## Advanced Biomedical Experimental Design & Statistics
### BMEG 802 (F-2021)

# Description ———

Understanding statistical analyses is an essential skill for scientists in academia and industry. Here we will discuss the philosophy of hypothesis testing, simulate datasets via sampling, and perform parametric and nonparametric tests. In additional to traditional tests (mean comparison, regression, ANOVA) we will also introduce some advanced techniques (maximum likelihood, Bayes, bootstrapping, and MCMC).

# Instructor Info ——

Dr. Joshua Cashaback

Friday, 3-5pm

201J

STAR Complex

joshcash@udel.edu

# Course Info ———

Lecture: M & W, 8:40-9:55am

ISE 322

NA

NA

# TA Info ——————

NA

NA

NA

NA

## UNIVERSITY OF DELAWARE.

## Overview

The ability to understand, perform and communicate statistics is an invaluable skillset in both academia and industry. The goal of this course is to form a strong foundation in statistics and probability that will guide us through fundamental and advanced techniques. This course will rely on students simulating datasets via sampling from probability distributions, which will be analyzed with both parametric and nonparametric tests. Module 1, Statistics and Probability Primer: We will review the building blocks of probability & statistics. Module 2, Fundamentals: Next, we will discuss several basic tests such as regression, hypothesis testing, effect size, and power analysis. Module 3, Omnibus Tests: This section will cover ANOVA (between, within, and mixed), ANCOVA, and nonparametric equivalents. Module 4, Advanced Techniques: Finally, we will introduce some more advanced techniques, including maximum likelihood, Bayes' Theorem, bootstrapping, and MCMC.

- Prerequisites: None

## Learning Objectives

- Understand the role and philosophy of hypothesis testing
- Build a stronger understanding of probability by using sampling and resampling techniques
- Identify the appropriate statistical tests to use.
- Perform basic to advanced statistical models.
- Develop an ability to write and communicate statistical results.

## Grading Scheme

| | |
|---|---|
| 60% | Biweekly Assignments (6 x 10% each) |
| 15% | Midterm |
| 10% | Individual Project |
| 15% | Final Exam |

## Material

There is no required textbook for this course. However, several additional resources will be provided to you in addition to lecture material. *Students are responsible for all material as it will appear on exams.*

## Assignments

The assignments are designed so that you will a) learn how to perform statistical analyses, and b) build confidence before the midterm and exam. The theme of each assignment are listed directly below. Late assignments will have 10% deduction for each day that the assignment is late. Note that you can work in groups, but each student needs to submit his/her own version of the assignment.

1. Hypothesis Testing, Effect Size, and Power
2. Regression
3. Between & Within AVOVA
4. Factorial ANOVA & ANCOVA
5. Maximum Likelihood and Bayes' Theorem
6. Bootstrapping and MCMC

## Midterm

There will be a take-home midterm exam worth 15% of the course grade. This will occur on [November 5th]. You will run the appropriate statistical tests on a number of data sets and interpret the results. There may also be some multiple choice and short-answer questions.

## Project

Each student will prepare a 5 page report (single space) on a statistical method not covered during lectures. Here the idea is to have you learn a statistical method that you or your advisor believes will be useful during your graduate studies. Students should emphasize: a) what the statistical method does, b) describe its theoretical basis, c) provide one or more worked examples, d) generate plots to show the results, e) interpret the results, and f) describe how you may use this technique in your studies. You can use real or generated data sets. Marks will also be given for the clarity of writing and figure quality. Students can choose a topic of their preference, with some possible topics listed below.

1. Survival Analysis (e.g., log-rank tests)
2. Information Criteria (AIC / BIC)
3. Bliss Independence and Loewe Additivity
4. Single Cell Analyses
5. Bioinformatics Analyses
6. Principle Component Analysis
7. Mixed Models
8. Hierarchical Modelling
9. Receiver Operator Curves (ROC)
10. Chi-Square and Fisher's Exact Test
11. Bayes Factor
12. Equivalence Testing
13. Fractional Factorial Analyses
14. MANOVA
15. Kalman, Particle Filters
16. Method of Moments
17. Entropy (e.g., Shannon, Sample, Approximate, Joint, Multiscale).

## Final Exam

The final exam will occur during the final exam period and the date will be scheduled by the University [December XX]. You will run the appropriate statistical tests on a number of data sets and interpret the results. There may also be some multiple choice and short-answer questions. The final exam will cover material from the entire course. The value of the exam will be 15% of your grade.

## Programming Language / Statistical Software

It is important to highlight that the goal here is for you to understand statistics and probability, which can be carried out in a variety of programming languages / software packages. To carry out these calculations you will use a programming language (R, Python, Matlab, etc.) or statistical software (e.g., R, SPSS, etc) of your choice. Different labs rely on different tools to run statistics analyses, and each has their own advantages and disadvantages. As such, you are free to learn a new tool or use the one your lab uses—whatever you feel is best for your education, graduate work, and future. Note that all sample code will be provided in R.

## Schedule

### MODULE 1: Probability, Statistics and Software Primer

Week 1: Sept 01
- Introduction

- Statistics & Probability Primer, R resources

Week 2: Sept 6, 8
- •Point and Continuous Probabilities

- •Lab 1

## MODULE 2: Fundamentals

Week 3: Sept 13, 15
- •Hypothesis Testing and Multiple Corrections

- •Lab 2

Week 4: Sept 20, 22
- •Effect Size and Power

- •Lab 3

Week 5: Sept 27, 29
- •Regression (bivariate, multiple)

- •Lab 4          • Assignment 1 report due Sept 27th before class.

## MODULE 3: Omnibus Tests (General Linear Models)

Week 6: Oct 4, 6
- •1-Way (Between) ANOVA

- •Factorial ANOVA, Kruskal Wallis      • Assignment 2 report due Oct. 6th before class.

Week 7: Oct 11, 13
- •Within ANOVA, Friedman Test

- •Lab 5

Week 8: Oct 18, 20
- •Between-Within ANOVA (Mixed Model)

- •Lab 6          • Assignment 3 report due Oct. 18th before class.

Week 9: Oct 25, 27
- •ANCOVA

- •Lab 7          • Assignment 4 report due Friday before 1pm.

## MODULE 4: Advanced Techniques

Week 10: Nov 1, 3
- •Maximum Likelihood

- •Lab 8, Midterm Review      • Take Home Midterm on Nov. 5th.

Week 11: Nov 8, 10
- •Bayesian Statistics

- •Lab 9

Week 12: Nov 15, 17
- •NO CLASS — SfN Conference      • Assignment 5 report due Nov. 17th before midnight.

Week 13: Nov 22, 25
- •NO CLASS — THANKSGIVING BREAK

Week 14: Nov 29, Dec 1
- •Markov chain Monte Carlo (MCMC)

- •Lab 10

---

Week 15: Dec 6, 8
- •Bootstrapping

- •Lab 11, Final Review

- Assignment 6 report due Dec 10th before 1pm.

- Project due Dec. 13th.

- Take Home Final on Dec. 15th.

---

## Grading Scale

| Letter Grade | Percent Grade |
| --- | --- |
| A | 93-100% |
| A- | 90-92.99% |
| B+ | 87-89.99% |
| B | 83-86.99% |
| B- | 80-82.99% |
| C+ | 77-79.99% |
| C | 73-76.99% |
| C- | 70-72.99% |
| D+ | 67-69.99% |
| D | 63-66.99% |
| D- | 60-62.99% |

## CANVAS

The syllabus, lectures and assignments will all be posted on CANVAS. I will attempt to have all lectures posted the day before the corresponding class.

## Attendance

You are highly encouraged to attend class to maximize your educational experience. That being said, attendance is not mandatory except for the midterm, final, and handing in assignments.

Absences on religious holidays listed in university calendars are recognized as an excused absence. Nevertheless, students are urged to remind the instructor of their intention to be absent on a particular upcoming holiday. Absences on religious holidays not listed in university calendars, as well as absences due to athletic participation or other extracurricular activities in which students are official representatives of the university, shall be recognized as excused absences when the student informs the instructor in writing during the first two weeks of the semester of these planned absences for the semester.

## Communication

If you have to get in touch with me via email, use the address listed above and put NEUROMECH-667 as the subject. *Note, I will NOT be answering homework or assignment questions via email, so please utilize class time (including prior to and following class), LAB days, and office hours.*

## Academic integrity

Please familiarize yourself with UD policies regarding academic dishonesty. To falsify the results of one's research, to steal the words or ideas of another, to cheat on an assignment, to re-submit the same assignment for different classes, or to allow or assist another to commit these acts corrupts the educational process. Students are expected to do their own work and neither give nor receive unauthorized assistance. Complete details of the university's academic integrity policies and procedures can be found at sites.udel.edu/studentconduct/sgup/ Office of Student Conduct, 218 Hullihen Hall, (302) 831-2117. E-mail: student-conduct@udel.edu

## Harassment and Discrimination

UD works to promote an academic and work environment that is free from all forms of discrimination, including harassment. As a member of the community, your rights, resource and responsibilities are reflected in the non-discrimination and sexual misconduct policies. Please familiarize yourself with these policies at www.udel.edu/oei . You can report any concerns to the University?s Office of Equity & Inclusion, at 305 Hullihen Hall, (302) 831-8063 or you can report anonymously through UD Police (302) 831-2222 or the EthicsPoint Compliance Hotline at www1.udel.edu/compliance. You can also report any violation of UD policy on harassment, discrimination, or abuse of any person at this site: sites.udel.edu/sexualmisconduct/how-to-report/

## Faculty Statement on Disclosures of Instances of Sexual Misconduct

If, at any time during this course, I happen to be made aware that a student may have been the victim of sexual misconduct (including sexual harassment, sexual violence, domestic/dating violence, or stalking), I am obligated to inform the university's Title IX Coordinator. The university needs to know information about such incidents in order to offer resources to victims and to ensure a safe campus environment for everyone. The Title IX Coordinator will decide if the incident should be examined further. If such a situation is disclosed to me in class, in a paper assignment, or in office hours, I promise to protect your privacy–I will not disclose the incident to anyone but the Title IX Coordinator. For more information on Sexual Misconduct policies, where to get help, and how to reporting information, please refer to www.udel.edu/sexualmisconduct. At UD, we provide 24-hour crisis assistance and victim advocacy and counseling. Contact 302-831-1001, UD Helpline 24/7/365, to get in touch with a sexual offense support advocate.

For information on various places you can turn for help, more information on Sexual Misconduct policies, where to get help, and reporting information please refer to www.udel.edu/sexualmisconduct.

## Accommodations for Students with Disabilities

Any student who thinks he/she may need an accommodation based on a disability should contact the Office of Disability Support Services (DSS) office as soon as possible. Students who have documentation of their need for accommodation should register via the SAM platform: andes.accessiblelearning.com/UDEL/. Reach DSS in the following ways: Visit at 240 Academy Street, Alison Hall Suite 130, Phone: 302-831-4643, fax: 302-831-3261, DSS website. Email: dssoffice@udel.edu

## Non-Discrimination

The University of Delaware does not discriminate against any person on the basis of race, color, national origin, sex, gender identity or expression, sexual orientation, genetic information, marital status, disability, religion, age, veteran status or any other characteristic protected by applicable law in its employment, educational programs and activities, admissions policies, and scholarship and loan programs as required by Title IX of the Educational Amendments of 1972, the Americans with Disabilities Act of 1990, Section 504 of the Rehabilitation Act of 1973, Title VII of the Civil Rights Act of 1964, and other applicable statutes and university policies. The University of Delaware also prohibits unlawful harassment including sexual harassment and sexual violence.

For inquiries or complaints related to non-discrimination policies, please contact: Interim Director, Institutional Equity & Title IX Coordinator - Fatimah Stone titleixcoordinator@udel.edu, 305 Hullihen Hall Newark, DE 19716 (302) 831-8063

For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact: Elizabeth Reed, Interim Director Office of Disability Support Services and University ADA Compliance Coordinator - ecreed@udel.edu, Alison Hall, Suite 130, Newark, DE 19716 (302) 831-4643 OR contact the U.S. Department of Education - Office for Civil Rights.