Causality and Experimental Design

Instructions: Please work in groups of size three or four on the following problems. Make sure that everyone is included in this activity: if you see someone without a group, invite them to join yours! Please do not use your textbook or the internet.

1. For each pair of explanatory and outcome variables below, suppose that someone (who hasn't taken SDS 220!) conducts an observational study and arrives at the stated conclusions. Are these claims warranted? In particular, what is one possible confounder of the exposure/outcome relationship that might alternatively explain the association?

   (a) *We all scream for ice cream:* An investigator decides to look at the relationship between ice cream consumption and public welfare in New England. She finds that higher levels of ice cream consumption are associated with more deaths by drowning and concludes that ice cream represents a clear and present danger to the public.

   One possible confounding variable in this scenario is the season (namely whether or not it is summer): individuals are both more likely to eat/consume ice cream in the summer and more likely to frequent pools, beaches, lakes, etc.

   So, while the investigator is correct that ice cream consumption is associated with drowning incidents *when we don't adjust for or control these possible confounding variables*, her claims of causality (that ice cream is a danger because it causes deaths by drowning) are not warranted.

   (b) *Nurse Ratched is ready to see you now:* A researcher observes that towns with higher numbers of doctors also report higher numbers of crimes. They conclude that doctors must commit crimes at higher rate than the general population does.

   One possible confounding variable in this scenario is population size: larger towns are more likely to have higher counts of doctors and also higher overall numbers of reported crime:

   This association is not necessarily causal, and thus the researcher is not justified in making their particular conclusion about doctors going on crime sprees.

   (c) *Get a move on:* A physician notices that heart disease occurs more frequently in patients who are less physically active. On the basis of this observation, she starts recommending that all of her patients engage in at least thirty minutes of exercise every day.

   Physical inactivity is generally considered to be a significant risk factor for developing cardiovascular disease. However, heart disease is a complex disease, and physical activity isn't necessarily the *only* possible explanation or cause for its development. The previous two examples were settings in which confounding distorted a true *null relationship*: it created the appearance of a causal link between two variables (ice cream/deaths, doctors/crime) that, in actuality, likely have no causal

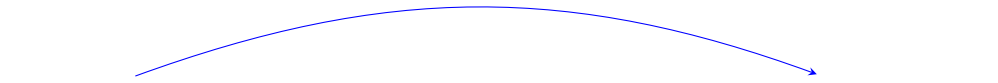
relationship with one another. But confounding can also distort true *causal relationships*: it can make two variables look either more or less related to one another than is strictly true. In this scenario, one possible confounder of the association between physical activity and heart disease is age: older individuals are both more likely to be inactive and more likely to have heart disease.

(This is partly why many clinical trials will block based on age: it is often an important confounder—particularly in medical contexts—and we want to ensure treatment allocation is balanced across age groups.) So, if the physician were basing her recommendations on this observational study only, she would be making recommendations based on an association that may or may not be causal.

2. A study shows that there is a positive correlation between the size of a hospital (measured by its number of beds, x) and the median number of days y that patients remain in the hospital. Does this mean that you can shorten a hospital stay by choosing a smaller hospital? Use a DAG to explain the association.

   Put another way, this question is asking whether the observation that "individuals who stay at smaller hospitals tend to spend less time hospitalized (i.e., have shorter durations of stay in the hospital)" is a statement about a *causal relationship* or an *association*. Is there some other confounding variable that might be driving the association the study found?

   One possible confounder in this setting is severity of illness/injury. Larger hospitals will generally have greater resources: they may have more specialized doctors/surgeons and more state-of-the-art equipment. They may also be more likely to serve as trauma centers, which are hospitals that are specifically equipped and staffed to provide care for patients with major traumatic injuries (falls, motor vehicle collisions, gunshot wounds, etc.). Thus patients with severe illness or injuries may be more likely to be admitted to larger hospitals *and* more likely to have longer admission durations.



   So no, you won't be able to shorten your hospital stay simply by choosing a smaller hospital.

3. A study is designed to test the effect of light level on exam performance of students. The researcher believes that light levels might have different effects on people who wear glasses and people who don't, so they want to make sure both groups of people are equally represented in each treatment. The treatments are fluorescent overhead lighting, yellow overhead lighting, and no overhead lighting (only desk lamps).

   (a) What is the response variable?

   The response variable is a student's exam performance.

   (b) What is the explanatory variable? What are its levels?

   The explanatory variable is the level of light in the room where students are taking the exam (aka our treatment). This is a nominal categorical variable taking on three levels: fluorescent overhead lighting, yellow overhead lighting, and no overhead lighting.

(c) What is the blocking variable? What are its levels?

The blocking variable is whether or not a student wears glasses, which is a nominal categorical variable. It has two levels: a student either (1) wears glasses or (2) doesn't.

4. Randomized experiments generally provide stronger evidence for the association between an explanatory and response variable than do observational studies. They also allow us to investigate and make claims regarding causality. Why aren't all studies done as experiments?

Although experiments represent an important "gold standard" in study design for their ability to control for all confounders (both measured and unmeasured), they are often impractical or unethical to conduct.

- Experiments tend to be incredibly costly. For medical/public health interventions, the process of enrolling patients, obtaining their informed consent for the experiment, randomizing them, administering the treatment/control, and following them over some period of time for the outcome of interest requires a lot of time, resources, money, and staffing. For lab/bench experiments, obtaining lab space, staffing the lab, purchasing reagents, and conducting the experiment can be similarly money and labor intensive.
- Some experiments may also be *unethical* to conduct. This is particularly the case when we consider conducting experiments on animals or on humans. In the medical field in particular, there is a long legacy/history of medical researchers conducting unethical experiments on minoritized and marginalized communities *without their fully informed consent*. (For some examples, see the Tuskegee Syphilis Study and the Puerto Rico Birth Control Trials.) This has led to incredibly important conversations about and strict codes of ethics for the responsible conduct of human experiments, summarized in (among other places) the Nuremburg Code and the Belmont Report. One of the key ethical tenets of clinical research is *equipoise*: we only have ethical justification to randomize individuals to different medical treatments if we are genuinely uncertain about the comparative benefits of those treatments. The second that we have conclusive evidence that one treatment provides greater therapeutic benefit than another (or that one treatment provides greater harm), we need to stop our experiment. This also means that certain types of experiments—like those looking at the health consequences of smoking or air pollution exposure or food toxins—are not ethical to conduct at all.

So we often need to rely on observational data to answer our research questions.