

YData: An Introduction to Data Science

Lecture 20: Causality

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Credit: data8.org



Reminders

- Assignment 07 posted; due April 1
- Break day next Wednesday (no class or OH)
- Midterm next Friday
 - Practice midterm posted; second posted on Gradescope
 - Review session on Monday (no new topics next week)
 - Exam available Friday during normal class time (no class)

12.3 Causality



Interact



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CAUSALITY

TREATING CHRONIC BACK
PAIN: A RANDOMIZED
CONTROLLED TRIAL

POTENTIAL OUTCOMES

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THE TEST STATISTIC

PREDICTING THE STATISTIC
UNDER THE NULL HYPOTHESIS

PERMUTATION TEST

CONCLUSION OF THE TEST

CAUSALITY

A META-ANALYSIS

Causality

Our methods for comparing two samples have a powerful use in the analysis of randomized controlled experiments. Since the treatment and control groups are assigned randomly in such experiments, differences in their outcomes can be compared to what would happen just due to chance if the treatment had no effect at all. If the observed differences are more marked than what we would predict as purely due to chance, we will have evidence of *causation*. Because of the unbiased assignment of individuals to the treatment and control groups, differences in the outcomes of the two groups can be ascribed to the treatment.

The key to the analysis of randomized controlled experiments is understanding exactly how chance enters the picture. This helps us set up clear null and alternative hypotheses. Once that's done, we can simply use the methods of the previous sections to complete the analysis.

A/B Testing

- **Null:** The two samples are drawn randomly from the same underlying distribution.
- If the null is true, all rearrangements of the variable values among the two samples are equally likely. So:
 - compute the observed test statistic
 - then shuffle the values and recompute the statistic; **repeat**; compare with the observed statistic

Deflategate

2015 AFC Championship Game

Syracuse, NY
11:04 AM ET

UNIVERSITY OF SYRACUSE UNIVERSITY
SYRACUSE UNIVERSITY
UNIVERSITY SYRACUSE UNIVERSITY
SYRACUSE UNIVERSITY

DEVELOPING STORY

PATRIOTS UNDER PRESSURE IN 'DEFLATEGATE' SCANDAL

LIVE

CNN

11:04 AM ET

RELIABLE SOURCES

R PARTS OF NEW YORK UP TO BOSTON, WITH WINDS OVER 60 MPH ► RELIABLE SOURCES

Tim Green | Former NFL Player

Deflategate

Wikipedia:

The 2015 AFC Championship Game football tampering scandal, commonly referred to as Deflategate, or Ballgazi

...

'Deflategate' returns, focus on Tom Brady's destroyed cellphone

POSTED 9:54 AM, MARCH 5, 2016, BY CNN WIRE, UPDATED AT 10:33AM, MARCH 5, 2016

Null hypothesis

The 4 Colts footballs are like a sample drawn at random without replacement from all 15 balls.

- To test this hypothesis, repeat this process:
 - Randomly permute all 15 balls
 - Label 11 of them “Patriots” and the remaining 4 “Colts”
 - Compare the averages of the two groups

(DEMO)

Causality

Recent study

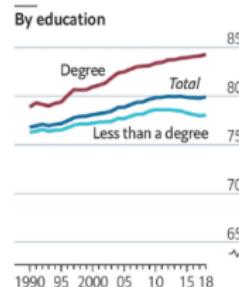
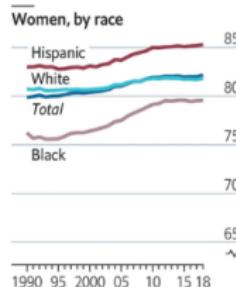
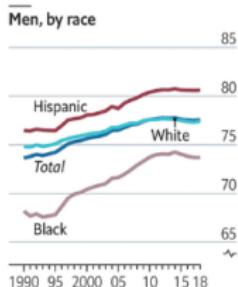
Daily chart

Educated Americans live longer, as others die younger

A college degree is becoming the main factor accounting for the difference in expected lifespans

Catching up, falling behind

United States, average life expectancy at age 25



Source: "Life expectancy in adulthood is falling for those without a BA degree, but as educational gaps have widened, racial gaps have narrowed" by Anne Case and Angus Deaton, PNAS, 2021.

The Economist

Recent study

- Is there a *causal* connection between education and mortality?
- What are some of the difficulties in answering this question?
- What are some potential confounding variables?

Randomized Controlled Experiment

- Sample A: **control group**
- Sample B: **treatment group**
- **The treatment and control groups are selected at random; this allows causal conclusions.**
- Any difference in outcomes between the two groups could be due to
 - chance
 - the treatment

Case study

- RCT to study Botulinum Toxin A (BTA) as a treatment to relieve chronic back pain
- 15 patients in the treatment group (received BTA)
- 16 in the control group (normal saline)
- Trials were run double-blind (neither doctors nor patients knew which group they were in)
- Only 2 patients in the control group had relief from pain ($\text{outcome}=1$); 9 patients in the treatment group had relief.
- Can this difference be just due to chance?

Potential Outcomes

- In the population there is one imaginary “ticket” for each of the 31 participants in the experiment.
- Each participant’s ticket looks like this:

**Potential
outcome**

**Potential
outcome**

**Outcome if assigned to
treatment group**

**Outcome if assigned to
control group**

The Data

16 randomly picked tickets show:

	Outcome if assigned to control group
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The remaining 15 tickets show:

Outcome if assigned to treatment group	
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The Hypotheses

- **Null:**
 - The distribution of all 31 potential control scores is the same as the distribution of all 31 potential treatment scores.
- **Alternative:**
 - The distribution of all 31 potential control scores is different from the distribution of all 31 potential treatment scores.

We only observe a sample from each set of potential outcomes

(DEMO)

AstraZeneca Vaccine

Science &
technology

Vaccination vactivation

EU countries pause AstraZeneca's covid-19 jab over safety fears

An abundance of caution could well backfire



AFP

AstraZeneca Vaccine (from The Economist)

- On March 15th France, Germany and Italy announced they were halting use of the AstraZeneca vaccine.
- Why? A Norwegian medical regulator reported four cases of blood clotting in adults given the vaccine. Similar—and similarly small—reports have come from Denmark, Italy and Austria.
- The World Health Organization (WHO) and European Medicines Agency (EMA) said they have no reason to believe the vaccine is unsafe.

Any confusion lies in the difficulty of **disentangling causation from correlation**. The EMA reckons that as of March 10th there had been 30 "thromboembolic events" among the 5m people in the EU who have received AZ's vaccine. By itself, that is no more remarkable than the fact that some of them will have suddenly had relief from chronic back pain or seen their cancer go into remission. The question is whether the rates are higher than would otherwise be expected. With clots, even as evidence from specific cases needs investigating, the mass of overall data shows that the vaccines are safe.

The
Economist

AstraZeneca Vaccine: Update

Just yesterday, the EMA declared it to be safe with respect to clotting:

- “The vaccine is not associated with an increase in the overall risk of blood clots (thromboembolic events) in those who receive it”
- “however, the vaccine may be associated with very rare cases of blood clots associated with thrombocytopenia, i.e. low levels of blood platelets (elements in the blood that help it to clot) with or without bleeding, including rare cases of clots in the vessels draining blood from the brain (CVST).”
- “A causal link with the vaccine is not proven, but is possible and deserves further analysis.”

<https://www.ema.europa.eu/en/news/>

[covid-19-vaccine-astrazeneca-benefits-still-outweigh-risks-despite-possible-link-rare-blood-clots](https://www.ema.europa.eu/en/news/covid-19-vaccine-astrazeneca-benefits-still-outweigh-risks-despite-possible-link-rare-blood-clots)

Discussion Question: A/B Testing of Covid Data

Suppose that clinical trials of the AstraZeneca vaccine resulted in data of this form:

Treatment	Symptoms	Thrombosis
Placebo	False	False
Vaccine	False	False
Placebo	True	False
Vaccine	False	False
Vaccine	True	False
Placebo	False	False
Vaccine	False	False
Vaccine	False	False

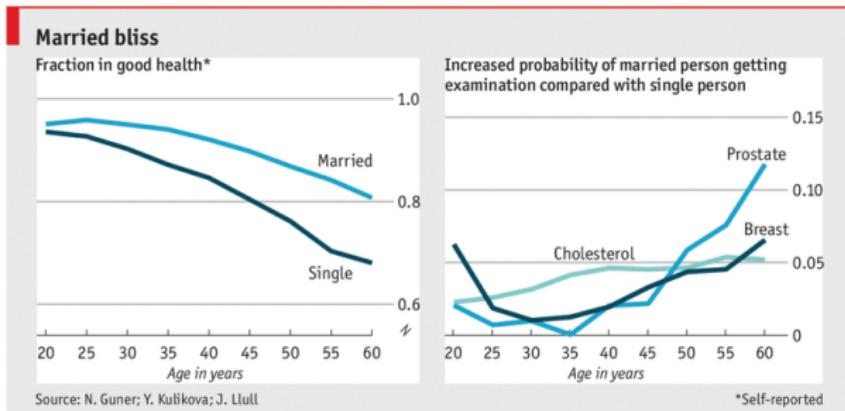
... (9992 rows omitted)

How would we perform an A/B test to decide whether or not there is excess risk of blood clotting, compared with random chance?

Discussion Question: A/B Testing of Covid Data

- We can treat the “Thrombosis” column just as the “Result” column in the BTA data
- Run permutation tests by shuffling the “Treatment” column
- Because the data come from a RCT, rejecting the Null hypothesis would be evidence in favor of a causal connection

Many other examples...



The link between marriage and better health is well established. Less clear is whether marriage causes good health or vice versa; healthy people may simply be more likely to marry in the first place. A group of researchers at the Universitat Autònoma de Barcelona—Nezih Guner, Yuliya Kulikova and Joan Llull—looked at data on Americans between the ages of 20 and 64 in order to try to work out which way the causation runs. Does marriage make people healthier?

Have a nice weekend!