EMORY | ROLLINS SCHOOL OF PUBLIC HEALTH

Course Information

Title: Advanced causal inference
Number: BIOS 760R
Semester: Fall 2022 (08/24 - 12/06)
Credit hours: 4
Course schedule: Mon-Wed 3:00-4:50pm, [location]

Instructor

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Teaching Assistants: [TBD]

Course Description

This course focuses on drawing causal conclusions from observational data. We start with introducing graphical models and semiparametric efficiency theory as two major tools in causal methodology. The rest of the course is divided into three main parts. The first part focuses on a major challenge in using observational data which is the presence of unmeasured confounders. We study this issue and discuss ways to tackle it via a series of methods including nonparametric graphical approaches and parametric approaches such as the use of instrumental variables. We also discuss conducting sensitivity analysis and deriving bounds as alternatives when the causal effect of interest is not identifiable. The second part focuses on different types of causal questions that one might be interested in. We look into mediation analysis and path-specific effects, as well as dynamic treatment regimes and policy learning. In the third part of the course, we dive deeper into classical assumptions in causal inference and discuss complications such as dependent samples, missing data, and unknown causal structures.
This course is an elective for BIOS PhD students and is open to PhD students from other departments on a limited, case-by-case basis.

Prerequisites

Knowledge of basic probability and statistical theory is required – BIOS 513 (or an equivalent course) is strongly recommended. Proficiency in R, at least at the level taught in BIOS 545, is required. BIOS 761 is strongly recommended.

Learning Objectives

Upon conclusion of the course, students should be able to:

- Mathematize a counterfactual question of interest, evaluate identification assumptions, and find estimation strategies to compute the target via finite samples.

- Describe the uses and limitations of observational data in inferring causal conclusions.
- Define causal and statistical models of a directed acyclic graph.
- Have a reasonable grasp on influence function theory.
- Given a causal model, identify and estimate mediation and path-specific effects.
- Discover ways in which causal inference can be useful for tackling various sources of bias in data analyses.
- Understand when to give up on causal interpretations of study findings.

Evaluation

Student grades will be based on:

- Five ($\sim$ biweekly) homework assignments (each constitutes 15% of the final grade for a total of 75%)
  The assignments will include theoretical problems, data analysis, and programming in R. The assignments must be typeset, preferably in LaTeX, and submitted online via Gradescope (specific instructions will be provided during the first lecture). The LateX template will be provided for each assignment.
- Class participation 5%
  Class participation will be conducted via random in-class quizzes
- Final take home exam 20%
  The final exam will be a mix of proofs and code implementation.

Grade scale

A	$93-100\%$	B+	$87-89.9\%$	B-	$80-82.9\%$	F	$<65\%$
A-	$90-92.9\%$	B	$83-86.9\%$	C	$65-79.9\%$		

Course Calendar ($\sim$ 14 weeks)

- **Week 1** Introduction
  - Causal questions: the lay of the land
- **Week 2** Causal inference and confounding bias
  - Average causal effect
  - Identification and estimation
- **Week 3** Causal graphical models
  - Different causal frameworks
  - Causal Directed Acyclic Graphs (DAGs)
  - Directed Acyclic Mixed Graphs (ADMGs)
    HW # 1 announcement
- **Week 4** Semiparametric estimation
  - Influence functions
  - Efficiency theory
- **Week 5** Unmeasured confounders (1/3)
  - Nonparametric approaches
  - Front-door model and its extensions
    HW # 2 announcement
- **Week 6** Unmeasured confounders (2/3)

  - Parametric approaches
  - Instrumental variables
- **Week 7** Unmeasured confounders (3/3)
  - Sensitivity analysis
  - Point identification vs bounds

  HW # 3 announcement
- **Week 8** Causal pathway analysis (1/3)
  - Single mediator: definitions, identification
  - Single mediator: estimation
- **Week 9** Causal pathway analysis (2/3)
  - Multiple mediators: path-specific effects (PSEs)
  - Identification and estimation

  HW # 4 announcement
- **Week 10** Causal pathway analysis (3/3)
  - Separable effects
  - Stochastic interventions
- **Week 11** Dynamic treatment regimes
  - Value-search, Q-learning
  - G-estimation
- **Week 12** Missing data
  - Causal inference in the presence of missing data
  - Missing data as a causal inference problem

  HW # 5 announcement
- **Week 13** Causal discovery and model selection
  - Conditional independence restrictions
  - Generalized independence restrictions (Verma constraints)
- **Week 14** Interference and dependent data
  - Violation of SUTVA assumption
  - Partial interference

  Final take-home exam

Course Materials

There is no required textbook for this course. The following materials are useful for diving deeper into the content as you please.

- *Causal Inference: What If* by Miguel A. Hernan and James M. Robins. [Link]
- *Semiparametric Theory and Missing Data* by Anastasios A. Tsiatis.
- *Causality: Models, Reasoning, and Inference* by Judea Pearl. [Link]
- *Targeted Learning: Causal Inference for Observational and Experimental Data* by van der Laan and Rose.
- *Graphical Models* by Steffen L. Lauritzen (1996)
- *Statistical Methods for Dynamic Treatment Regimes (reinforcement learning, causal inference, and personalized medicine)* by Bibhas Chakraborty and E.M. Moodie.
- Selected papers, tutorials, websites to be shared as the semester progresses.

Course Policies

Students are expected to attend lectures and participate in discussions during class. Punctuality is important for class attendance. Late homework submissions (without prior approval of instructor) will be penalized (# of late days $\times$ 20% of the grade will be deducted). Late submission of the final exam (without prior approval of instructor) will result in an F grade. We will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates, the TAs, and myself. Rather than emailing questions to the teaching staff, I encourage you to post your questions on Piazza.

As the instructor of this course I endeavor to provide an inclusive learning environment. If you experience barriers to learning in this course, do not hesitate to discuss them with me and the Office for Equity and Inclusion, 404-727-9877.

RSPH Policies

Accessibility and Accommodations

Accessibility Services works with students who have disabilities to provide reasonable accommodations. In order to receive consideration for reasonable accommodations, you must contact the Office of Accessibility Services (OAS). It is the responsibility of the student to register with OAS. Please note that accommodations are not retroactive and that disability accommodations are not provided until an accommodation letter has been processed.

Students who registered with OAS and have a letter outlining their academic accommodations are strongly encouraged to coordinate a meeting time with me to discuss a protocol to implement the accommodations as needed throughout the semester. This meeting should occur as early in the semester as possible.

Contact Accessibility Services for more information at (404) 727-9877 or accessibility@emory.edu. Additional information is available at the OAS website.

Stress Management and Mental Health

As a student, you may find that personal and academic stressors in your life, including those related to remote study, COVID-19, economic instability, and/or racial injustice, are creating barriers to learning this semester. If you are struggling with concentration, motivation, or emotional concerns that feel overwhelming and are impacting your daily functioning, please know that there are university resources available to support you. For more information on these resources see:

- Counseling & Psychological Services
- Office of Spiritual & Religious Life
- Student Case Management and Interventions Services
- Student Health Services Psychiatry
- Emory Anytime Student Health Services
- Emory Student Telehealth - 24/7 Medical & Mental Health Support

Honor Code

You are bound by Emory University's Student Honor and Conduct Code. RSPH requires that all material submitted by a student fulfilling his or her academic course of study must be the original work of the student. Violations of academic honor include any action by a student indicating dishonesty or a lack of integrity in academic ethics. Academic dishonesty refers to cheating, plagiarizing, assisting other students without authorization, lying, tampering, or stealing in performing any academic work, and will not be tolerated under any circumstances.