Midterm

Your Name - Net ID - Section Number

Due Oct 25, 2023

This midterm must be turned in on Brightspace by Oct 25, 2023. It must be your own work, and your own work only – you must not copy anyone's work, or allow anyone to copy yours. This extends to writing code. You **may not** consult with others. All work must be independent.

Your homework submission must be written and submitted using Rmarkdown. No handwritten solutions will be accepted. You should submit:

1. A compiled PDF file named yourNetID_solutions.pdf containing your solutions to the problems.
2. A .Rmd file containing the code and text used to produce your compiled pdf named yourNetID_solutions.Rmd.

Note that math can be typeset in Rmarkdown in the same way as Latex. Please make sure your answers are clearly structured in the Rmarkdown file:

1. Label each question part
2. Do not include written answers as code comments.
3. The code used to obtain the answer for each question part should accompany the written answer. Comment your code!

Problem 1 (25 points)

A cafe is testing out a promotion set to determine which pastry goes well with their new espresso blend. Customers are told that the promotion set is $5 for a cup of espresso and a random pastry item. After receiving the promotional set, they are asked to rate the product. There are two types of pastries: a sweet scone and a savory bagel, customers are randomly assigned to receive either type. Let $D_i = 1$ if the customer receives the bagel (the "treatment") and $D_i = 0$ if they receive the scone. Let Y_i denote the observed rating from the ith customer.

Part a (12 points)

In your own words, explain what the following quantities represent in this setting and indicate whether this quantity is observable without making assumptions: (4 points each)

1. $Y_i(1)$
2. $E(Y_i(1)|D_i = 0)$
3. $E(Y_i|D_i = 0)$

Part b (4 points)

Suppose we have 6 customers who bought the set this morning, the observed randomization and potential outcomes are:

Customer	D_i	$Y_i(1)$	$Y_i(0)$
1	1	5	5
2	1	9	5
3	0	8	6
4	0	4	1
5	1	8	5
6	0	7	5

Write down the individual treatment effects (ITE) and observed outcome for each customer.

Part c (4 points)

Estimate the difference in means (treatment - control) in this case using the table in part b, assuming consistency holds. Is this quantity equal to a causal effect in this case? Why or why not?

Part d (5 points)

The cafe hired a new barista who is very considerate. She asks each customer whether they prefer sweet or savory things, and then gives them their preferred pastry item with their espresso. Is it possible to estimate the average treatment effect of getting the bagel on ratings with data collected after this new barista was hired? Why or why not?

Problem 2 (25 points)

The STAR (Student–Teacher Achievement Ratio) Project is a four-year longitudinal study examining the effect of class size in early grade levels on educational performance and personal development (whether they finish high school). A longitudinal study is one in which the same participants are followed over time. This particular study lasted from 1985 to 1989 and involved 11,601 students. During the four years of the study, students were randomly assigned to small classes, regular-sized classes, or regular-sized classes with an aid. In all, the experiment cost around $12 million. Even though the program stopped in 1989 after the first kindergarten class in the program finished third grade, the collection of various measurements (e.g., performance on tests in eighth grade, overall high-school GPA) continued through to the end of participants' high-school attendance.

The variables of interest are:

1. classsize - Treatment variable - size of class before the fourth grade.
2. sex
3. race
4. g4math - total scaled score for the math portion of the fourth-grade standardized test
5. g4reading total scaled score for the reading portion of the fourth-grade - standardized test
6. gpa - high school gpa
7. grad - finish high school, 1 yes, 0 no

Part a (8 points)

Consider the variables $sex, classize, gpa$, and $grad$ Draw a DAG representing the causal relationship between them in this experiment.

```
library(dagitty)
# ?dagitty(): See the help file
```

Part b (10 points)

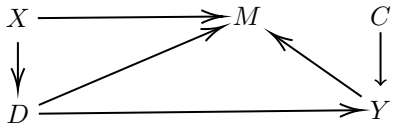
Suppose in the experiment, the researcher found out the CATE for female students is different from CATE for male students. We want to know whether these two CATEs are statistically different from each other. Can we conclude anything about this from the fact that one of them is statistically different from zero and the other is not? Why or why not?

Part c (7 points)

Imagine we wanted to estimate the effect of class size on finishing high school in this experiment. What would be necessary for you to control to estimate an unbiased treatment effect? How would you estimate the treatment effect? Explain your answer.

Problem 3 (25 points)

Consider the following Directed Acyclic Graph:



Part a (15 points)

List all of the paths from D to Y. On each path, identify confounders and colliders.

Part b (10 points)

Are there any variables that we should condition on in order to identify the causal effect of D on Y? Explain.

4 Design Your Study (25 points)

Design your own study from start to finish. Choose an *interesting* question that we have not mentioned in class. Answer the following questions: (1) Explain the effect you wish to estimate in words and why you think it's interesting. Carefully explain both your treatment, outcome, and the research question you wish to answer. (2) What is the "ideal experiment" for your question? (3) Draw the ideal experiment in a DAG. Can you estimate the effect of your treatment on your outcome? Is it identifiable and how do we know? (4) If you were to collect observational data on this topic, what potential confounders and mediators would exist? Please explain them in words. (5) Draw out a DAG that corresponds to this observational study. Please include at least one confounder and one mediator. (6) Using the DAG you drew in question 5, can you estimate the impact of your treatment on your outcome? Is the effect identifiable? Explain why or why not.

*Note: You cannot reuse an example we went over in class nor an example you used in a previous problem set.