

Causal inference and experimental design

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1 Class resources

- All resources: <https://macartan.github.io/ci>
- This syllabus: <https://macartan.github.io/ci/syllabus.pdf>
- Slides (in progress): https://macartan.github.io/ci/ci_2024.html
- Puzzles (in progress): <https://macartan.github.io/ci/exercises.html>
- [Student survey](#)
- Git repo <https://github.com/macartan/ci>

2 Times and locations

Institutsgebäude, Universitätsstraße 3b

Raum: K12B

- Jan 12: 12-14 (short introductory lecture)
- Jan 19: 12-18
- Jan 26: 12-18
- Feb 2: 12-18
- Feb 9: 12-18

The longer sessions will be structured roughly as follows.

- 12:00 - 13:50: lecture
- 13:50 - 14:30: team presentations and discussions
- 14:30 - 15:15: late lunch break
- 15:15 - 17:00: lecture
- 17:00 - 17:10: break
- 17:10 - 18:00: team presentations and discussions

3 Abstract

The course addresses advanced topics in causal inference and experimental design. It is a hands on course in which theoretical results are introduced through lecture, demonstrated in practice, and worked on in groups. Topics likely include sampling and randomization schemes, including multilevel trials, restricted randomization, and patient preference trials; Bayesian approaches to causal inference, exact inference: sharp nulls for complex hypotheses, inverting hypothesis tests, Mediation analysis, Multiple comparisons, Open science workflows.

4 Expectations

- 5 tasks
- (Required) Work in four “exercise teams”: 1 team (and typically 2 exercises) per session $\times 4$
- (Optional) Prepare a research design or short paper, perhaps building on existing work. Typically this contains:
 - a problem statement
 - a description of a method to address the problem
 - analytic or simulation based results describing properties of the solution
 - a discussion of implications for practice.
 - A passing paper will illustrate subtle features of a method; a good paper will identify unknown properties of a method; an excellent paper will develop a new method.
- Plus general reading and participation.

5 Readings

The course is primarily lecture and exercise based. We will not discuss readings in class, though some are relevant for different exercises. I do recommend the readings both for giving background to the lectures and for going beyond the lectures.

All readings are linked from this document.

I will draw material especially from two recent books I worked on, both open access:

- [Research Design in the Social Sciences](#)
- [Integrated Inferences](#)

I point a number of times to bits from this excellent draft text, also open access:

- [Hernán and Robins \(forthcoming\)](#)
- Cunningham’s “[mixed tape](#)” is a great accompanying read to fundamentals and topics:

Recommended non open access readings include:

- [Gerber and Green \(2012\)](#) with supplementary material available here: <https://isps.yale.edu/FEDAI>

6 Prerequisites

You should already have background in statistics up to the point with feeling comfortable with regression.

In addition you should know some R. Really, the more you can invest on getting on top of R before the class the better.

- Resources for learning R: <http://www.r-bloggers.com/how-to-learn-r-2/>

Please make sure your R is up-to-date and that you are working in R **studio**. Then make sure you have the following packages installed.

```
pacman::p_load(
  rstan,
  dagitty,
  DeclareDesign,
  CausalQueries,
  ri2,
  tidyverse,
  knitr
)
```

6.1 File Sharing via Git

I encourage you to set up and send me your `git` user names and we can access all materials on github. The git contains slides and exercises but will also have a folder structure where group presentations can be stored.

6.2 Writing with Rmd or qmd

Please plan to do drafting in Quarto. This is a simple markup language that lets you integrate writing and coding. This document is written in `quarto` and the slides will be also.

The key thing is that you can insert code chunks like this.

```
# Define a random number
x <- rnorm(1)
```

Code like this is run as the document compiles, and results can be accessed as needed, like this: we just sampled the random number $x = -0.8689442$.

I recommend using Rstudio as an editor. More information here: <https://quarto.org/docs/get-started/hello/rstudio.html>

7 Modules and Readings

7.1 Day 1: Intro

7.1.1 Course outline, tools,

- [Keele \(2015\)](#) gives a good high level overview of many key ideas in this course
- See [Wickham, Çetinkaya-Rundel, and Golemund \(2023\)](#) on [Workflow](#) and [Quarto](#)

7.1.2 Introduction to Declare design

- [DD, Ch 2](#) introduces ideas at a high level
- [DD, Ch 13](#) gives more practical guidance on getting started

7.2 Day 2: Causality

7.2.1 Fundamental problems and basic solutions

- [II Ch 2](#), goes over both potential outcomes and DAGs
- [Holland](#) is a beautiful classic reading on the fundamental problem of causal inference
- Imai, King, and Stuart (2008)
- [Hernán and Robins \(forthcoming\)](#) Ch 6

7.2.2 2.2 General inquiries and causal identification

- [II Ch 4](#)
- [DD, Ch 7](#)
- See also: [Hernán and Robins \(forthcoming\)](#) (Section 3.1, 7.2, 8.4, 10.1)
- Lundberg, Johnson, and Stewart (2021)

7.3 Day 3: Estimation and Inference

7.3.1 Frequentist

- [Freedman \(2008\)](#) helps make connections between design based inference and regression
- [Lin \(2012\)](#) relieves some worries you might have after reading Freedman (2008)

7.3.2 Bayesian

- [II ch 5](#) gives an introduction to Bayesian ideas
- `rstan`'s [Getting started](#) gets you going on `Stan`; try running the 8 schools model

7.4 Day 4:

7.4.1 Experimental Design

- [DD, Ch 8](#) on data strategies
- [DD, Ch 9](#) on answer strategies

7.4.2 Design evaluation

- [DD, Ch 7](#)

7.5 Day 5:

7.5.1 Topics and techniques

Readings here depend in part on our final topic selection but likely readings include:

- [Imai and Kim \(2021\)](#) and De Chaisemartin and d'Haultfoeuille (2020) on diff in diff
- [Imai, Keele, and Tingley \(2010\)](#) on mediation
- Knox, Lowe, and Mummolo (2020) on patient preference trials

7.5.2 Open science

- DD sections: [Ethics, PAPs, Populated PAPs, Reconciliation](#)
- [Alvarez, Key, and Núñez \(2018\)](#)
- [Humphreys, De la Sierra, and Van der Windt \(2013\)](#) on fishing and registration
- [Humphreys \(2015\)](#) on ethics in experiments

References

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- Gerber, Alan S, and Donald P Green. 2012. *Field Experiments: Design, Analysis, and Interpretation*. Norton.
- Hernán, Miguel A, and James M Robins. forthcoming. *What If?* Boca Raton: Chapman & Hall/CRC. https://www.hsph.harvard.edu/miguel-hernan/wp-content/uploads/sites/1268/2024/01/hernanrobins_WhatIf_2jan24.pdf.
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- Imai, Kosuke, Luke Keele, and Dustin Tingley. 2010. "A General Approach to Causal Mediation Analysis." *Psychological Methods* 15 (4): 309–34.
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- Wickham, Hadley, Mine Çetinkaya-Rundel, and Garrett Grolemund. 2023. *R for Data Science*. O’Reilly Media, Inc.