**Bayesian modeling of behavior**
**Fall 2016 (graduate and undergraduate)**
**Wei Ji Ma**

This syllabus is subject to change. Changes will be announced in class and by email.

**Description**
This course will provide an intuitive yet mathematically rigorous introduction to Bayesian models of behavior in perception, memory, decision-making, and cognitive reasoning. This course is not about Bayesian data analysis, but about theories that the brain itself is a Bayesian decision-maker. Nevertheless, we will spend some time on model fitting and model comparison. The course will be taught at an introductory level, with many examples and basic exercises. Didactic principles will be strictly adhered to. If you wish to analyze your own data in a Bayesian framework, there will be an opportunity to do so in a final project.

**Prerequisites**
- Calculus 1 or equivalent
- Introductory course in probability or probability-based statistics. Ask the instructor if you are not sure.
- Ability to program in Matlab. If you have not programmed in Matlab before but have other programming experience, you will need to do a tutorial before the course starts.

Lecturer
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| **Lecture** | Wednesdays, 4-6 | Meyer 815 |
| **Recitation** | Thursdays, 2-4 | Meyer 815 |

**Office hours**
There will be no set office hours, but you can make an appointment anytime. Please schedule appointments at least 24 hours in advance.

**Materials**
- *Bayesian modeling of perception*, by Ma, Kording, and Goldreich. Will be distributed in electronic form

- You will need Matlab. If you have a laptop, please install Matlab on it before the course starts (instructions: http://www.cns.nyu.edu/~eero/math-tools/Handouts/matlab-installation.txt).

**Grading**

The total grade will be calculated as follows:

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| Best 9 of 11 homework sets | 55% |
| Project | 30% |
| Participation | 15% |

*Letter grade*

Your numerical grade will be turned into a letter grade according to the following scale: 90-100 A; 87-89 A-; 84-86 B+; 80-83 B; 77-79 B-; 74-76 C+; 70-73 C; 67-69 C-; 64-66 D+; 60-63 D; 57-59 D-; 0-56 F.

*Homework*

- There will be 11 homework sets. The lowest two homework grades will not be counted.
- Homework is due at 2 PM on each recitation Thursday, through NYU Classes → Assignments. You can only submit your work as a single attachment. Late homework will not be accepted by the system and will count as 0.
- Only typed work will be accepted. DO NOT handwrite or take a picture of handwriting. For equations, use Latex (free), Equation Editor for Word (free), or Mathtype (not free).
- You are expected to work on these homework assignments independently. If you are stuck on a problem:
    - Try your best first – this could mean struggling for hours, but that is often the best way to learn.
    - If you are still stuck, the preferred method is to contact the instructor.
    - If you ask a classmate for help after trying hard yourself, then you must indicate on your homework whom you worked with on what. You will not be penalized for learning with your peers. We ask that you say who you worked with for a few reasons: 1) Honesty. 2) We want to know what material is difficult so we can spend more time helping you learn. If you relied on a peer for a challenging question then we want to make sure that you understand the material before test time.

- Under no circumstances should you copy a classmate's answer, even if you modify it slightly. Copying someone else's work is cheating, is easy to detect, and will result in a grade of 0.
- If a classmate asks you for help on the homework: do not give them your answer – this is cheating and will result in a grade of 0. First, make sure that the classmate has tried their best on the homework. Second, explain how you got started and how you thought about the problem. If you can help someone learn that way, that is impressive.

*Project*

- The project will consist of developing and fitting a Bayesian model to a task not discussed in class.
- Logistical details will be announced later.

*Participation*

- Attendance is mandatory. Your participation grade will be based on attendance, as well as on participation during lecture and recitation.
- To request an excused absence, please email the instructor in advance.

**Schedule**

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| Week 1 | | **Probability is everywhere.** Where does uncertainty come from? Subjective probability distributions. Prior, likelihood, posterior. Matlab refresher. |
| Week 2 | HW 1 due | **All steps of Bayesian modeling in a simple example.** Gaussian prior, Gaussian noise model. Derive estimate distribution. |
| Week 3 | HW 2 due | **What can go wrong in Bayesian modeling**. Keeping the different variances and probability distributions apart. |
| Week 4 | HW 3 due | **Model fitting.** Maximum-likelihood estimation. Parameter recovery. Optimization algorithms. Summary statistics. |
| Week 5 | HW 4 due | **Cue combination.** Reprise of Weeks 2 and 3 for tasks in which multiple cues get combined |
| Week 6 | HW 5 due | **Binary decisions.** Making the link with signal detection theory. |
| Week 7 | HW 6 due | **Structure inference and marginalization.** Examples: categorization, visual search |
| Week 8 | HW 7 due | **Time and learning.** Evidence accumulation. Parameter updating. |

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| Week 9 | HW 8 due | **Cost and reward.** Expected utility |
| Week 10 | HW 9 due | **Neural Bayesian models.** How do neural populations encode probabilities? How do neural networks implement Bayesian computation? |
| Week 11 | HW 10 due | **Bayesian cognition.** Collected work of Josh Tenenbaum |
| Week 12 | HW 11 due | **Conceptual issues.** Are Bayesian models vacuous? Are they overly powerful? The importance of model comparison.<br>**Work on project** |
| Week 13 | | **Work on project** |
| Week 14 | | **Project presentations** |