STAT 2040: Principles of Statistics

Collecting Data: Observational Studies

SECTION 1.3

- Association versus Causation
- Confounding Variables
- Observational Studies
- Randomized Experiments

Question of the Day

Does exercise improve cognitive ability?

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

Causality Implied?

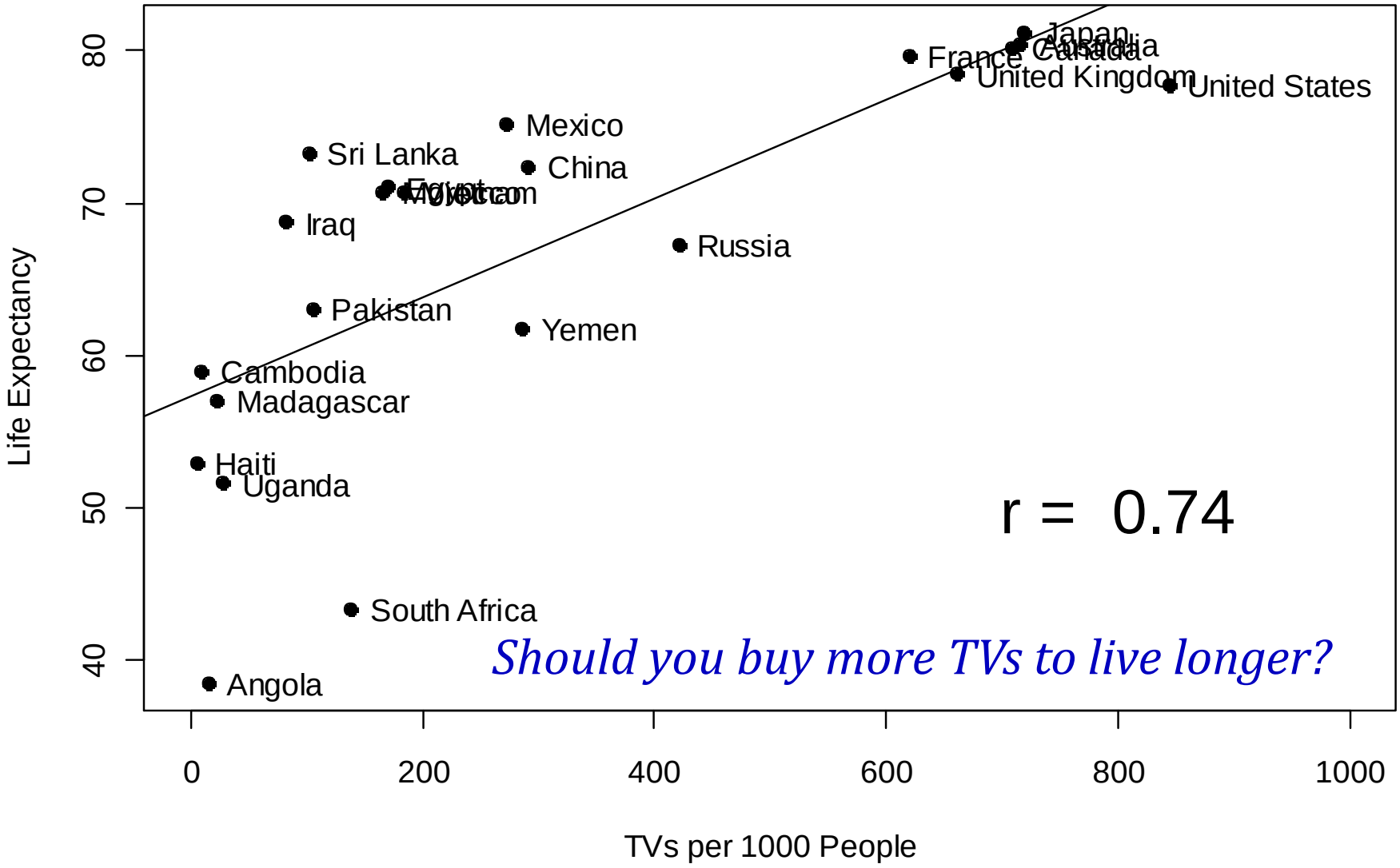
Do the wordings of the following headlines imply a *causal* association?

- Physical Activity Improves Cognitive Function
- Physical activity linked to greater mental flexibility in older adults
- Exercise Makes You Smarter
- Exercise Holds Immediate Benefits for Affect and Cognition in Younger and Older Adults

Wording

- Phrases implying causation:
  - causes / causal association
  - changes
  - increases / decreases
  - improves
  - reduces
- Words not implying causation:
  - linked
  - associated
  - correlated
  - relationship

TVs and Life Expectancy



More Examples

- www.tylervigen.com/spurious-correlations
- You can even discover your own! tylervigen.com/discover

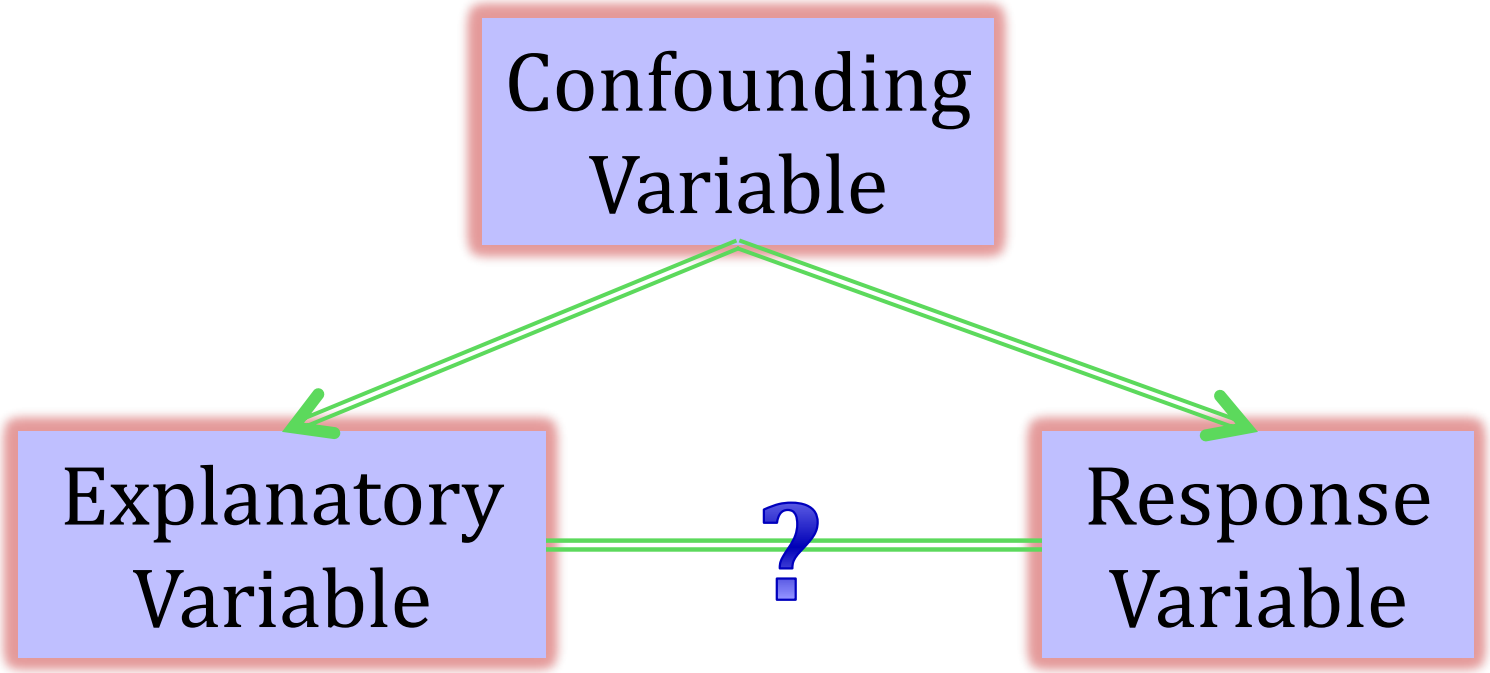
It's a Common Mistake!

"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

Confounding Variable

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



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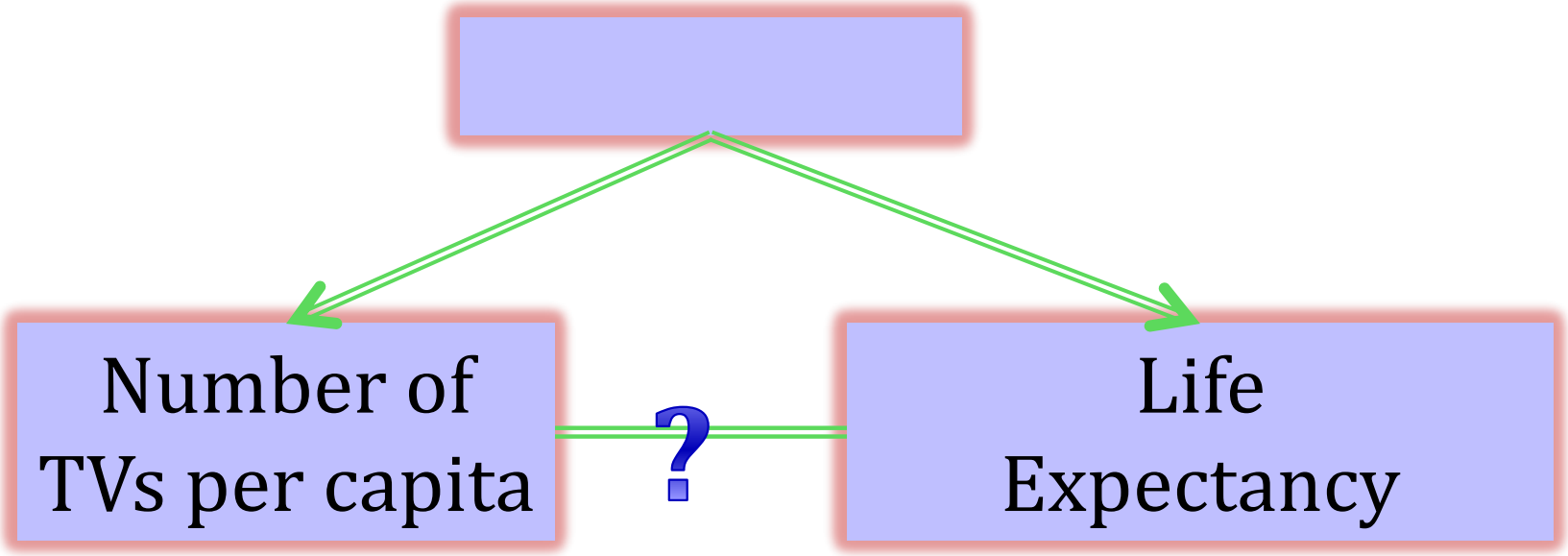
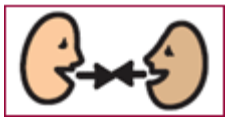


Confounding Variables

- Confounding variables provide an explanation for an association between the explanatory and response variables
- Whenever confounding variables are present, a causal association cannot be determined!
- For more information on confounding, see

Assessing bias: the importance of considering confounding



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
- What might be a confounding variable?

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

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?

  (a) Yes (b) No

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

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

- What is the explanatory variable?
- Is it actively manipulated?

Observational Studies

- There are almost always confounding variables in observational studies

Observational studies can almost never be used to establish causation

"We looked at 100 adults between the ages of 60 and 80, and we used accelerometers to objectively measure their physical activity over a week," said University of Illinois postdoctoral researcher Agnieszka Burzynska, who led the study with Beckman Institute for Advanced Science and Technology director Art Kramer.

The researchers also used functional MRI to observe how blood oxygen levels changed in the brain over time, reflecting each participant's brain activity at rest. And they evaluated the microscopic integrity of each person's white-matter fibers, which carry nerve impulses and interconnect the brain.

"We found that spontaneous brain activity showed more moment-to-moment fluctuations in the more-active adults," said Burzynska, who now is a professor at Colorado State University. "In a previous study, we showed that in some of the same regions of the brain, those people who have higher brain variability also performed better on complex cognitive tasks, especially on intelligence tasks and memory."

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Can we make conclusions about causality? a) Yes b) No

Abstract

PURPOSE: To examine the impact of integrating physical activity with elementary curricula on fluid intelligence and academic achievement.

METHODS: A random sample of 3rd grade teachers integrated physical activity into their core curricula approximately 30 minutes a day, 3 days a week from January 2008 to April 2008. Noninvasive fluid intelligence cognitive measures were used along with State-mandated academic achievement tests.

RESULTS: Experimental Group children averaged close to 1200 pedometer steps per integration day, thus averaging 3600 steps per week. Children in the Experimental Group performed significantly better on the SPM Fluid Intelligence Test. Children in the Experimental Group also performed significantly better on the Social Studies State mandated academic achievement test. Experimental Group children also received higher scores on the English/Language Arts, Math and Science achievements tests, but were not statistically significant compared with Control Group children. Children classified in Fitnessgram's Healthy Fitness Zone for BMI earned lower scores on many of the SPM Fluid Intelligence components.

Reed, JA, et. al. (2010). Examining the impact of integrating physical activity on fluid intelligence and academic performance in an elementary school setting: a preliminary investigation, *Journal of Physical Activity and Health*, May, **7**(3):343-41.

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Abstract

OBJECTIVE: To investigate whether greater cardiorespiratory fitness (CRF) is associated with better cognitive function 25 years later.

METHODS: We studied 2,747 participants in the community-based Coronary Artery Risk Development in Young Adults Study of black and white men and women aged 18 to 30 years at recruitment in 1985-1986 (baseline year 0). Symptom-limited maximal treadmill test durations at years 0 and 20 provided measures of CRF. Cognitive tests at year 25 measured verbal memory (Rey Auditory Verbal Learning Test [RAVLT]), psychomotor speed (Digit Symbol Substitution Test [DSST]), and executive function (Stroop Test).

RESULTS: Per minute of baseline CRF, the RAVLT was 0.12 words recalled higher (standard error [SE] = 0.03, $p < 0.0001$), the DSST was 0.92 digits higher (SE = 0.13, $p < 0.0001$), and the Stroop Test score was 0.52 lower (better performance, SE = 0.11, $p < 0.0001$), after accounting for race, sex, age, education, and clinical center. Compared with the lowest quartile of CRF, each cognitive test was 21% to 34% of an SD better in the highest CRF quartile. Further adjustment for lifestyle and clinical measures attenuated coefficients for RAVLT and DSST slightly, while the coefficient predicting the Stroop Test lost more than half its value ($p = 0.07$). Analysis in the subset of 1,957 participants who also completed the year-20 treadmill test showed that 20-year change in CRF was positively associated only with DSST ($p < 0.001$).

CONCLUSIONS: Better verbal memory and faster psychomotor speed at ages 43 to 55 years were clearly associated with better CRF 25 years earlier.

Zhu, N. et. al. (2014) Cardiorespiratory fitness and cognitive function in middle age: the CARDIA study, *Neurology*, April 15; **82**(15):1339-46.

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Is the stated conclusion valid? a) yes b) no

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This was written up on Psychology Today with the headline "Physical Activity Improves Cognitive Function." Is this headline valid based on the study? a) yes b) no

- Video

This is an a) observational study b) experiment

- Video

Can we make conclusions about causality? a) Yes b) No

- Video

This is an a) observational study b) experiment

Randomization

- How can we make sure to avoid confounding variables?

RANDOMLY assign values of the explanatory variable

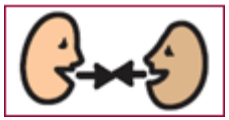
Randomized Experiment

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

- 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

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



Coming to Class

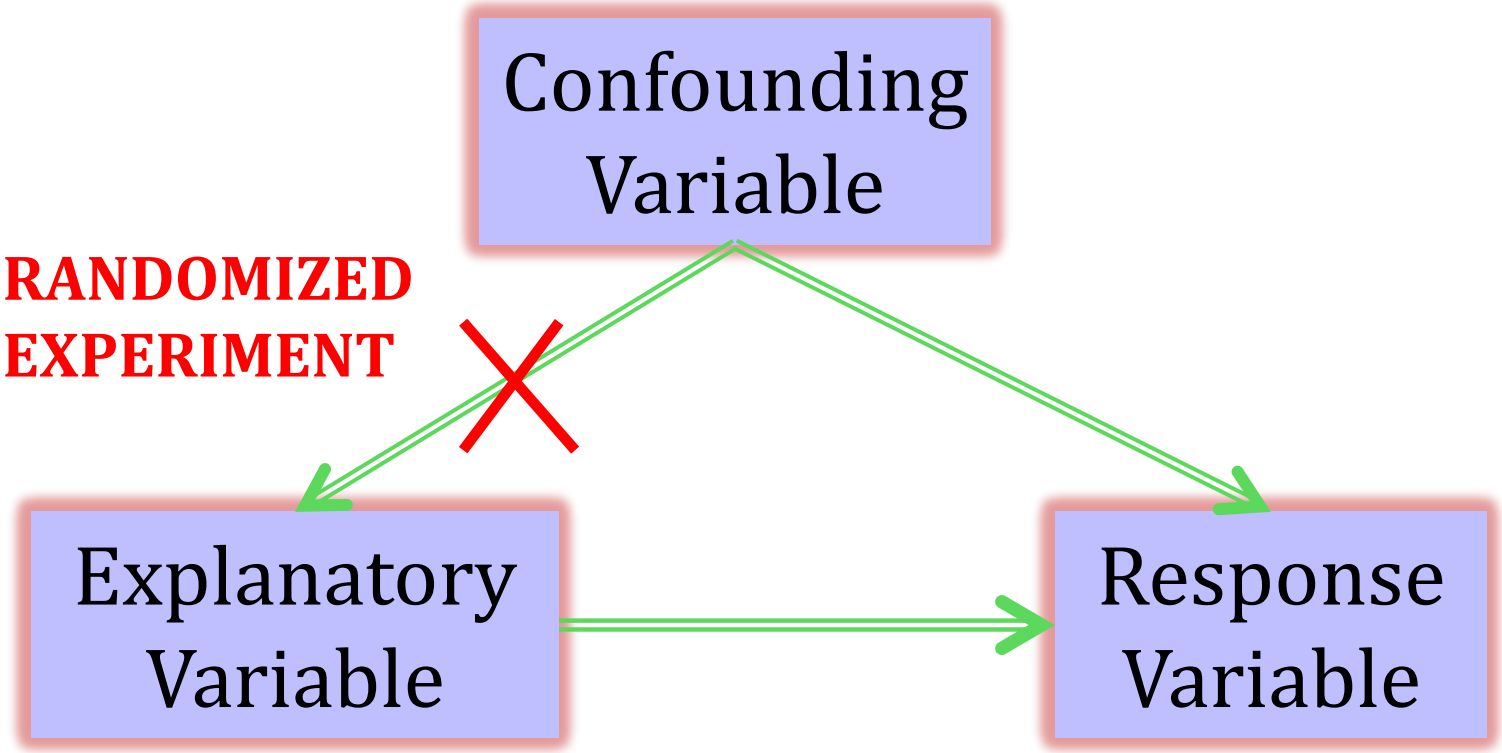
- How much does coming to class every day improve grades on the STAT 22040 final exam?
- Cases: students in this class
- Observational study?
  - What would an observational study look like?
  - Why wouldn't this allow us to answer the question?
- Randomized experiment?
  - What would a randomized experiment look like?
  - Why would this allow us to answer the question?
  - Why can't we do this?

Treatment Groups

- If the explanatory variable is not randomly assigned, there could be important baseline differences between the treatment groups
- If the explanatory variable is randomly assigned, the treatment groups should look similar in all baseline variables

Randomized Experiments

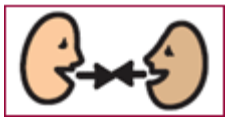
- Because the explanatory variable is randomly assigned, it is not associated with any other variables. Confounding variables are eliminated!!!



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 Cognition

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

Exercise and Cognition

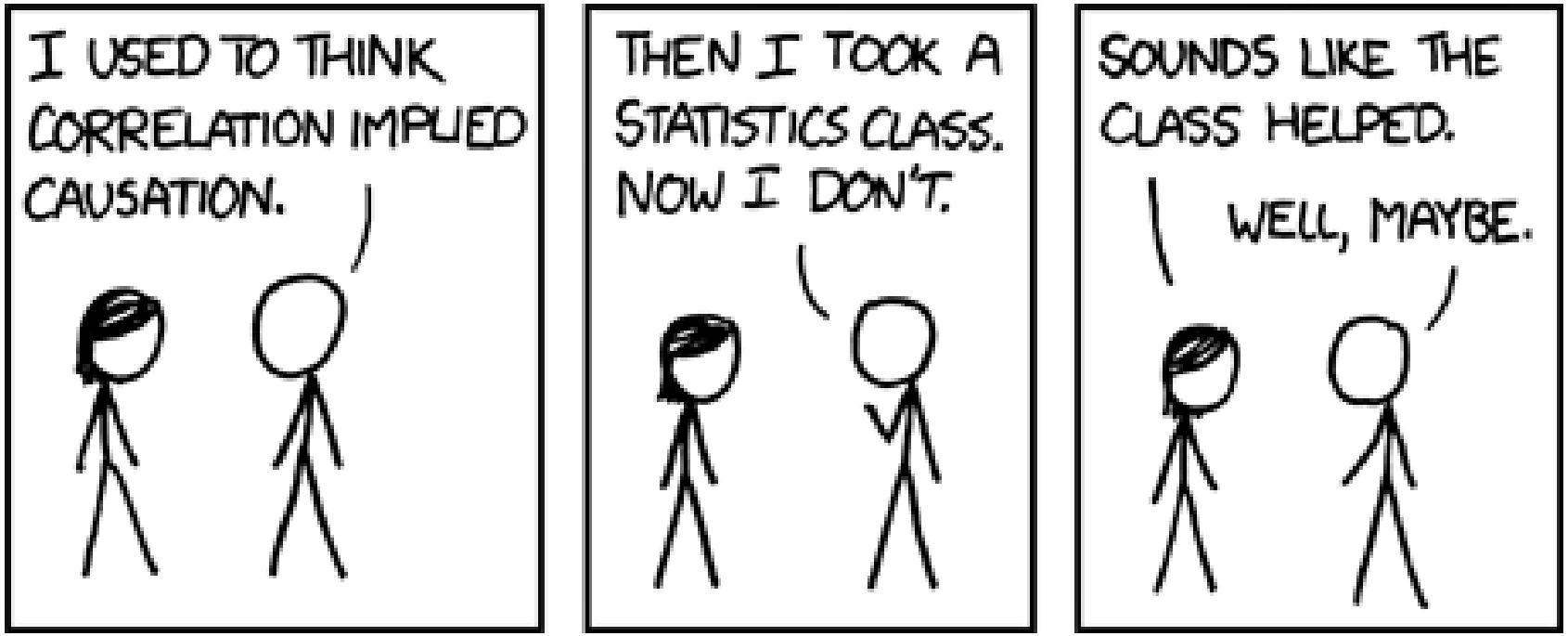
- A sample of mice were divided *randomly* into two groups. One group was given access to an exercise wheel, the other group was kept sedentary
- "*The brains of mice and rats that were allowed to run on wheels pulsed with vigorous, newly born neurons, and those animals then breezed through mazes and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

  (a) Yes (b) No

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

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



http://xkcd.com/552/