# Chapter 11

## Experiments and Observational Studies

D. Raffle
6/1/2015

# Recall

When we study populations:

- We are usually interested in some number or **parameter** that describes the population.
- We estimate parameters with **statistics**, which are calculated from **samples**
- Samples are randomly drawn from the population of interest
- If our sample is **representative**, our statistics will be good estimators of the parameters.

# Experiments and Observational Studies

There are two major types of studies:

- Experiments
- Observational Studies

Observational studies can be further broken down into:

- Prospective Studies
- Retrospective Studies

# Case Study

Consider the following study:

- To examine the effect of music programs on academic performance, a sample of students music students and non-music students were collected at a particular high school.

They found the following average GPAs:

- Music students: 3.59
- Non-Music Students: 2.91

What does this tell us?

- Should every student be forced to play an instrument?

# Observational Studies

Key characteristics:

- Researchers simply **observe** the subjects
- Various measurements or values are recorded for each subject
- Good for describing or discovering relationships, especially in large populations
- **Cannot** prove cause-and-effect, only provide evidence
- Handling lurking or confounding variables can be tough

## Case Study

For our students:

- This was an observational study
- Did they prove that playing an instrument increases grades?
- Other factors could be at play
- Families with more money can afford musical instruments and pay for tutors
- If you have to work after school, you don't have time for band practice or homework

# Retrospective Studies

Retrospective studies collect data on events that already occured

- This is the most common type of retrospective study

They can be unreliable:

- Rely on subjects' memories
- Historical records can be incomplete
- We only have information for people "in the system"

Examples:

- Medical Records
- Customer History
- Academic Records

# Prospective Studies

Prospective studies identify subjects first, then make observations as time goes on

- This is commonly used in genetics or family studies

Pros:

- Better for finding causal relationships
- Can record any variables we want, not just what's already in records

Cons:

- Takes a long time (often years)
- Can be expensive
- Rare events require very large samples

# Case Study

The study on music and academic performance could have been either type.

Retrospective:

- Choose a random sample of students in a given year
- Examine academic records of these students
- Calculate GPA

Prospective:

- Choose a random sample of kindergarten students
- Record their performance as they go through school and if/when they start in a music program

## Case Study

Which would have been better?

Retrospective:

- Can be done very quickly at any point in time
- Very cheap – just need to get records

Prospective:

- We can see if performance changed **for each student** as they picked up an instrument
- We can also track if they pick up a part-time job or have any family problems

# Experiments

While observational studies have researchers passively observing, researchers actively impose **treatments** on the subjects.

Examples:

- Clinical trials
- Scientific experiments
- Marketing trials
- Psychological experiments

Experiments are the **only** type of study that can prove cause-and-effect.

# Treatments

In experiments, we call the explanatory variables **factors** and their possible values **levels**. A **treatment** is a unique combination of factor levels.

Say we wanted to test the affects of medicine $X$ taken every 2 hours or every 4 hours, compared to a placebo.

- The factor *medicine* has levels: "X", "Placebo"
- The factor *interval* has levels: "2 hours", "4 hours"
- We get four treatments: "X, 2 hours"; "X, 4 hours"; "Placebo, 2 hours"; "Placebo, 4 hours"

# Performing Experiments

Designing an experiment is essentially just following the scientific method

1. Come up with a hypothesis (question)
2. Identify the **factors**
3. Identify the **response**
4. Select the **experimental units** (subjects, participants, classroom, petri dishes, etc.)
5. Decide on the **levels** of the factors and make **treatments**
6. Assign treatments to experimental units
7. Analyze the results and compare treatments

# Assigning Participants to Treatments

For any experiment (especially those with humans), decided who gets which treatment is important.

- Never let the subjects choose (or even know)
- Don't assign people to treatments based on what you think they need (giving the sickest the new drug)
- In fact, never assign treatments yourself
- Give each participant a label and let software **randomly** assign treatments

There's one catch

- Experiments can introduce ethical dilemmas

# Case Study

Say we want to study the relationship between Post-Traumatic Stress Disorder (PTSD) and suicide in veterans. What would the different studies look like?

Retrospective:

- Examine medical records of soldiers and compare suicide rates of those with and without PTSD

Prospective:

- Track soldiers as they get discharged and watch their mental health

Experiment:

- Randomly assign soldiers to high-pressure combat situations where they'd be likely to develop PTSD and see if they commit suicide in the following years

# Experiments: Major Principles

There are four major principles in experimental design:

1. Control
2. Randomization
3. Replication
4. Blocking

# Control

**Control** in an experiment means regulating as many conditions as possible, like:

- Temperature
- Time of Day
- Classroom conditions

Why?

- Controlling allows us to isolate the treatments we want to study
- This eliminates (or at least mitigates) the effects of lurking variables

# Randomization

Randomizing the assignment of treatments helps us by:

- Equalizing the effects of uncontrollable variation across the sample
- Distributes uncontrollable effects (lurking variables) evenly across the groups
- The effects of lurking variables will "average out" so they don't matter

Generally, we control what we can and randomize what we can't.

# Replication

When we **replicate**, we apply a treatment to more than once

- We assign multiple subjects the same treatment
- Ideally, we repeat the entire experiment on a new sample

Why?

- This helps us mitigate the chances of our results being a coincidence

# Blocking

When we **block**, we group similar observations together and apply all treatments within the block.

Why block?

- By blocking, we get more precise results by eliminating variation between the groups

Examples

- Blocking by gender if we expect men and women to react differently
- Blocking by age if we think it has a large effect

# Case Study

A certain researcher thinks that taking an herbal supplement will help insomniacs get to sleep.

What is the hypothesis?

- Taking the supplement decreases the time it takes for insomniacs to fall asleep

What is the factor?

- Take the herbal supplement or don't take it

What is the response?

- The time it takes to fall asleep

## Case Study

What are our experimental units?

- Individuals with insomnia

What are our treatments?

- Placebo or supplement (or various doses)

How do we assign treatments?

- Randomly, and without the subjects knowing

Analyzing

- Did the people who got the supplement fall asleep faster, on average?

## Case Study

Should we block here?

- People in different lines of work will have different stress levels
- Stress level can affect sleeping habits, so we should consider blocking on industry
- The supplement might affect men and women differently, so we might want to block on gender
- People often sleep less as they get older, so blocking by age range might be a good idea

# The Placebo Effect

The **control group** is a group that doesn't get a treatment. Unfortunately, there's a complication called the **placebo effect**

- People subconsciously react when they're told they might react to something.
- This means that we can't just give some people pills and not give anything to the others – our results might just be due to the placebo effect.
- To get around this, we give everyone a treatment, but some people get an inert treatment called a **placebo**

This isn't just limited to subjects

- If the researcher knows who gets the drug in a medical trial, they might act more hopeful when examining them
- The researcher can unknowingly influence the results of the trial

# Control Groups

We can mitigate the effects of the placebo effect using **blinding**

Single blinding:

- The subjects don't know whether they get the treatment or a placebo

Double blinding:

- Neither the subject nor the researcher know whether the subject got the treatment or a placebo

# Lurking and Confounding

Thus far, we've used lurking and confounding interchangeably when a third variable affects the relationship between two that we are interested in. There is a subtle difference.

Say we are interested in how $X$ affects $Y$, but there is a third factor $W$

Lurking Variable:

- $W$ affects both $X$ and $Y$
- $X$ and $Y$ are not related
- This can make it look like $X$ and $Y$ are associated
- Forest fires and ice creams sales are both linked to temperature

## Confounding Variables

- $W$ directly affects $X$
- $W$ may also be related to $Y$
- If we don't know about $W$, it will make it look like $X$ causes $Y$ exclusively
- Drinking habits and age of death might be related
- Drinking habits might also be related to social class
- Social class can also affect the age of death
- If we control for social class, we might not see an association between drinking and age of death

## Summary

- Observational studies are when researchers simply observe their subjects. They can be retrospective or prospective.
- In experiments, researchers actively impose a treatment on the subjects
- We can control for the placebo effect using blinding
- We can control for lurking and confounding variables with randomization, replication, and blocking