Section 1.3

Experiments and Observational Studies

Outline

- Association versus Causation

- Confounding Variables

- Observational Studies vs Experiments

- Randomized Experiments

Mini Review Quiz

To estimate the proportion of students who support a smoke-free campus, you compute the proportion that say yes after responding to an email sent to all students asking "Do you support a smoke-free campus?" The data collected is

a) Not biased
b) Biased because of wording bias
c) Biased because asked over email instead of in person
d) Biased because responses may be inaccurate
e) Biased because volunteer samples are almost always biased

Data Collection and Bias
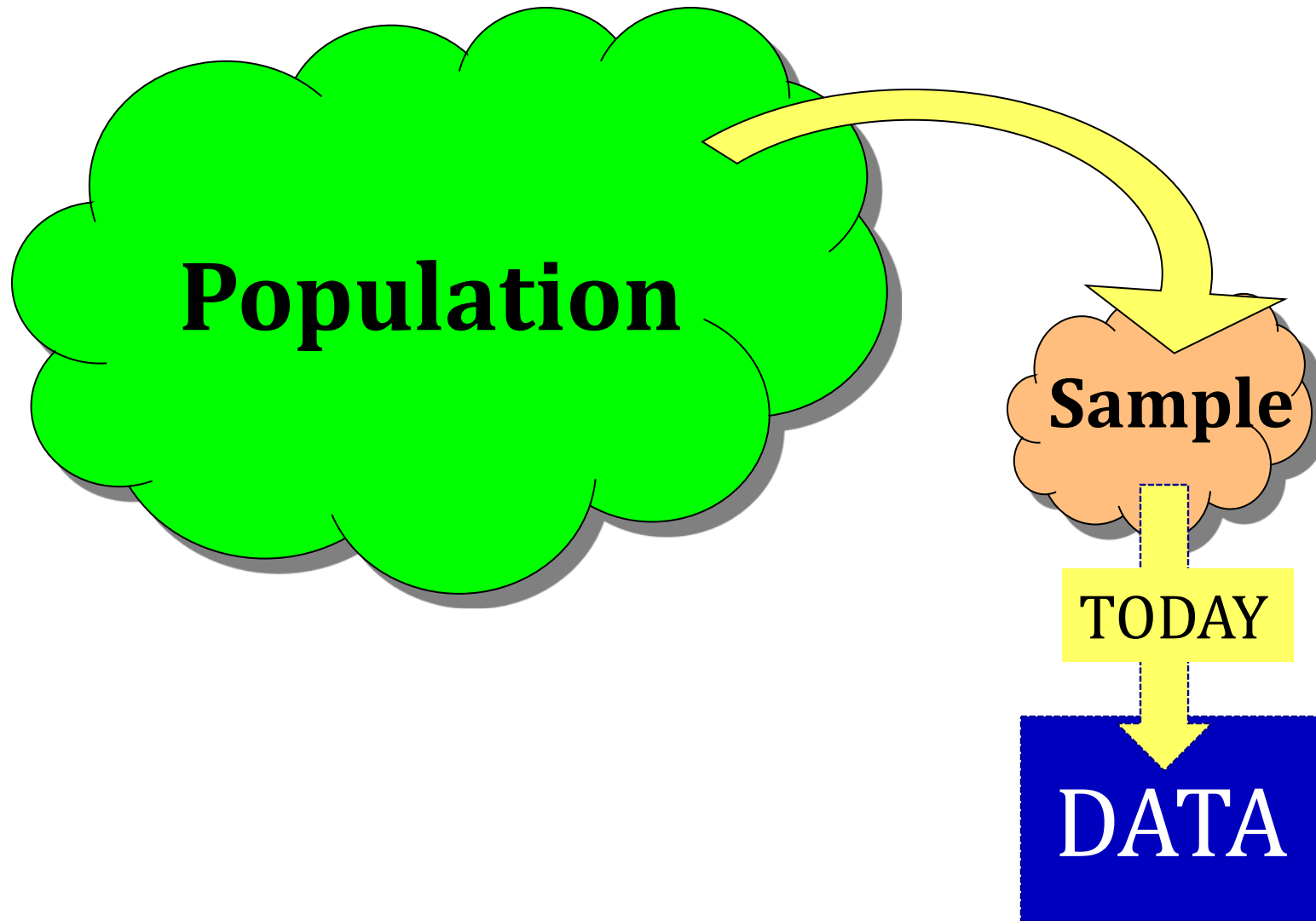
Association and Causation

Two variables are ***associated*** if values of one variable tend to be related to values of the other variable

Two variables are ***causally associated*** if changing the value of the explanatory variable influences the value of the response variable
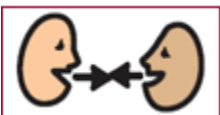
Explanatory, Response, Causation

For each of the following headlines:
- Identify the explanatory and response variables (if appropriate).
- Does the headline imply a ***causal*** association?

1. *"Daily Exercise Improves Mental Performance"*

2. *"Want to lose weight? Eat more fiber!"*

3. *"Cat owners tend to be more educated than dog owners"*

Association and Causation

- **ASSOCIATION IS NOT NECESSARILY CAUSAL!**

- Come up with two variables that are *associated,* but not causally

- Come up with two variables that are *causally associated*

  ○ Which is the explanatory variable?
  ○ Which is the response variable?

College Education and Aging

- *"Education seems to be an elixir that can bring us a healthy body and mind throughout adulthood and even a longer life,"* says Margie E. Lachman, a psychologist at Brandeis University who specializes in aging. For those in midlife and beyond, a college degree appears to slow the brain's aging process by up to a decade, adding a new twist to the cost-benefit analysis of higher education — for young students as well as those thinking about returning to school."*
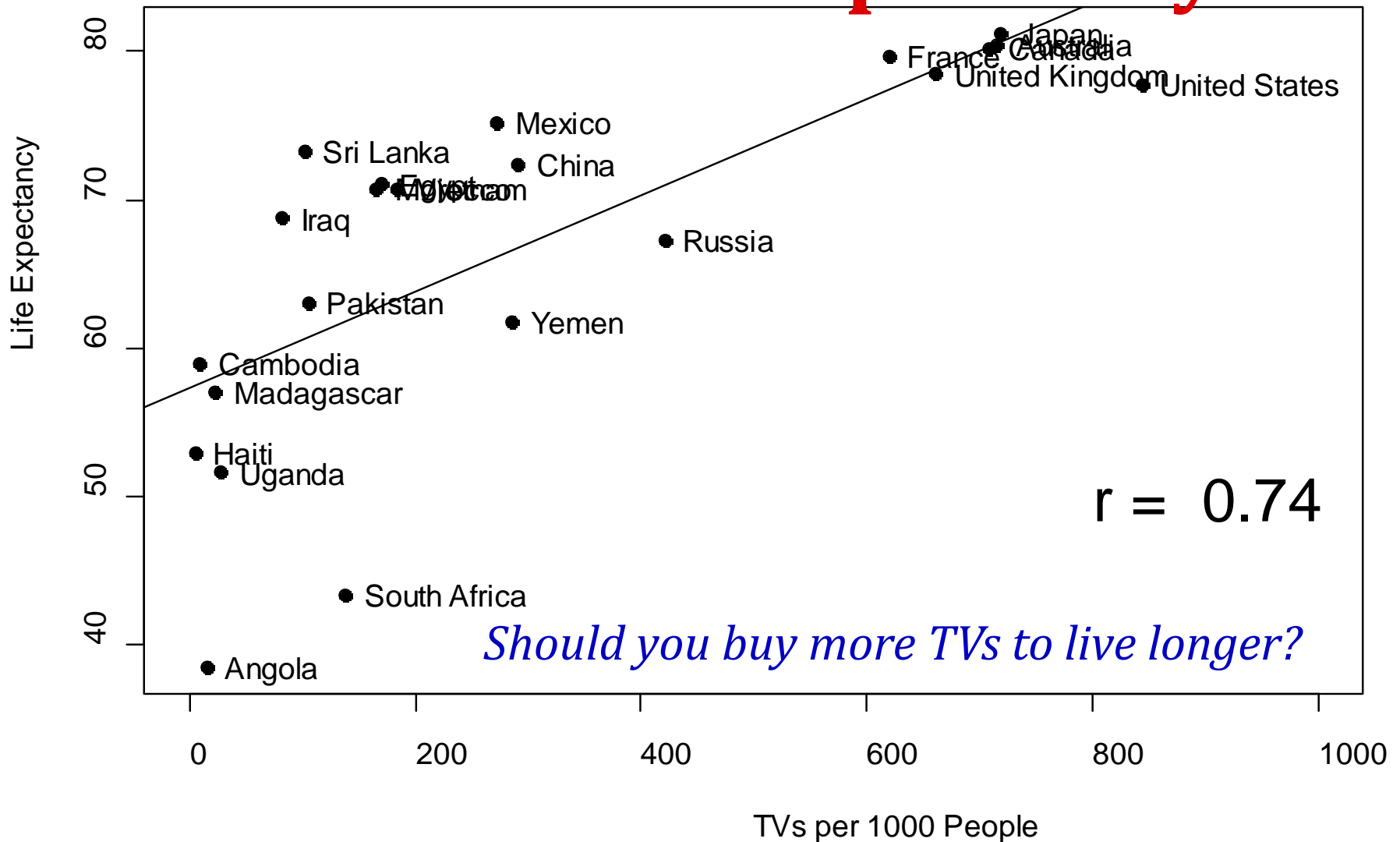
A Sharper Mind, Middle Age and Beyond

-NY Times, 1/19/12

- Are you convinced that a college education slows the brain's aging?

    People who go to college may be different to begin with!

TVs and Life Expectancy

Life Expectancy vs TVs per 1000 People

- Japan
- Canada
- France
- United Kingdom
- United States
- Mexico
- Sri Lanka
- China
- Egypt / Vietnam / Morocco
- Iraq
- Russia
- Pakistan
- Yemen
- Cambodia
- Madagascar
- Haiti
- Uganda
- South Africa
- Angola

r = 0.74

Should you buy more TVs to live longer?

Association does not imply causation!
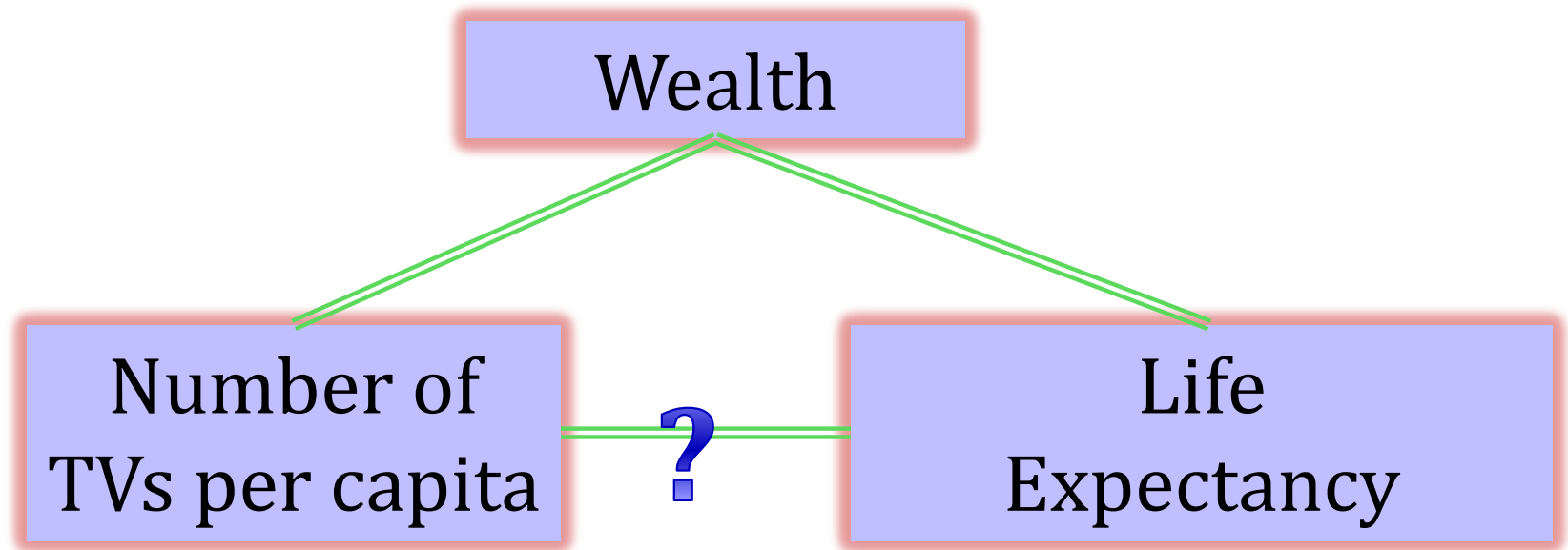
Confounding Variable

A third variable that is associated with both the explanatory variable and the response variable is called a ***confounding variable***

- A confounding variable can offer a plausible explanation for an association between the explanatory and response variables

- **Whenever confounding variables are present (or may be present), a causal association cannot be determined**

Confounding Variable

Confounding Variable

Explanatory Variable   ?   Response Variable

TVs and Life Expectancy

Wealth
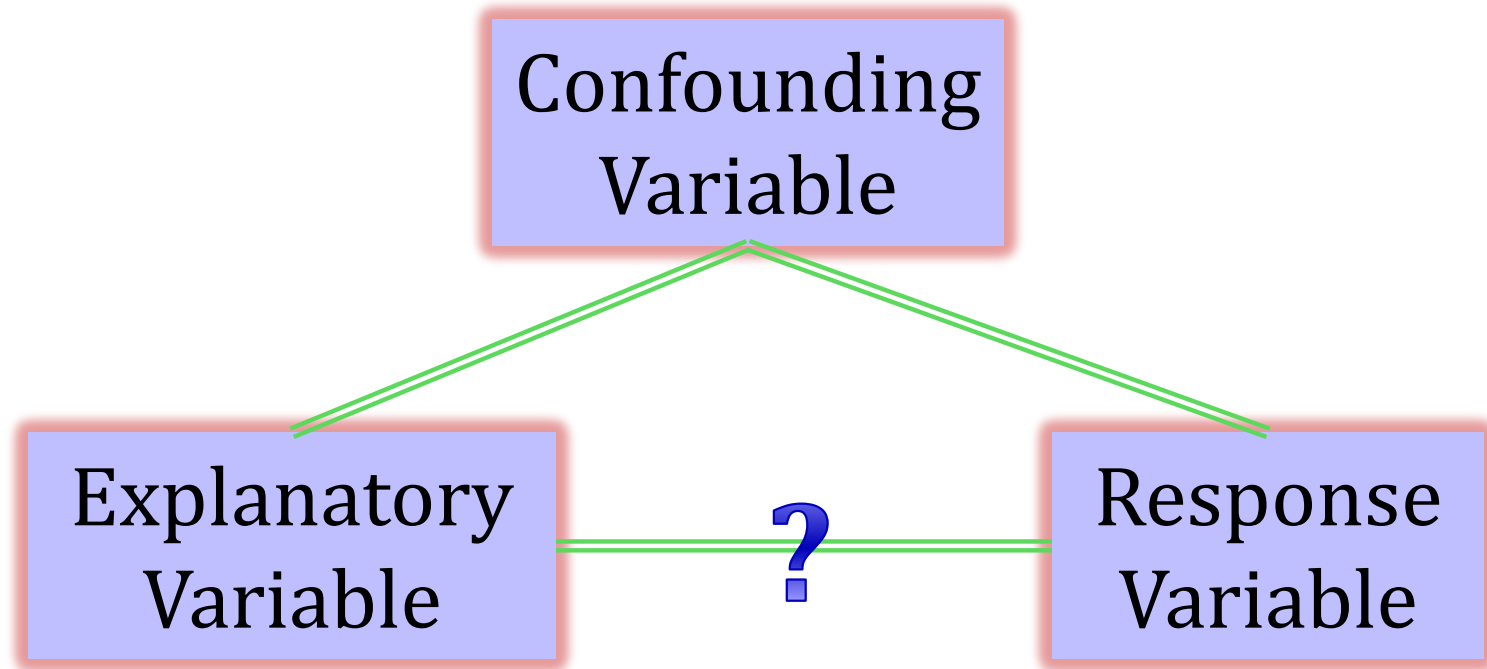
Number of TVs per capita **?** Life Expectancy

Confounding Variable

For each of the following relationships, identify a possible confounding variable:

1. More ice cream sales have been linked to more deaths by drowning.

2. The total amount of beef consumed and the total amount of pork consumed worldwide are closely related over the past 100 years.

3. People who own a yacht are more likely to buy a sports car.

4. Air pollution is higher in places with a higher proportion of paved ground relative to grassy ground.

5. People with shorter hair tend to be taller.

Experiment vs Observational Study

An *observational study* is a study in which the researcher does not actively control the value of any variable, but simply observes the values as they naturally exist

An *experiment* is a study in which the researcher actively controls one or more of the explanatory variables

Observational Studies

- There are almost always confounding variables in observational studies

Observational studies can almost never be used to establish causation

Kindergarten and Crime

- Does Kindergarten Lead to Crime?

- Yes, according to research conducted by New Hampshire state legislature Bob Kingsbury

- *"Kingsbury (R-Laconia), 86, recently claimed that analyses he's been carrying out since 1996 show that communities in his state that have kindergarten programs have up to 400% more crime than localities whose classrooms are free of finger-painting 5-year-olds. Pointing to his hometown of Laconia, the largest of 10 communities in Belknap County, the legislator noted that it has the only kindergarten program in the county and the most crime, including most or all of the county's rapes, robberies, assaults and murders."*
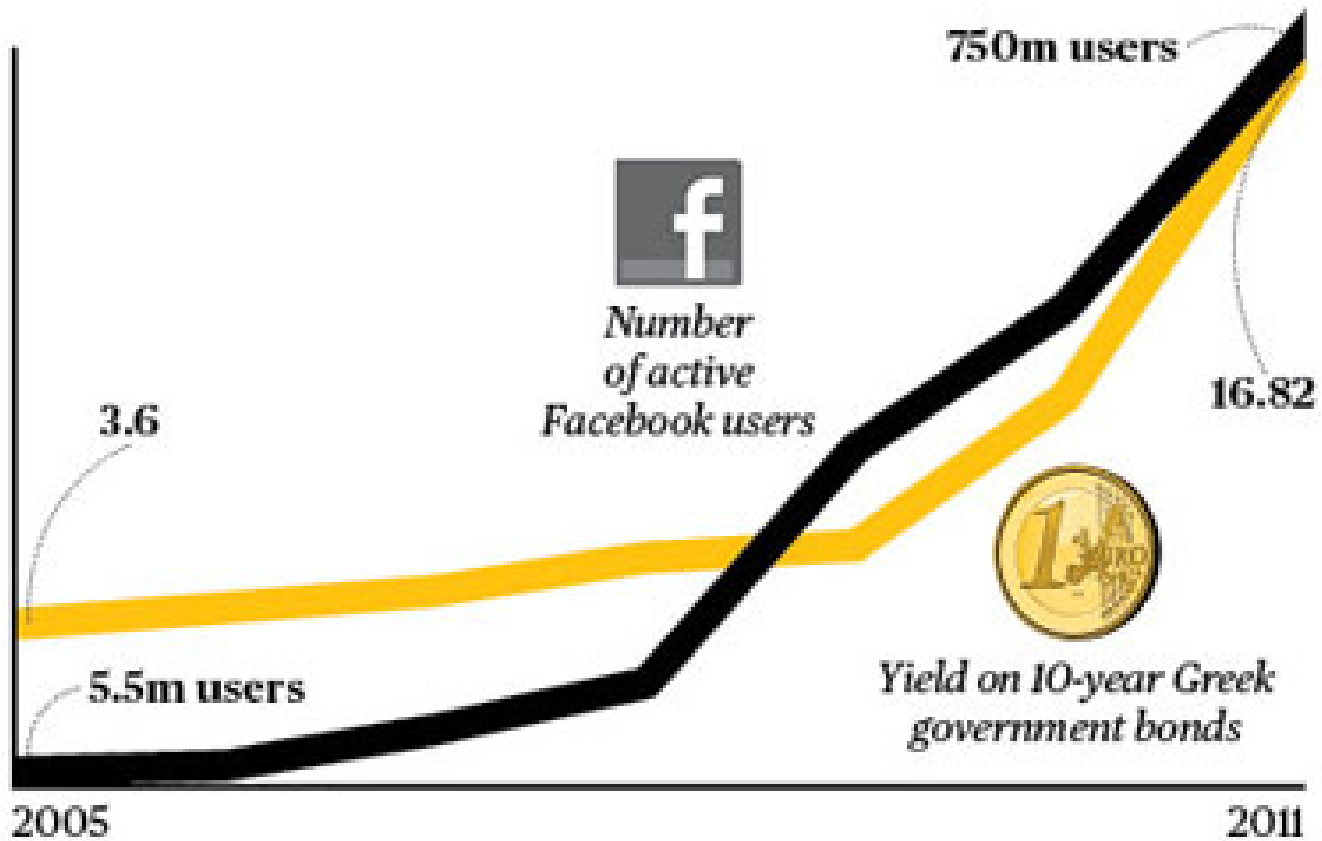
Szalavitz, M. "[Does Kindergarten Lead to Crime? Fact-Checking N.H. Legislator's `Research](#)'," healthland.time.com, 7/6/12.

Texas GOP Platform

- A few days later, the Texas GOP 2012 Platform announced that it opposed early childhood education

- *Causation or just association?*

Source: Strauss, V. "Texas GOP rejects 'critical thinking' skills. Really." www.washingtonpost.com, 7/9/12.

Fig. 1
IS FACEBOOK DRIVING THE GREEK DEBT CRISIS?

750m users

Number of active Facebook users

3.6

16.82

5.5m users

Yield on 10-year Greek government bonds

2005   2011

Data from Facebook and Bloomberg
http://www.businessweek.com/magazine/correlation-or-causation-12012011-gfx.html

Fig. 2

IS GLOBAL WARMING A HOAX PROPAGATED BY SCIENTISTS?

$146.9m

Average global temperature

$69.8m

National Science Foundation R&D Budget

+0.63C

+0.13C above 1950-1980 avg.

1993

2009
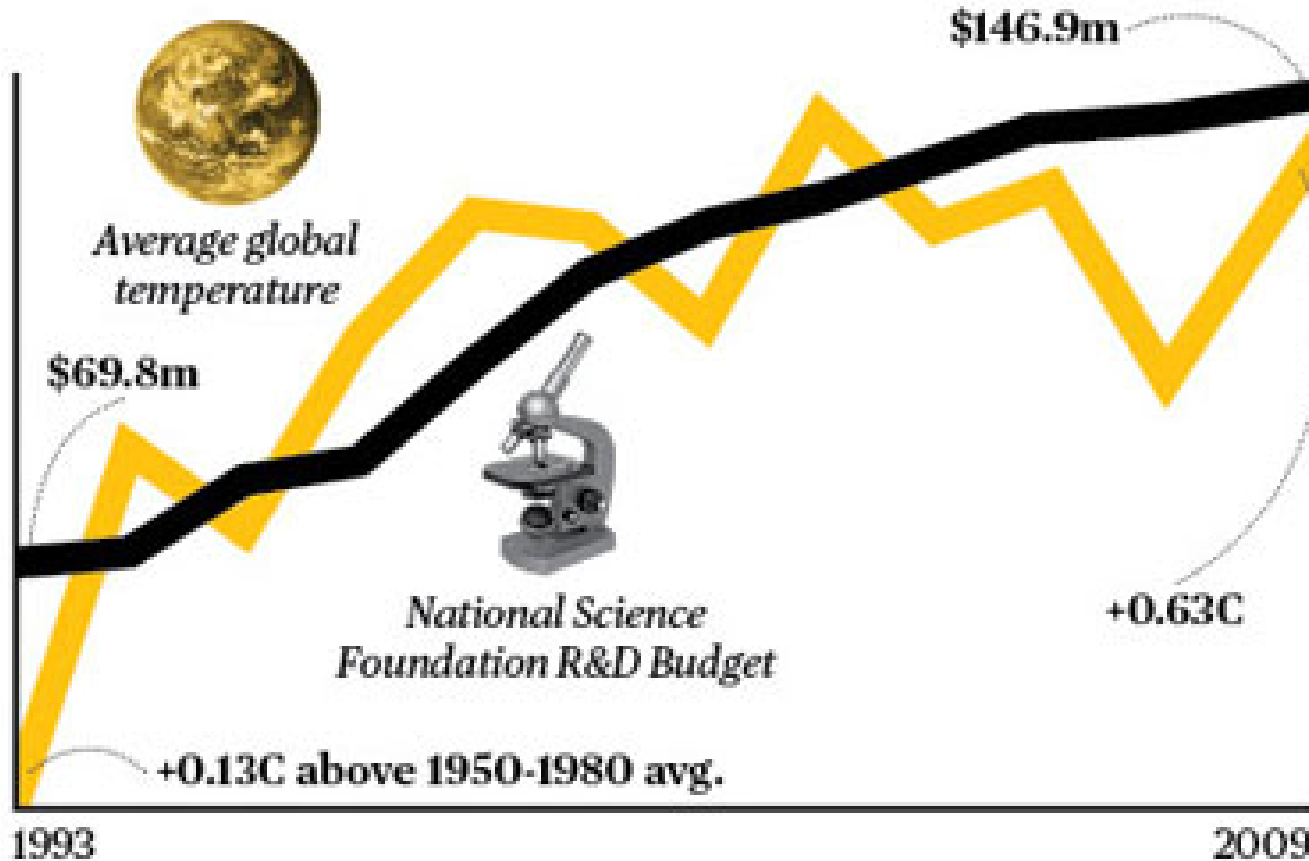
Data from NASA and National Science Foundation

http://www.businessweek.com/magazine/correlation-or-causation-12012011-gfx.html

Fig. 3
DID AVAS CAUSE THE U.S. HOUSING BUBBLE?

15,826

100 Housing price index

193.74

281 Avas

Babies named "Ava"

1991

2009
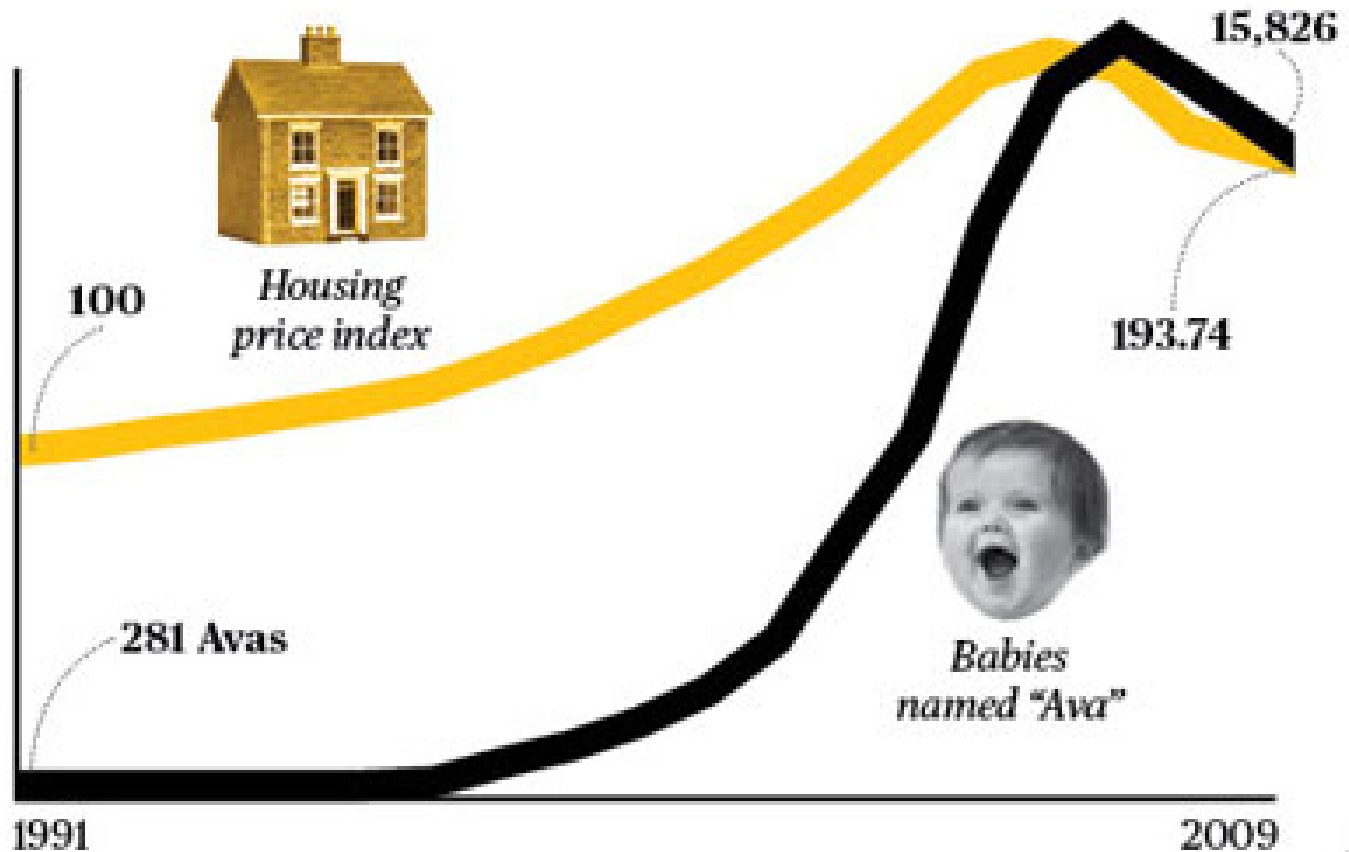
Data from US Social Security Administration and National Housing Finance Agency

Fig. 4

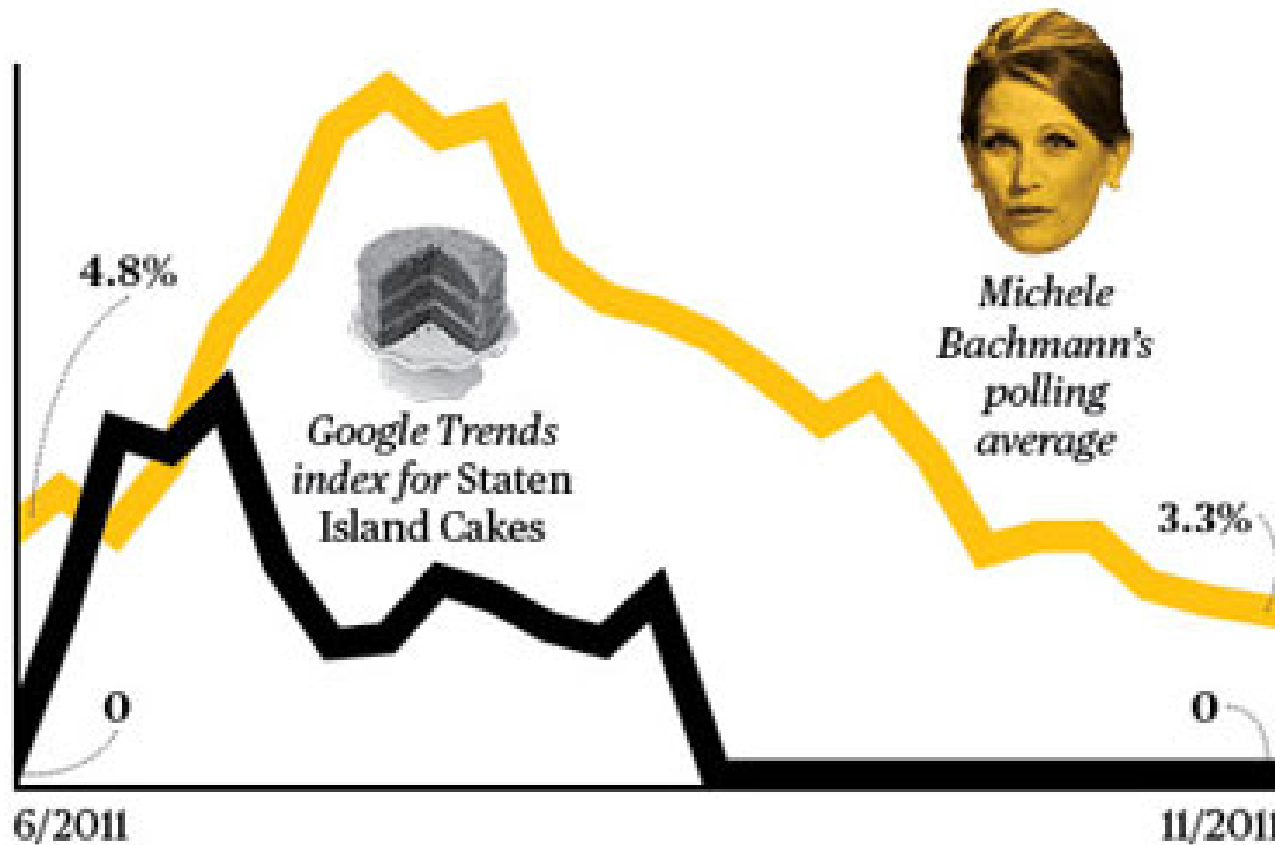**WOULD M. NIGHT SHYAMALAN START MAKING GOOD MOVIES AGAIN IF PEOPLE BOUGHT MORE NEWSPAPERS?**

85% (The Sixth Sense)

Total newspaper ad sales

$46,289m

$22,795m

6% (The Last Airbender)

Shyamalan's movies' score on Rotten Tomatoes

1999

2010
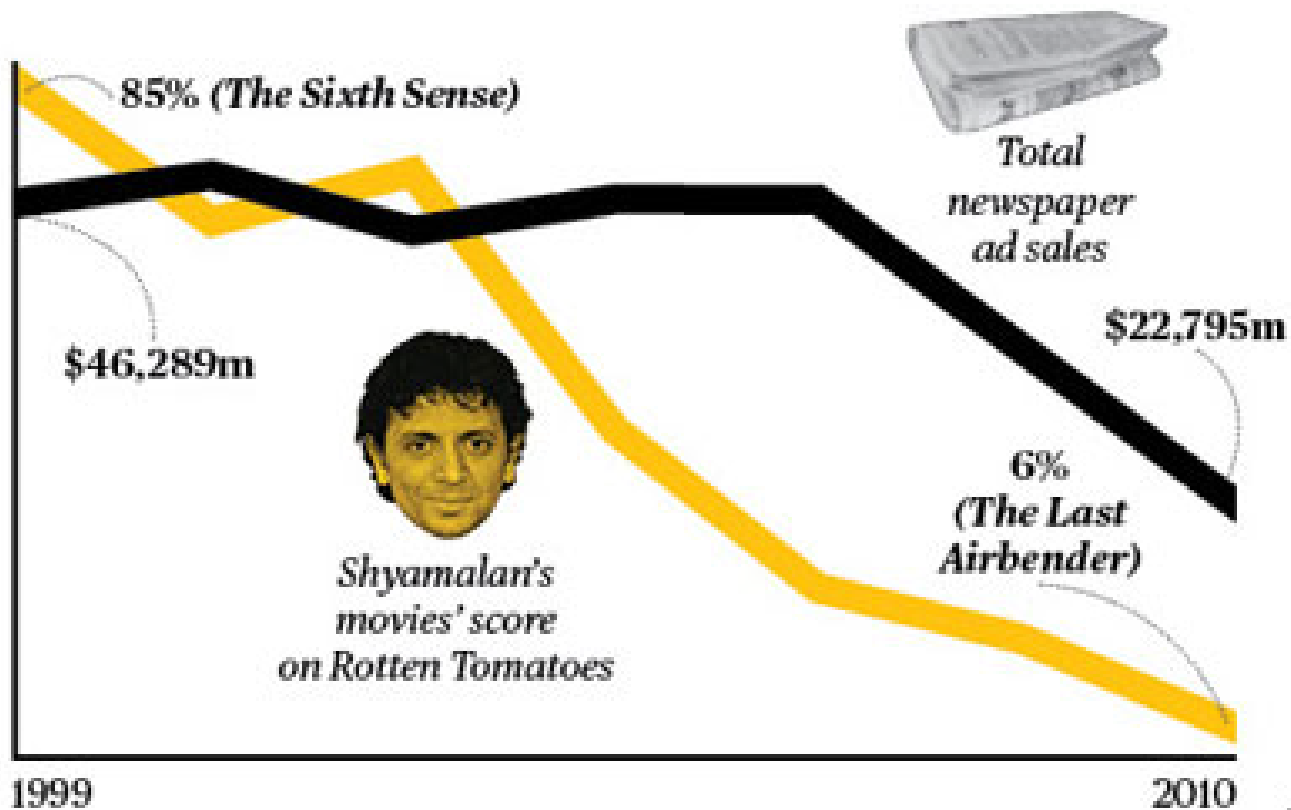
Data from Rotten Tomatoes, Newspaper Association of America
http://www.businessweek.com/magazine/correlation-or-causation-12012011-gfx.html

Fig. 5
DID WE TV SABOTAGE MICHELE BACHMANN'S CANDIDACY
BY TAKING *STATEN ISLAND CAKES* OFF THE AIR?

4.8%

Google Trends index for Staten Island Cakes

Michele Bachmann's polling average

3.3%

0

0

6/2011

11/2011

Data from Google, Real Clear Politics
http://www.businessweek.com/magazine/correlation-or-causation-12012011-gfx.html

Fig 6
IS THIS MOUNTAIN RANGE AFFECTING THE MURDER RATE?

836

Murders in New York State

866

1965

2010
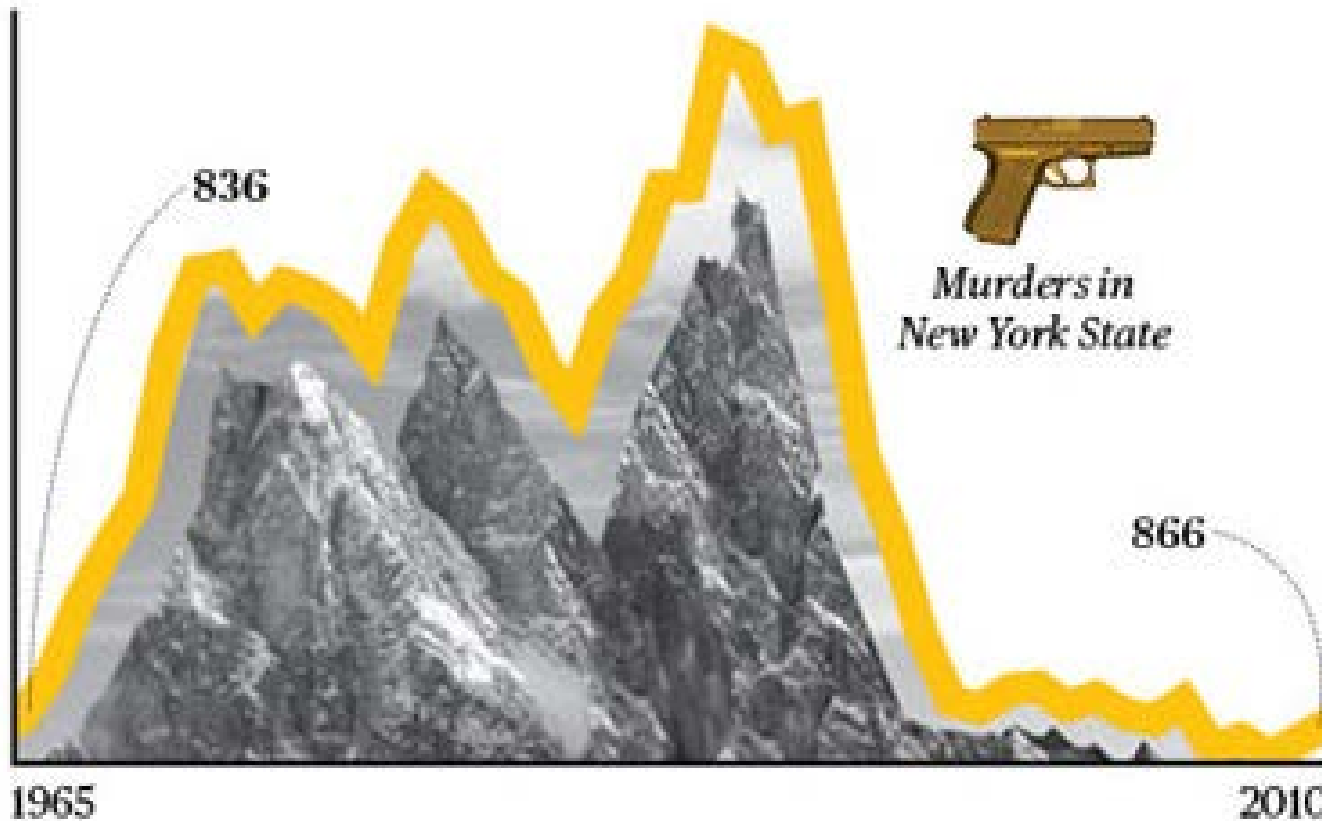
Data from NY Law Enforcement Agency
http://www.businessweek.com/magazine/correlation-or-causation-12012011-gfx.html

It's a Common Mistake!

"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

Randomization

- How can we make sure to avoid confounding variables?

RANDOMLY assign values of the explanatory variable

Randomized Experiment
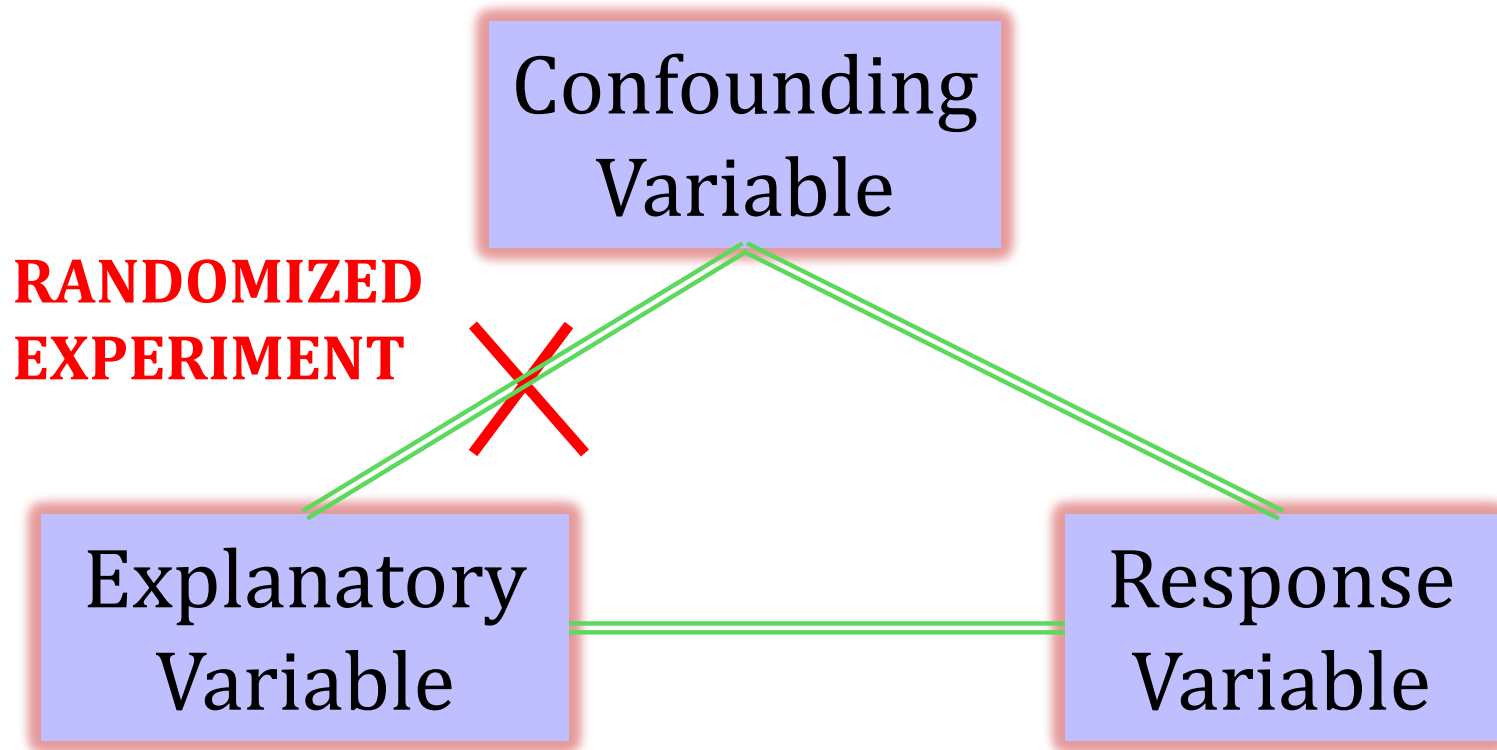
In a ***randomized experiment*** the explanatory variable for each unit is determined randomly, before the response variable is measured

Randomized Experiment

- The different levels of the explanatory variable are known as *treatments*

- Randomly divide the units into groups, and randomly assign a different treatment to each group

- If the treatments are randomly assigned, the treatment groups should all look similar

Randomized Experiments

- Because the explanatory variable is randomly assigned, it is not associated with any other variables. Confounding variables are eliminated!!!

Randomized Experiments

- 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.

Exercise and the Brain

- 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."*

- Is this conclusion valid?

   No. Observational study – cannot yield causal conclusions.

Allen, N. "One way to ward off Alzheimer's: Take a Hike," msnbc.com, 10/13/10.
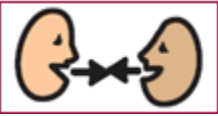
Exercise and the Brain

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

Exercise and the Brain

- 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

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

  Yes. Randomized experiment— can yield causal conclusions.

Reynolds, "Phys Ed: Your Brain on Exercise", *NY Times, July 7, 2010.*

How to Randomize?

- Option 1: As with random sampling, we can put all the names/numbers into a hat, and randomly pull out names to go into the different groups

- Option 2: Put names/numbers on cards, shuffle, and deal out the cards into as many piles as there are treatments

- Option 3: Use technology

Let's Try It!

- Is just 5 seconds of exercise enough to increase your pulse rate?

- Treatment groups: exercise versus sedentary

- Randomly divide the class into the two groups

- Give the treatment

- Measure the response (pulse rate)

- We'll learn how to analyze this later...

Knee Surgery for Arthritis

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.

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

No. Need a control or comparison group. What would happen without surgery?

Control Group

• 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

Knee Surgery for Arthritis

- 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!

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

Placebo Effect

- Often, people will experience the effect they think they should be experiencing, even if they aren't actually receiving the treatment

- Example: Eurotrip

- 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

Study on Placebos

- Blue pills are better than yellow pills

- Red pills are better than blue pills

- 2 pills are better than 1 pill

- 4 pills are better than 2 pills

- And shots are the best of all!

Placebo and Blinding

- 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

Green Tea and Prostate Cancer

• 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

Green Tea and Prostate Cancer

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

Yes! Good randomized experiments allow conclusions about causality.

Types of Randomized Experiments

- Randomizing cases into different treatment groups is called a ***randomized comparative experiment***

- We can also give each treatment to each case, and just randomize the *order* in which treatments are received: ***matched pairs experiment***

- Either are valid randomized experiments!

Matched Pairs

Example: To see if people read faster on paper or a kindle, a study was done in which 16 people read two sets of instructions of similar length, one on a kindle and one on paper. The order in which they read the instructions was randomized. (Reading was faster on paper.)

Why not always randomize?

- Randomized experiments are ideal, but sometimes not ethical or possible

- Often, you have to do the best you can with data from observational studies

- Example: research for the Supreme Court case as to whether preferences for minorities in university admissions helps or hurts the minority students

Randomization in Data Collection

Was the sample randomly selected?

Yes → Possible to generalize to the population

No → Should not generalize to the population

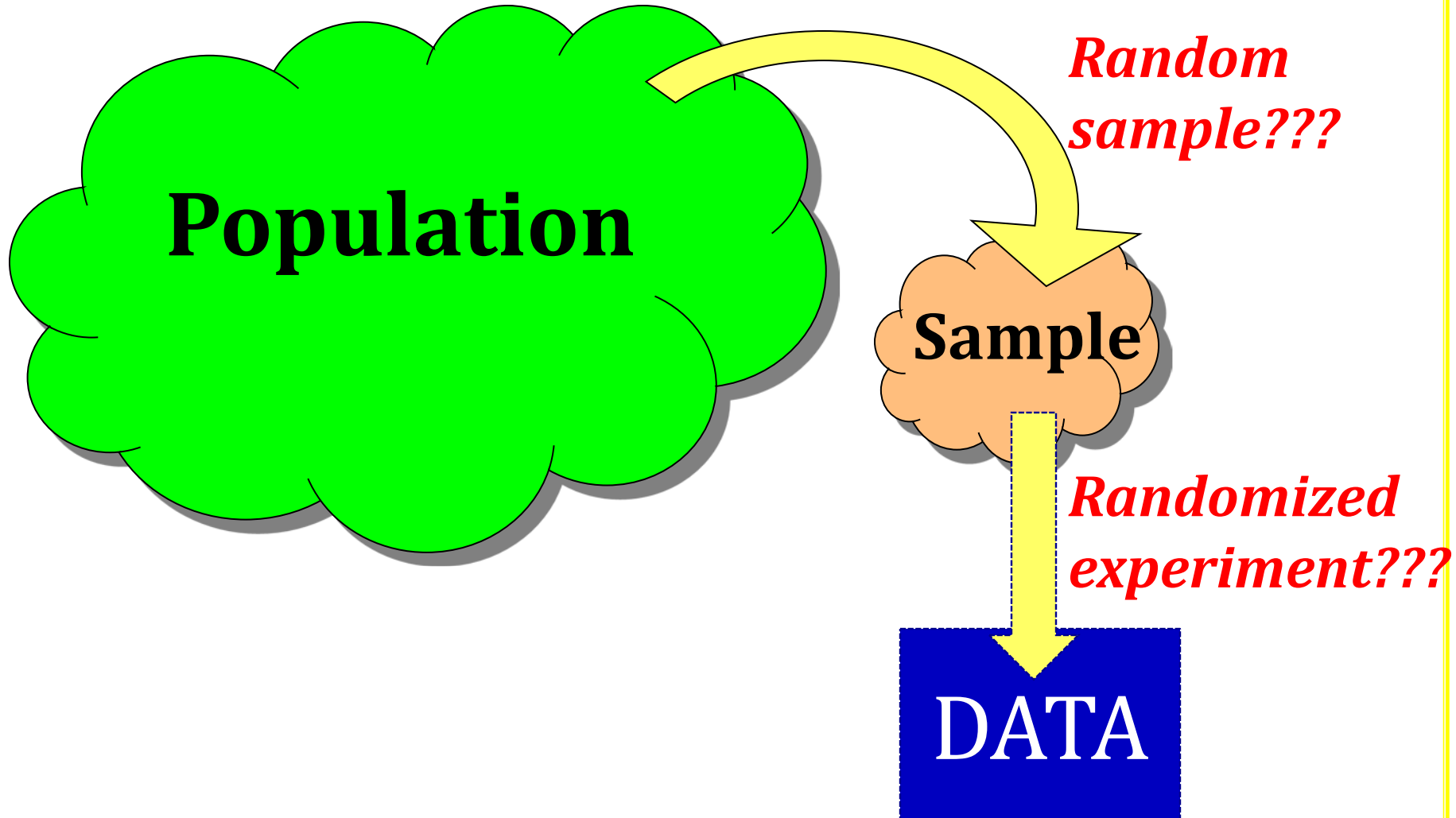Was the explanatory variable randomly assigned?

Yes → Possible to make conclusions about causality

No → Can not make conclusions about causality

Two Fundamental Questions in Data Collection

Population

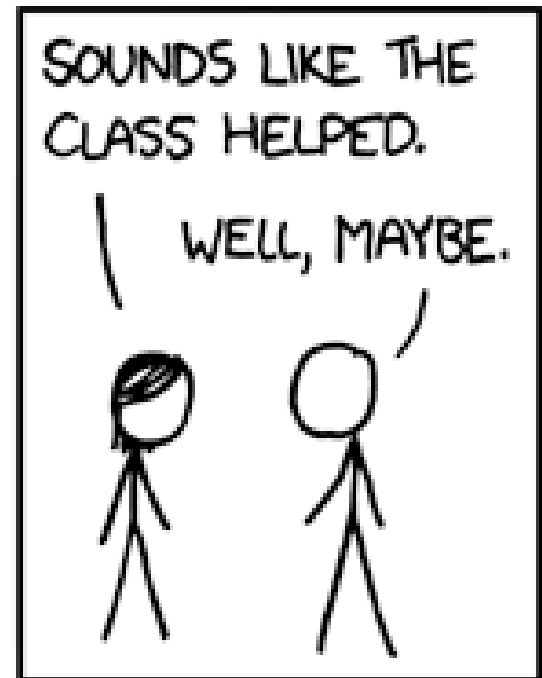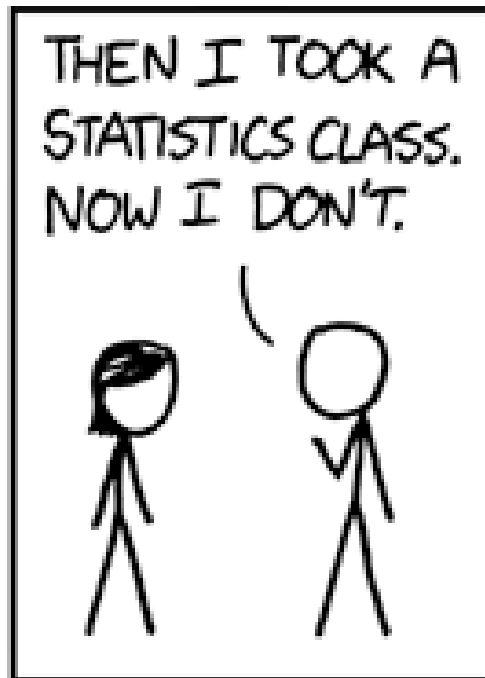*Random sample???*

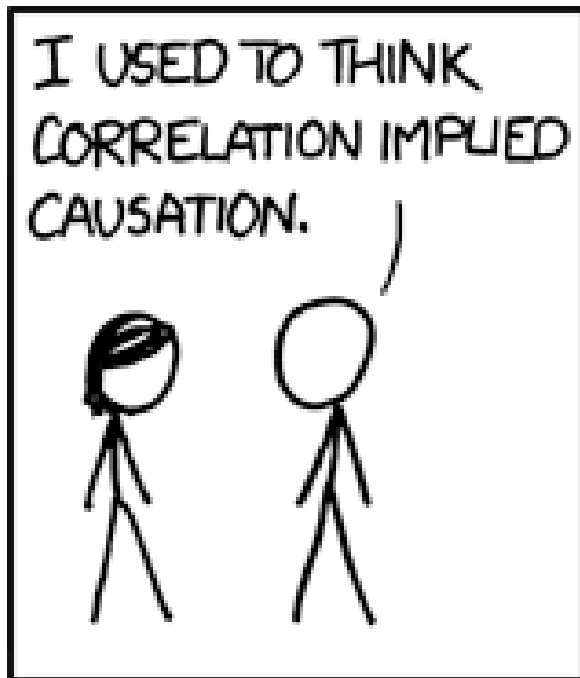Sample

Randomized experiment???

DATA

Randomization

- Doing a randomized experiment on a random sample is ideal, but rarely achievable

- If the focus of the study is using a sample to estimate a statistic for the entire population, you need a random sample, but do not need a randomized experiment (example: election polling)

- If the focus of the study is establishing causality from one variable to another, you need a randomized experiment and can settle for a non-random sample (example: drug testing)

Summary

- Association does not imply causation!

- In observational studies, confounding variables almost always exist, so causation cannot be established

- Randomized experiments involve randomly determining the level of the explanatory variable

- Randomized experiments prevent confounding variables, so causality can be inferred

- A control or comparison group is necessary

- The placebo effect exists, so a placebo and blinding should be used

http://xkcd.com/552/