Week 4: Statistical theory

1. The magic of randomness: causation

Stat 140 - 02

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Slides posted at *http://sshanshans.github.io/stat140*

What do you think of when you hear the word

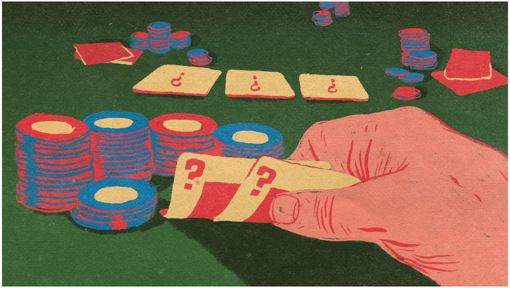
Random

"The most decisive conceptual event of twentieth century physics has been the discovery that the world is not deterministic ... A space was cleared for chance"

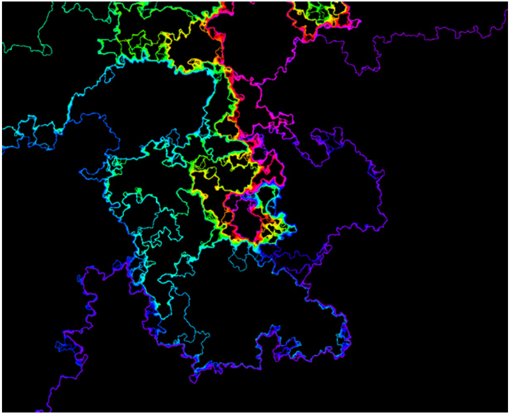
Ian Hocking, *The taming of chance*

Flip a coin

Toss a dice

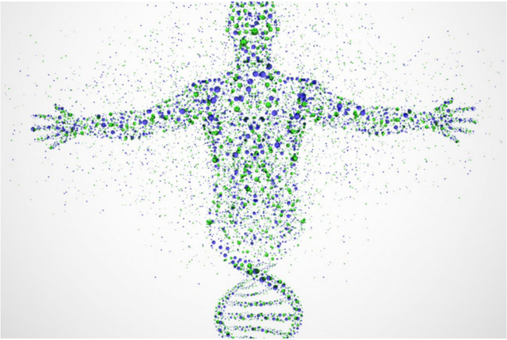


Gambling



Random shapes

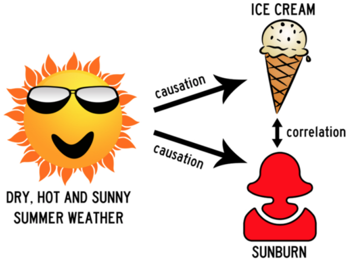
Mountain landscape



Gene mutation → evolution

In week 3, we looked at the relationship between two numerical variables.

Just because there is a linear relationship between two variables does not mean we have evidence that one variable causes the other.



"The invalid assumption that correlation implies cause is probably among the two or three most serious and common errors of human reasoning."

Stephen Jay Gould

Researchers observed from data that people who smoke get lung cancer at a higher rate than those who do not smoke. Does smoking cause lung cancer?

The tobacco lobby used to say no, arguing that:

- there might be a gene that predisposes people to both enjoy smoking and get cancer;
- people who like to smoke may tend to follow unhealthy lifestyles (e.g., alcohol use), and that may be the real cause of lung cancer;

The differences between lung cancer rates in the smokers and non-smokers may be due to smoking, or they may be due to a **confounding factor**. In this case, tobacco lobbies suggested two possible confounding factors: genes and lifestyle.

In seatbelt studies, one compares the fatality rates in accidents in which seatbelts were worn to the fatality rate in accidents without seatbelts.

Can you conclude that seatbelts save lives?
No. Remember there might be confounding factors.

What might be some confounding factors?

In seatbelt studies, one compares the fatality rates in accidents in which seatbelts were worn to the fatality rate in accidents without seatbelts.

But one has to worry about confounding factors. For example,

- People who don't wear seatbelts may drive more recklessly.
- People who don't wear seatbelts may prefer cars that are not designed with safety in mind.

The two possible confounding factors here are: driving behaviors and car safety preference.

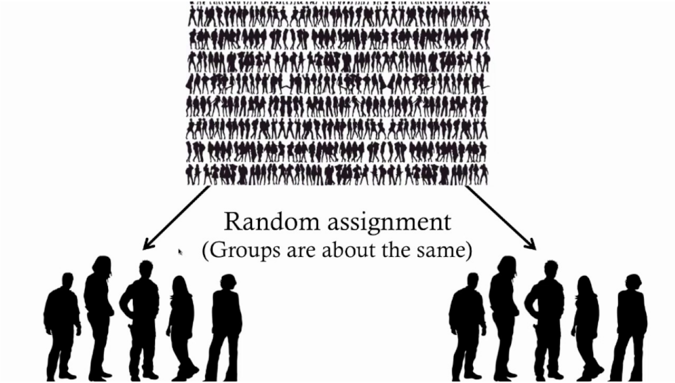
- A study found that elderly people who walked at least a mile a day had significantly higher brain volume (gray matter related to reasoning) and significantly lower rates of Alzheimer's and dementia compared to those who walked less
- The article states: *"Walking about a mile a day can increase the size of your gray matter, and greatly decrease the chances of developing Alzheimer's disease or dementia in older adults, a new study suggests."*

Poll question

Is this a valid conclusion?

a. Yes
b. No

How would you design an experiment to determine whether exercise actually causes changes in the brain?


Random assignment
(Groups are about the same)

- A sample of mice were divided randomly into two groups. One group was given access to an exercise wheel, the other group was kept sedentary
- "The brains of mice and rats that were allowed to run on wheels pulsed with vigorous, newly born neurons, and those animals then breezed through mazes and other tests of rodent IQ" compared to the sedentary mice

Poll question

Is this evidence that exercise causes an increase in brain activity and IQ, at least in mice?

a. Yes
b. No

If a randomized experiment yields a significant association between the two variables, we can establish causation from the explanatory to the response variable.

Randomized experiments are very powerful!
They allow you to infer causality

Researchers conducted a study on the effectiveness of a knee surgery to cure arthritis. It was randomly determined whether people got the knee surgery. Everyone who underwent the surgery reported feeling less pain.

Poll question

Is this evidence that the surgery causes a decrease in pain?

a. Yes
b. No

- When determining whether a treatment is effective, it is important to have a comparison group, known as the **control group**
- It isn't enough to know that everyone in one group improved, we need to know whether they improved more than they would have improved without the surgery
- All randomized experiments need either a control group, or two different treatments to compare

In the knee surgery study, those in the control group received a fake knee surgery. They were put under and cut open, but the doctor did not actually perform the surgery. All of these patients also reported less pain!

In fact, the improvement was indistinguishable between those receiving the real surgery and those receiving the fake surgery!

"The Placebo Prescription," NY Times Magazine, 1/9/00.

Often, people will experience the effect they think they should be experiencing, even if they aren't actually receiving the treatment. This is known as the **placebo effect**

One study estimated that 75% of the effectiveness of anti-depressant medication is due to the placebo effect

For more information on the placebo effect (it's pretty amazing!) read "The Placebo Prescription"

- Control groups should be given a placebo, a fake treatment that resembles the active treatment as much as possible
- Using a placebo is only helpful if participants do not know whether they are getting the placebo or the active treatment
- If possible, randomized experiments should be **double-blinded**: neither the participants or the researchers involved should know which treatment the patients are actually getting

- A study was conducted on 60 men with PIN lesions, some of which turn into prostate cancer
- Half of these men were randomized to take 600 mg of green tea extract daily, while the other half were given a placebo pill
- The study was double-blind, neither the participants nor the doctors knew who was actually receiving green tea
- After one year, only 1 person taking green tea had gotten cancer, while 9 taking the placebo had gotten cancer

Poll question

A difference this large is unlikely to happen just by random chance. Can we conclude that green tea really does help prevent prostate cancer?

a. Yes
b. No

The gold standard for a statistical study is the double-blind, randomized, controlled experiment.

A study is **controlled** if one group receives the treatment and another group does not. (In medicine, that group usually gets either a placebo, or standard medical care, or both.)

A study is **double-blind** if neither the subjects nor the scientists know who is assigned to which group until after the data are collected. This

- prevents subjects in different groups from behaving in different ways;
- prevents scientists from introducing any unconscious bias into the data collection process.

A study is **randomized** if the control group and the treatment group are chosen at random.

Without randomization, the groups may differ in a systematic way. For example, surgeons used to assign only the healthiest patients to receive an experimental new surgical treatment, since those patients could best withstand the invasive procedure. But the outcomes for those patients are not a reliable forecast for how normal patients would respond.

1. Confounding factor
2. How to handle confounding factor
3. Gold standard of randomized experiments