Course Syllabus

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Quantitative Neuroscience Core

Instructor	Joshua Gold	jigold@pennmedicine.upenn.edu
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Meeting times	MWF	9–10 am
Meeting Location	Barchi Library	

Introduction

This course is designed to be an overview of quantitative approaches used for rigorous and reproducible neuroscience research. This course does not cover statistics in a traditional way, in the sense that we will not provide a comprehensive survey of statistical tests, nor will we dive very deeply into formal mathematical derivations of those tests (information about such things can be found in textbooks and all over the web). Instead, we will focus on teaching you to apply quantitative approaches to your thinking about neuroscience research from beginning to end, including defining clear hypotheses; designing experiments to test those hypotheses; then collecting, visualizing, analyzing, and interpreting data in reference to those hypotheses.

There are two main components to the course. The first component consists of a series of four modules, each of which is designed to use a specific example from neuroscience to illustrate a set of quantitative approaches and tools. The second component consists of group projects that focus on designing and implementing quantitative analyses for existing data sets (e.g., from your rotation project).

Learning Objectives

1) Develop good habits for transparent, reproducible science. Transparency is the idea that none of your data or methods should be hidden. Reproducibility is the idea that you should be designing, conducting, and analyzing experiments in a way that maximizes the probability that someone else doing the same

experiments would come to the same conclusions. To support these ideas, we will incorporate into the course the use of several on-line tools that, even if you do not end up using these particular tools in your own research, will help establish good habits for record keeping (we will use LabArchives electronic notebooks, **https://researchnotebooks.upenn.edu** (https://researchnotebooks.upenn.edu/), version control for code (we will use GitHub, **https://github.com** (https://github.com/), and data storage (we will use PennBox: **https://upenn.app.box.com** (https://upenn.app.box.com/)).

2) Learn to think about statistics in the context of good experimental design. The question "what statistical test should I use?" can be answered only after answering more basic questions, like "what are the alternative hypotheses that I am testing?"and "how well does my experimental design allow me to distinguish those hypotheses?"

3) Learn foundations of statistical reasoning, particularly how to think about randomness using probability distributions. Even the most sophisticated statistical procedures are ultimately about distinguishing signal from noise. This ability depends on understanding what is meant by "noise", or randomness. The primary mathematical tool for quantifying and manipulating randomness is the probability distribution, which describes the probability of obtaining all possible values of a quantity of interest (e.g., the outcome of an experiment). We therefore will spend some time learning about probability distributions and then build on those concepts to better understand how to use probability distributions to make inferences.

4) Learn to visualize your data effectively to lay bare your statistical reasoning. Ultimately your ability to convince other people that you have a robust finding will not depend on the results of a statistical test but rather on your ability to show the finding in a clear and compelling way; that is, in a way that is transparent in terms of what you measured, clearly reflects the experimental design, and illustrates both the signal and noise that you found. We will focus on specific ways to visualize data effectively throughout the course.

Using Matlab

We will use Matlab (**https://www.mathworks.com** (https://www.mathworks.com/)) in this course, so it will benefit you to have at least a rudimentary understanding of how to use it. It is available for free to all BGS students (please contact Christine for instructions on how to get it). We suggest that you get a copy as soon as possible and learn to use its basic functionality.

How to use the tutorials and exercises

Numerous class sessions will involve in-class discussions and homework involving Matlab. For Matlab-based tutorials (e.g., this **one** (https://github.com/PennNGG/Statistics/blob/master/ConfidenceIntervals/ConfidenceIntervals.m) that we will cover early in the course), you should download the code from GitHub to your computer, then go through the tutorial line-by-line, executing one line of code at a time. The goal of these tutorials is to give you a detailed perspective on a particular topic, and how to implement various concepts in Matlab code. For Matlab-based

exercises (e.g., the "Quantal release" exercises here that we will cover early in the course), you should try to answer the questions yourself in Matlab; answers are given in posted files on GitHub that you can then use to check your answers.

Resources for Learning Matlab

- From Mathworks: https://www.mathworks.com/help/matlab/getting-started-with-matlab.html (https://www.mathworks.com/help/matlab/getting-started-with-matlab.html)
- Coursera: https://www.coursera.org/learn/matlab (https://www.coursera.org/learn/matlab)
- Wallisch et al, *Matlab for Neuroscientists*(https://www.sciencedirect.com/book/9780123838360/matlab-for-neuroscientists (https://www.sciencedirect.com/book/9780123838360/matlab-for-neuroscientists))
- The summer Matlab course offered by the NGG

Note for students who prefer Python: the long-term plan is to teach the course using Python, but we are not there yet. If you prefer to use Python now, please come talk to me – I am all for it but want to work out the details on an individual basis.

Other Resources

- The Society for Neuroscience, Promoting Awareness and Knowledge to Enhance Scientific Rigor in Neuroscience (https://neuronline.sfn.org/collection/promoting-awareness-and-knowledge-to-enhance-scientific-rigor-in-neuroscience)
- The Journal of Physiology, *Statistical Reporting Guidelines (https://physoc.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1469-7793(CAT)VirtualIssues(VI)StatisticalReporting)*
- BGS guidelines on the Responsible Conduct of Research (RCR) and Scientific Rigor and Reproducibility (SRR) (https://www.med.upenn.edu/bgs-rcr-exdes/)
- Motulsky, H. *Intuitive Biostatistics* (http://www.intuitivebiostatistics.com)
- Collected readings on quantitative rigor
- Tutorials and answers to exercises on the NGG statistics GitHub repository (https://github.com/PennNGG/Statistics)

Grading

Grades are based on: 1) class participation, including engagement in discussions (20%); and 2) a final project involving three in-class presentations (20% each) and electronic records of analysis strategies and code (20%).

For our philosophy of grading, see here (https://www.med.upenn.edu/ngg/handbook.html) .

Course Summary:

Date	Details	
Wed Jan 15, 2020	QNC Overview and goals (https://canvas.upenn.edu/calendar?event_id=2606684&include_contexts=course_1358934)	9am to 10am
Fri Jan 17, 2020	QNC Reproducibility and transparency I: Electronic Laboratory Notebooks (https://canvas.upenn.edu/calendar?event_id=2606695&include_contexts=course_1358934)	9am to 10am
Wed Jan 22, 2020	QNC Reproducibility and transparency II: Code Archives (https://canvas.upenn.edu/calendar?event_id=2617686&include_contexts=course_1358934)	9am to 10am
Fri Jan 24, 2020	QNC Probability Distributions I: Concepts (https://canvas.upenn.edu/calendar?event_id=2606700&include_contexts=course_1358934)	9am to 10am
Mon Jan 27, 2020	QNC Probability Distributions II: Binomial Distribution case study (https://canvas.upenn.edu/calendar?event_id=2606696&include_contexts=course_1358934)	9am to 10am
Wed Jan 29, 2020	QNC Probability Distributions III: Frequentist versus Bayesian Approaches (https://canvas.upenn.edu/calendar?event_id=2606701&include_contexts=course_1358934)	9am to 10am
Fri Jan 31, 2020	QNC Probability Distributions IV: Confidence Intervals (https://canvas.upenn.edu/calendar?event_id=2606702&include_contexts=course_1358934)	9am to 10am
Mon Feb 3, 2020	QNC Two-Sample Inference I: Experimental Design and Power Analysis (https://canvas.upenn.edu/calendar?event_id=2617711&include_contexts=course_1358934)	9am to 10am
Wed Feb 5, 2020	QNC Two-Sample Inference II: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617719&include_contexts=course_1358934)	9am to 10am
Fri Feb 7, 2020	QNC Two-Sample Inference III: T-Test (https://canvas.upenn.edu/calendar?event_id=2617720&include_contexts=course_1358934)	9am to 10am

Mon Feb 10, 2020	QNC Two-Sample Inference IV: Wilcoxon Test (https://canvas.upenn.edu/calendar?event_id=2617721&include_contexts=course_1358934)	9am to 10am
Wed Feb 12, 2020	QNC Measures of Association I: Case Study (https://canvas.upenn.edu/calendar?event_id=2617723&include_contexts=course_1358934)	9am to 10am
Fri Feb 14, 2020	QNC NO CLASS (NGG Recruitment) (https://canvas.upenn.edu/calendar?event_id=2617724&include_contexts=course_1358934)	12am
Mon Feb 17, 2020	QNC Measures of Association II: Parametric Correlation (https://canvas.upenn.edu/calendar?event_id=2617725&include_contexts=course_1358934)	9am to 10am
Wed Feb 19, 2020	QNC Measures of Association III: Nonparametric Correlation (https://canvas.upenn.edu/calendar?event_id=2617726&include_contexts=course_1358934)	9am to 10am
Fri Feb 21, 2020	QNC Measures of Association IV: Partial Nonparametric Correlation (https://canvas.upenn.edu/calendar?event_id=2617727&include_contexts=course_1358934)	9am to 10am
Mon Feb 24, 2020	QNC Modeling I: Case Study (https://canvas.upenn.edu/calendar?event_id=2617728&include_contexts=course_1358934)	9am to 10am
Wed Feb 26, 2020	QNC Modeling II: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617729&include_contexts=course_1358934)	9am to 10am
Fri Feb 28, 2020	QNC Modeling III: Model Parameterization (https://canvas.upenn.edu/calendar?event_id=2617730&include_contexts=course_1358934)	9am to 10am
Mon Mar 2, 2020	QNC Modeling IV: Model Fitting (https://canvas.upenn.edu/calendar?event_id=2617731&include_contexts=course_1358934)	9am to 10am
Wed Mar 4, 2020	QNC Student Presentations: Hypothesis (https://canvas.upenn.edu/calendar?event_id=2617732&include_contexts=course_1358934)	9am to 10am
	QNC Student Presentations: Hypothesis	

Fri Mar 6, 2020	(https://canvas.upenn.edu/calendar?event_id=2617733&include_contexts=course_1358934)	9am to 10am
Mon Mar 9, 2020	QNC Student Presentations: Hypothesis (https://canvas.upenn.edu/calendar?event_id=2617734&include_contexts=course_1358934)	9am to 10am
Wed Mar 11, 2020	QNC Student Presentations: Hypothesis (https://canvas.upenn.edu/calendar?event_id=2617735&include_contexts=course_1358934)	9am to 10am
Fri Mar 13, 2020	QNC Student Presentations: Hypothesis (https://canvas.upenn.edu/calendar?event_id=2617736&include_contexts=course_1358934)	9am to 10am
Mon Mar 16, 2020	QNC Student Presentations: Hypothesis (https://canvas.upenn.edu/calendar?event_id=2617737&include_contexts=course_1358934)	9am to 10am
Wed Mar 18, 2020	QNC Student Presentations: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617738&include_contexts=course_1358934)	9am to 10am
Fri Mar 20, 2020	QNC Student Presentations: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617739&include_contexts=course_1358934)	9am to 10am
Mon Mar 23, 2020	QNC Student Presentations: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617740&include_contexts=course_1358934)	9am to 10am
Wed Mar 25, 2020	QNC Student Presentations: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617741&include_contexts=course_1358934)	9am to 10am
Fri Mar 27, 2020	QNC Student Presentations: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617742&include_contexts=course_1358934)	9am to 10am
Mon Mar 30, 2020	QNC Student Presentations: Data Visualization (https://canvas.upenn.edu/calendar?event_id=2617743&include_contexts=course_1358934)	9am to 10am

Wed Apr 1, 2020	QNC Student Presentations: Statistics (https://canvas.upenn.edu/calendar?event_id=2617744&include_contexts=course_1358934)	9am to 10am
Fri Apr 3, 2020	QNC Student Presentations: Statistics (https://canvas.upenn.edu/calendar?event_id=2617745&include_contexts=course_1358934)	9am to 10am
Mon Apr 6, 2020	QNC NO CLASS (https://canvas.upenn.edu/calendar?event_id=2617746&include_contexts=course_1358934)	12am
Wed Apr 8, 2020	QNC NO CLASS (https://canvas.upenn.edu/calendar?event_id=2617747&include_contexts=course_1358934)	12am
Fri Apr 10, 2020	QNC NO CLASS (https://canvas.upenn.edu/calendar?event_id=2617748&include_contexts=course_1358934)	12am
Mon Apr 13, 2020	QNC Student Presentations: Statistics (https://canvas.upenn.edu/calendar?event_id=2617749&include_contexts=course_1358934)	9am to 10am
Wed Apr 15, 2020	QNC NO CLASS (https://canvas.upenn.edu/calendar?event_id=2617750&include_contexts=course_1358934)	12am
Fri Apr 17, 2020	QNC NO CLASS (https://canvas.upenn.edu/calendar?event_id=2617751&include_contexts=course_1358934)	12am
Mon Apr 20, 2020	QNC Student Presentations: Statistics (https://canvas.upenn.edu/calendar?event_id=2617752&include_contexts=course_1358934)	9am to 10am
Wed Apr 22, 2020	QNC Student Presentations: Statistics (https://canvas.upenn.edu/calendar?event_id=2617753&include_contexts=course_1358934)	9am to 10am
Fri Apr 24, 2020	QNC Student Presentations: Statistics (https://canvas.upenn.edu/calendar?event_id=2617754&include_contexts=course_1358934)	9am to 10am