

# Study Design

Grinnell College

September 20, 2024

We have spent time over the last few weeks focused on what we can do with data.

- Making graphics + visuals
- Describing graphics + visuals
- Tables

Statistics (largely) involves the following three broad domains:

- Design – how do we obtain our data
- Description – graphics and summaries
- Inference – decision-making

By the end of today you will be able to answer:

- What is the difference between experiments and observational studies?
- How do we make *causal* claims?
- How do we avoid *biases* in our data?

## Review (again)

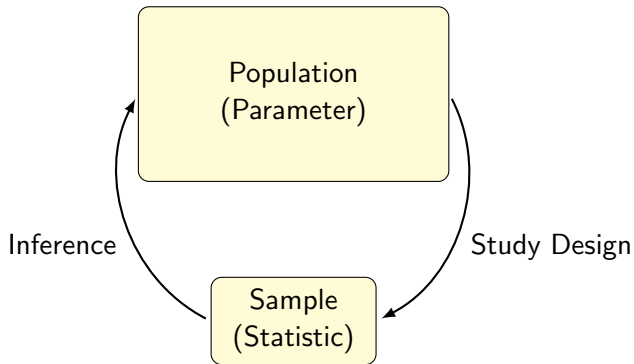
**Population** is a big group of subjects/events/things about which we wish to learn about

**Parameter** is a *quantifiable* attribute of a population. Most of the time, the parameter value is unknown

**Sample** is a much smaller, subgroup of a larger population

**Statistic** is a numerical summary of the sample that we calculate from our sample data

# The Statistical Framework



# Anecdotal Evidence

source: IMS Textbook

- 1) A man on the news got mercury poisoning from eating swordfish, so the average mercury concentration in swordfish must be dangerously high.
- 2) I met two students who took more than 7 years to graduate from Duke, so it must take longer to graduate at Duke than at many other colleges.
- 3) My friend's dad had a heart attack and died after they gave him a new heart disease drug, so the drug must not work.

# Types of Studies

**Experiments** are studies that involve manipulating a *treatment* that each participant receives

- typically treatments are *randomly assigned* to participants
- we then measure participants' *response* to the treatment
- the treatment is the explanatory variable

**Observational Studies** are studies that do not involve manipulating the explanatory variables for participants.

- we are simply "observing" what is going on without intervening
- nearly all surveys are observational studies

# Types of Studies – Conclusions

The type of study affects the conclusions we can draw from data.

## Experiments

- Good experiments with *random assignment* of treatments can establish a cause-and-effect relationship
- We need to control everything that could change the response except for the treatments
  - ▶ randomization of treatments is the best way to accomplish this

## Observational Studies

- No random assignment → can't definitively establish cause-and-effect relationships
- we are limited to talking about associations only



**Surveys** are a type of observational study where we ask people about their attitudes/opinions/beliefs

Some important things to think about:

- How do we select people we talk to?
- How many people do we talk to?
- How do we obtain information?
  - ▶ phone, email, in-person?

How do we select people?

We want our sample to be **representative** of our population.

- this means that our sample is nearly the same as our population, only smaller
  - ▶ i.e.: same proportions M/F, same age/ethnic demographics
- a representative sample allows us to generalize our results from the sample to the pop.
- **biased**: a sample that is **not** representative

Not always possible to get a representative sample, but this is what we want to strive for

# How do we select people?

## Random Sample

We can choose people at random from our population to reduce the chances of getting a biased sample.

- usually the best way to get a representative sample
- allows us to **generalize** from our sample to the pop.

## Sample Size ( $n = ?$ )

- number of people we survey is important (more people = more info)
- sample size is very important, but proportion of pop. surveyed is not
- better to have small sample that is representative, than a large sample that is biased

# How do we select people?

**Census** – Would conducting a census of the entire population be better?

Issues

- difficult
- time consuming
- expensive

# Sampling Methods

## Simple Random Sample (SRS)

- each combination of observations has same chance of being selected
- if we were to select multiple SRSs again, different observations will be chosen
  - ▶ variability by sampling → sampling variability

## Stratified Sample

- **strata**: subgroups of pop., within each the individuals are similar
  - ▶ individuals within a strata are similar, but strata themselves can be very different
- we take a SRS from each strata to ensure each group has representation

[geologylearn.blogspot.com/2015/10/rock-layers.html](http://geologylearn.blogspot.com/2015/10/rock-layers.html)



# Sampling Example

Scenario: We want to ask 200 Grinnell students their opinion on if they prefer living in the dorms

**How do we do this with an SRS?**

**Why might we want to use a stratified sample?**

# Biased Samples

**Biased** samples are not representative of the population

## **Voluntary Response Sample**

- people select themselves to participate
- usually people with strong opinions respond to surveys

## **Convenience Sample**

- people are chosen in a non-random way
  - ▶ poll at a specific location
- name comes from the fact that this is 'easy' to do

# Biased Samples

## Sampling Bias

- bad sampling methods
- **undercoverage**: certain groups may not be represented in samples
- **sampling frame** (list of who we can sample from) may be missing some of the population

## Non-response Bias

- some people can't be surveyed or choose not to participate

## Response Bias

- we don't always get accurate info from people
- question wording
- not wanting to provide truthful answers



# Biased Samples

It is not always possible to take a random sample from the population.

- Clinical trials (ethical issues)
- random sample of all humans?
- random sample of all fish?

## Big Ideas

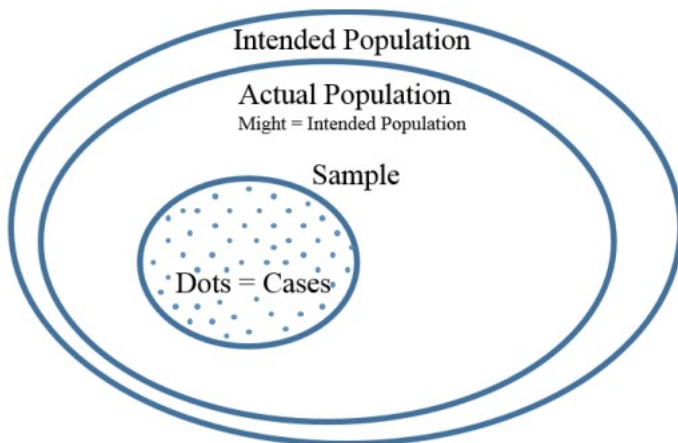
Watch for ways in which the sample may be different from the population.

Non-random sample may not represent our intended population, so we may need to rethink our population.

Actual population may not always be clearly defined

- all people willing to participate in a survey?
- all fish that we had access to while collecting data?

# Intended vs. Actual population



source: Dr. Ziegler's Stat 104 notes (ISU)

# Observational Studies

## Observational Studies (again)

Studies where we simply 'observe' what is happening.

- we **can** see associations between variables
- we **cannot** make causal connections between variables

Further classification:

- **Prospective study**: pick our sample and collect data as things happen
- **Retrospective study**: look at historical data or past records

# Experiments

## Experiments (again)

- study where researchers manipulate explanatory variables to see effect
- explanatory variable values are randomly assigned to each participant

## Experimental Units (EUs)

- the observations (= cases) within our experiment
- who/what the experiment is actually performed on
- experimental unit = subject = participant

# Experiments

## Factors

- another name for the explanatory variables in the experiment
- each experiment must have at least one factor
- these are the variables being manipulated for each subject
- **levels** of a factor = values used for that factor
  - ▶ each factor needs at least two levels

## Treatments

- combo of factors and levels that are given to an EU
- one factor → levels = treatments

## Response Variables

- EUs' response to a treatment
- can have multiple response variables
- can be quantitative or categorical (blood pressure vs 'did blood pressure improve')

# Designing Experiments

There is much more that goes into designing good experiments. Below are a few commonly used principles. Unfortunately many different principles have the same / similar names.

## Control – 2 types

- comparing a treatment to a control group that did not receive the treatment
  - ▶ treatment vs placebo (or vs 'Gold Standard')
  - ▶ not used in all experiments
- control outside sources that might affect response (other variables)

## Replication – 2 types

- having multiple *replicates* (cases = EUs) for each treatment
- *repeatability*: being able to repeat an experiment and get similar results
  - ▶ same results with a new sample?
  - ▶ do you trust results of a study that we can't confirm on a different sample?

# Designing Experiments – Randomness (2 types)

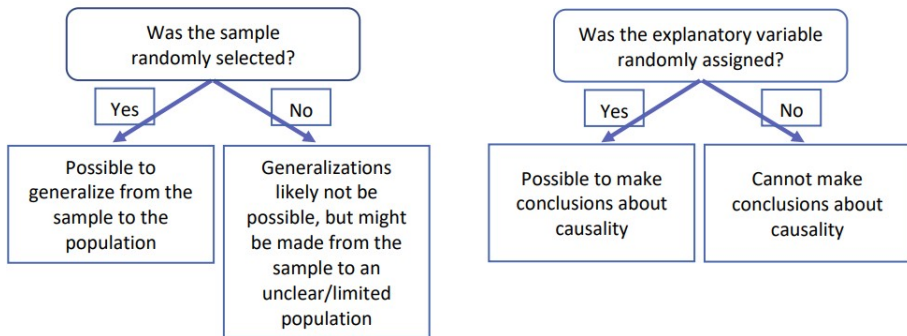
**Random Sampling:** picking our sample at random from the population

- goal: get sample that is very similar to our population (representative)
- allows us to generalize our conclusions about the sample to the entire population

**Random Assignment** (randomization): randomly assigning each EU to receive one of the treatments

- allows us to make cause-and-effect claims
- balances out effect of confounding variables between both groups so that they don't affect our results
- results in treatment groups being similar in every regard except for which treatment they receive

# Experiments – Randomness



source: Modified Figure 1.3 from Locke et. al. textbook, Dr. Ziegler (ISU)



# Designing Experiments

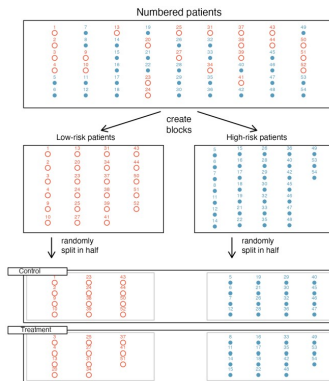
**Confounding Variable:** a variable that affects our results when we don't want it to

- makes it impossible to tell if explanatory variables actually **caused** changes in response

## Blocking (not tested on)

Sometimes we know ahead of time that a particularly variable is likely to mess with (confound) our results

- group EUs into **blocks** (similar EUs are grouped together)
- run experiment once for each block, compare results



source: IMS Textbook Fig. 2.6

# Wrapping up – Reflection

What is the difference between an Experiment and an Observational Study?

Why do Experiments let us make cause-and-effect conclusions?

What are some ways we can avoid biases when getting our sample?