edu/college/learningcenter/index.html.

Writing Assistance

Students requiring assistance with writing can make an appointment with a writing consultant or fellow at the Writing, Speaking, and Argument Program at Rush Rhees Library G-122 (phone: 585-273-3584; email: wsap@ur.rochester.edu; web: https://writing.rochester.edu/.

Disability Resources

This course respects and welcomes students of all backgrounds and abilities, and we encourage students to talk with us about any concern or situation that affects their ability to complete their academic work successfully. Students requiring accommodations should contact the Office of Disability Resources in Taylor Hall (phone: 585-276-5075; email: disability@rochester.edu; web: https://rochester.edu/college/disability/).

College Course Credit Hour Policy

This course follows the College credit hour policy for four-credit courses. This course meets two times weekly for three academic hours per week. The course also includes independent out-of-class assignments for at least one academic hour per week. In this course, the independent out-of-class assignments include readings of large and/or difficult academic papers and writings of brief reports on several of these papers.

Course Schedule

The following is a **rough** plan for the course. Depending on various factors, the course may cover materials at a slower or faster pace, and the course may omit some materials listed below and/or add other materials.

Note: Classes indicated with an asterisk ("") are Discussion Classes.*

Class 1 (Jan 20): Organization / Introduction

Class 2 (Jan 22): Reasoning and Decision Making I

**Class 3* (Jan 27): Discussion Class: Reasoning and Decision Making II

- Assigned reading: Kahneman, D. (2011). *Thinking, Fast and Slow*. New York: Farrar, Straus, and Giroux. (pages 3-15 and 19-30)
- Assigned brief report: Write a report on assigned reading

Class 4 (Jan 29): Introduction to Probability I

- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 1)
- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 2)
- Assigned reading: Russell, S. & Norvig, P. (2010). *Artificial Intelligence: A Modern Approach (Third Edition)*. Upper Saddle River, NJ: Pearson Education. (pages 480-509)

Class 5 (Feb 3): Introduction to Probability II

- Assigned reading: Russell, S. & Norvig, P. (2010). *Artificial Intelligence: A Modern Approach (Third Edition)*. Upper Saddle River, NJ: Pearson Education. (pages 480-509)

Class 6 (Feb 5): Probability Problem Set

- Assigned reading: Read (and think about) the problems on the list of "Probability Problems" compiled by the instructor

Class 7 (Feb 10): Statistical Inference

Class 8 (Feb 12): Midterm Exam I

Class 9 (Feb 17): Implementing Probabilistic Processing Using Python

Class 10 (Feb 19): Our Expectations Influence Visual Perception
- Assigned reading: Dawson, M. R. W. (1998). *Understanding Cognitive Science*. Malden, MA: Blackwell Publishers. (pages 243-270)

Class 11 (Feb 24): Building a Bayesian Model
- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 3)
- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 4)

**Class 12* (Feb 26): Discussion Class: Sensory Cue Integration
- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 5)
- Assigned reading: Ernst, M. O. & Bülthoff, H. H. (2004). Merging the senses into a robust percept. *Trends in Cognitive Sciences*, *8*, 162-169.
- Assigned brief report: Write a report on Ernst & Bülthoff (2004)
- Distribute Homework #1 (due at start of Class 17)

**Class 13* (Mar 3): Discussion Class: Visual Motion Perception
- Assigned reading: Geisler, W. S. & Kersten, D. (2002). Illusions, perception, and Bayes. *Nature Neuroscience, 5*, 508-510.
- Assigned reading: Weiss, Y., Simoncelli, E. P., & Adelson, E. H. (2002). Motion illusions as optimal percepts. *Nature Neuroscience, 5*, 598-604.
- Assigned brief report: Write a report on Weiss, Simoncelli, & Adelson (2002)

Class 14 (Mar 5): Midterm Exam II

Class 15 (Mar 17): Review of Midterm Exam II

Class 16 (Mar 19): Bayesian Learning and Generalization
- Assigned reading: Tenenbaum, J. B. & Griffiths, T. L. (2001). Generalization, similarity, and Bayesian inference. *Behavioral and Brain Sciences, 24*, 629-640.

**Class 17* (Mar 24): Discussion Class: Visual Memory
- Assigned reading: Hemmer, P. & Steyvers, M. (2009). A Bayesian account of reconstructive memory. *Topics in Cognitive Science, 1*, 189-202.
- Assigned reading: Griffiths, T. L. & Tenenbaum, J. B. (2006). Optimal predictions in everyday cognition. *Psychological Science, 17*, 767-773.
- Assigned brief report: Write a report on Griffiths & Tenenbaum (2006)

Class 18 (Mar 26): Introduction to Posterior Sampling

Class 19 (Mar 31): Same-Different and Other Causal Inference Problems I

- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 10)
- Distribute Homework #2 (due at start of Class 25)

Class 20 (Apr 2): Same-Different and Other Causal Inference Problems II

Class 21 (Apr 7): Visual Search

- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 11)

Class 22 (Apr 9): Nuisance Variables and Ambiguity; Combining Inference with Utility

- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 9)
- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 13)

**Class 23* (Apr 14): Discussion Class: Bayesian Response to Kahneman/Tversky I

- Assigned reading: Sanborn, A. N. & Chater, N. (2016). Bayesian brains without probabilities. *Trends in Cognitive Sciences*, *20*, 883-893.
- Assigned brief report: Write a report on Sanborn & Chater (2016)

Class 24 (Apr 16): Bayesian Response to Kahneman/Tversky II

- Assigned reading: Bates, C. J. & Jacobs, R. A. (2019). Efficient data compression leads to categorical bias in perception and perceptual memory. *Proceedings of the Forty-First Annual Conference of the Cognitive Science Society*.

Class 25 (Apr 21): Bayesian Brain I

- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 14)

Class 26 (Apr 23): Bayesian Brain II

- Assigned reading: Ma, W. J., Körding, K. P., & Goldreich, D. (2023). Bayesian Models of Perception and Action (Chapter 14)

Class 27 (Apr 28): Student presentations of final papers

Class 28 (Apr 30): Review for Final Exam