Bayesian Inference

PSYCH 4KK3, PSYCH 730

Term 2, 2016 (Wednesdays, 2:30 - 5:20 PM, MDCL 1009)

Teaching Team

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Description

This course explores the far-reaching applications in science of a simple but remarkably insightful equation. First introduced in 1764, Bayes' formula elegantly embodies the scientific method, in which predictions made from hypotheses are put to the test, and inferences regarding the relative merits of the hypotheses are drawn from the resulting data. Bayesian inference is increasingly used as a powerful research tool by scientists in all disciplines. It provides a sophisticated method for drawing inferences from data, used both for statistical analysis and as a model of human brain function. Students will apply Bayes' formula to gain insight into scientific and everyday reasoning. They will learn modern statistical analysis techniques, derived from Bayes' formula, that provide a coherent and attractive alternative to the conventional p-value methods. They will be introduced to the Bayesian foundations of signal detection theory and to Bayesian models of sensory perception. This conceptually sophisticated course is presented in an interactive and mathematically accessible fashion.

Graduate students taking Psych 730 are required to attend all lectures and complete all work along with the undergraduates in Psych 4KK3. The graduate students will write somewhat more advanced versions of the midterm test and final exam than the undergraduates and will complete two additional homework assignments involving extensive reading and/or data analysis.

The course web site plays an integral role in this course. The web site contains this syllabus and links to the online course textbook, homework assignments, a password-protected system for students to check their marks, and the Bayes-Engage discussion forum. The password to the website will be provided during the first lecture.

Meetings

Lecture: Wednesdays, 2:30 - 5:20 PM (MDCL 1009).
Tutorial (optional but strongly recommended): Fridays, 11:30 AM - 12:20 PM (BSB 138).

Objectives

Upon completion of this course, the student will understand:

- the concept of conditional probabilities
- how to work with the sum and product rules of probability theory
- the meaning of each element of Bayes' formula: prior, likelihood, and posterior
- key features of the scientific method that emerge from the application of Bayes' formula.
- how Bayesian inference differs from frequentist statistical methods.
- how to apply Bayesian inference to clinical diagnostic testing and genetics scenarios.
- how to use Bayesian inference to estimate the values of binomial, Poisson, and Gaussian parameters
- how to use Bayesian inference for curve-fitting and robust parameter estimation.
- how to perform Bayesian model comparison
- how to model human sensory perception as Bayesian inference

Materials

Required Textbook: Goldreich, D. (2015) Introduction to Bayesian Inference (online)

Students are responsible for reading each assigned textbook chapter in its entirety. Some homework and exam questions may be based on material in the book that was not covered during lectures. Note: The book is a work in progress and may be modified slightly throughout the semester. If you are planning on printing the book, please wait until we reach the corresponding course section before printing each chapter, to ensure that you print the most recent version.

Required Calculator: The McMaster Standard Calculator (Casio FX-991) is permitted in exams and for in-class Brain Boggler exercises unless otherwise specified. This calculator is available at the McMaster Campus Store. No other calculator is permitted.

Evaluation

Students will be graded on in-class critical thinking activities called Bayesian Brain Bogglers, weekly homework assignments, a midterm test, and a comprehensive final exam. The student's course percentage score is a weighted average of the following five items:

Item	Weight
Bayesian Brain Bogglers	5%
Everyday Bayes Group Assignments	5%

Homework Assignments	20%
Midterm Test	25%
Comprehensive Final Exam	45%

Bayesian Brain Bogglers

The brain bogglers are in-class exercises designed to encourage critical thinking about Bayesian inference.

Some of the brain boggler exercises will require a calculator; the student should bring the McMaster Standard calculator (Casio FX-991) to class.

Typically, one brain boggler will be given per week, though some weeks may have more.

Unless otherwise announced, each brain boggler exercise is worth 2 points. Each answer will typically receive either zero, half, or full-credit (0, 1, or 2 points).

The student's running brain boggler total is reported online in the check-marks system.

The student's brain boggler percentage score, used in the student's course percentage score calculation, is the number of brain boggler points earned divided by the total number of points possible.

Everyday Bayes

Throughout the semester, groups of students are required to submit an Everyday Bayes assignment every second week. Student groups (of approximately 4 students each) will be assigned at the beginning of the term. To earn full credit, an Everyday Bayes submission must report two astute observations regarding the use of Bayesian inference in everyday life, correctly worked out mathematically with Bayes' formula. In order to produce high-quality Everyday Bayes submissions, students are encouraged to keep a Bayes-Blog, a private journal of their everyday Bayesian observations, and to then compare notes and check their group-mates' work when they meet outside of class, in order to decide which observations they will submit.

Unless otherwise announced, each EveryDay Bayes assignment is worth 8 points (i.e., 4 points per correctly worked observation). One point will be deducted for each error in procedure, calculation, or interpretation.

Each Everyday Bayes score will be posted (out of 100%) online in the check-marks system.

At the end of the semester, the average of each student's Everyday Bayes scores will be taken as the student's final Everyday Bayes score.

Homework

Homework assignments are inked on the schedule table, and are due at the beginning of class each week. Late homework returns will not be accepted.

Students are encouraged to type their answers whenever possible.

Students are encouraged to study with a partner or in a group when attempting to answer the assignment questions. However, students must write their own assignment answers and must submit their assignments individually. Copying part or all of another student's assignment is strictly prohibited and will result in a failing grade on the assignment.

The point value of each question will be indicated on the homework assignment.

The score for the entire homework assignment will always be reported on a 0-to-100% scale. For example, suppose an assignment has three questions, worth 2, 4, and 4 points each. If a student earns half credit on the first question, full credit on the second, and half credit on the third, then the student's score will be 1 + 4 + 2 = 7, and the score will be reported as 70%.

The student's homework assignment scores are reported online in the check-marks system.

At the end of the term, the student's lowest homework assignment score will be dropped. The average of the student's remaining homework assignment scores will then be calculated. This is the student's course homework score.

Graduate students taking Psych 730 will complete two additional homework assignments (identified as GS HW A and GS HW B in the schedule table). These assignments, which will involve extra reading and/or data analysis, are intended to deepen the graduate students' understanding of the material covered in each of the two course sections. These assignments will be weighted equally with the other assignments in the calculation of the student's course homework score. Grad students must complete both GS HW assignments (A and B). The lowest GS HW grade will not be dropped (only the lowest of the 10 other assignments will be dropped).

Midterm Test and Final Exam

The student should bring the McMaster standard calculator (Casio FX-991) to all exams. Only the McMaster standard calculator will be allowed.

Graduate students taking Psych 730 will write somewhat more advanced versions of the midterm test and final exam than the undergraduates taking Psych 4KK3.

Each test / exam is given a mark on a scale from 0 - 100%. The student's test marks are reported online in the check-marks system.

Create-a-Question: As an optional exercise, students are encouraged to try to generate an excellent exam question of their own. Please email the instructor with your proposed exam question and answer. Questions that are carefully and articulately worded, and that probe student understanding of important concepts, will be considered for inclusion. The instructor will not inform you in advance of the exam whether your question will be used, and will not provide feedback as to whether your answer is correct. If it is used on an exam, your name will not be attached to your question, but a note will be attached to indicate that the question was student-generated. Furthermore, if it is used, your question may be edited and/or otherwise modified by the instructor.

Course Grade Calculation

The following formula is used to calculate the student's course percentage score:

Course percentage score = (course Brain Boggler percentage score)(0.05) + (course Everyday Bayes percentage score)(0.05) + (course Homework percentage score)(0.20) + (Midterm test percentage score)(0.25) + (Final Exam percentage score)(0.45)

The student's course grade will be determined from the student's course percentage score, as follows:

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

Missed Work
Please see the university policy statement concerning missed work. Students who are absent for no more than three days may report their absence, once per term, without documentation, using the McMaster Student Absence Form (MSAF). Please note that the MSAF may not be used for term work worth 25% or more of the course grade, nor can it be used for the final examination. This means that the MSAF cannot be used for the midterm test or the final exam in this course. Absences of more than three days must be reported to the student's Faculty/Program office, with documentation, and relief from course work may not necessarily be granted. A mark of zero will automatically be entered for all missed work until the instructor receives notification from the MSAF system or the student's Faculty Office, and is contacted by the student to discuss how to remedy the missed work situation.

It is the student's responsibility to learn all material that the student has missed for any reason. This can be done by reading the posted lecture notes and assigned textbook chapters, by consulting with classmates, and by attending office hours.

If a student is unable to attend a class, but has been able to complete the homework assignment, then the student should submit the homework assignment by email, prior to the start of the class period, to the instructor (goldrd@mcmaster.ca). Late email submissions will not be accepted.

Email policy
Any email should state the course number and/or title in its subject heading. Please do not email the teaching assistants or instructor with specific Bayesian inference questions; we will not answer such questions by email. Instead, specific content questions should be asked in office hours, in the tutorial sessions, or in class. In addition, students are strongly encouraged to post any such questions on the Bayes-Engage forum, where other students can help to answer them.

Recordings
Photographs and video recordings are strictly prohibited.

Students may make audio recordings of the lectures, for personal use only and not to be posted online, emailed, distributed or otherwise shared. Students should inform the instructor in advance if they wish to make an audio recording.

Cell Phone Use
Cell phone use, including texting, is prohibited in the classroom. Students who need to use their cell phones are expected to leave the classroom and return when they have finished.

Academic Integrity
As a student, you are expected to behave honestly and ethically at all times.

According to McMaster University's Academic Integrity Policy, you are engaging in academic dishonesty if you "knowingly act or fail to act in a way that results or could result in unearned academic credit or advantage" (Academic Integrity Policy, p. 6). This behaviour can result in serious consequences, such as a grade of zero on an assignment, loss of credit with a notation on the transcript that reads “Grade of F assigned for academic dishonesty," and/or suspension or expulsion from the university. It is your responsibility to understand what constitutes academic dishonesty. The following are just three forms of academic dishonesty:

1. Plagiarism.
2. Improper collaboration.
3. Copying or using unauthorized aids in tests and examinations.

For more information on academic dishonesty and academic integrity, please read the Academic Integrity Policy: http://www.mcmaster.ca/academicintegrity

Online Privacy
This course makes use of an online discussion forum. You should be aware that your chosen forum username will be apparent to all other students in the course. The

technology used in the course web pages is designed to keep private all additional information you provide (your name, email address, student number, and passwords). However, you should be aware that submission of such information on this or any other web site always carries some risk that the information will become public (for example, if the web site is "hacked"). Your continuation in this course will be interpreted to indicate that you consent to the disclosure of your chosen username in the online forum, and that you accept the risk of submitting the additional requested information. If you have any questions or concerns about the privacy of your information, please discuss these with the instructor.

Weekly Schedule

The table below shows weekly lecture topics, corresponding textbook readings, and homework assignments. Students are encouraged to read the assigned material prior to each class period. Prior to each class, the instructor will post the majority of the slides to be shown in lecture. For your convenience, the slides will be posted in three PDF formats: Small (four slides per page), Lined (three slides per page, with lines on the right for taking notes), and Large (one full-size slide per page). In the table, HW = individual homework assignment; EB = Everyday Bayes group assignment.

Week	Topic	Assignment Due
	Part 1: Basic Bayes; Parameter Estimation	
Jan 6	Basic Bayes: coins, apples, and other interesting items (Ch. 1)	--
Jan 13	Basic Bayes: medicine and genetics (Ch. 1)	HW 1
Jan 20	Basic Bayes: experimental design, scientific skepticism, everyday Bayes (Ch. 1)	HW 2, EB 1
Jan 27	Parameter estimation: binomial and Poisson (Ch. 2)	HW 3
Feb 3	Parameter estimation: Gaussian (Ch. 2)	HW 4, EB 2
Feb 10	Midterm test (2 hours)	HW 5
	Part 2: Advanced Parameter Estimation; Model Comparison; Bayesian Brain; Decision Theory	
Feb 24	Curve fitting (Ch. 3)	GS HW A, EB 3
Mar 2	Robust estimation (Ch. 4)	HW 6
Mar 9	Hierarchical models and advanced numerical methods (Chs. 5, 6)	HW 7, EB 4
Mar 16	Model comparison (Ch. 7)	HW 8
Mar 23	Bayesian brain: perception as Bayesian inference (Chs. 9, 10)	HW 9, EB 5
Mar 30	Bayesian decision theory (Ch. 11)	HW 10
Apr 6	Course review	GS HW B, EB 6
TBA	Final exam (comprehensive, 2.5 hours)	

Note: The course schedule may be modified during the semester, at the discretion of the instructor. Modifications will be made directly to the table above and announced in class.