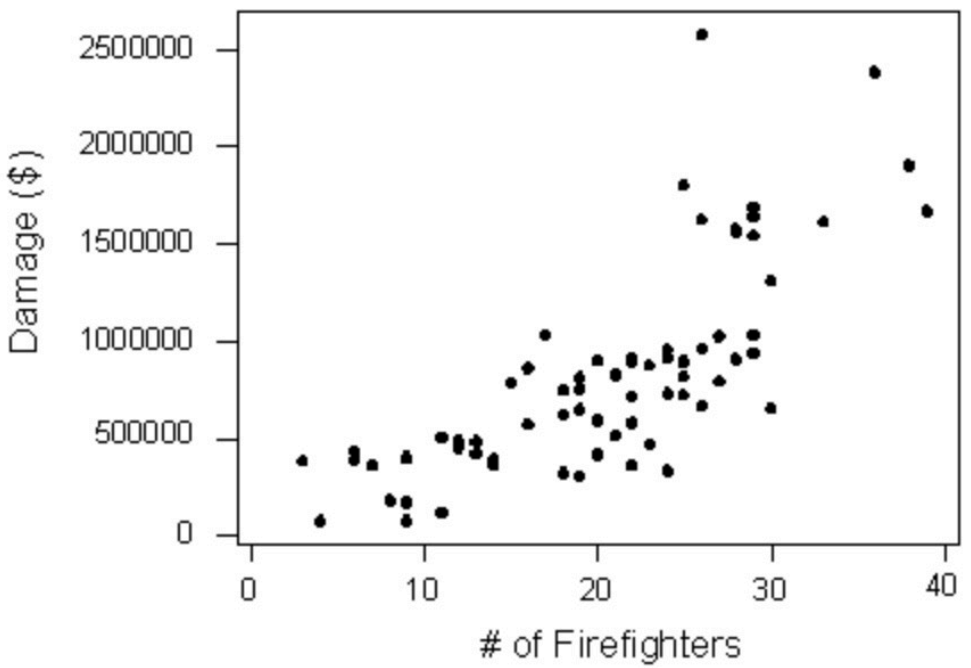
Data Collection via Experiments

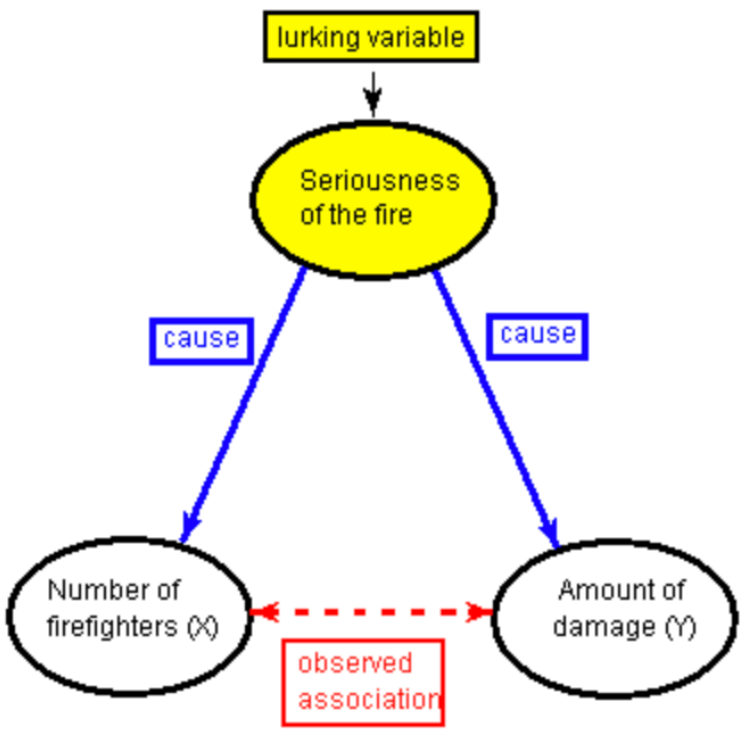
2 Study Designs

1. Observational Studies
    - Sample a group of people and watch/observe their behavior
2. Experiments
    - Recruit a group of people and assign them a treatment

Why Experiment?

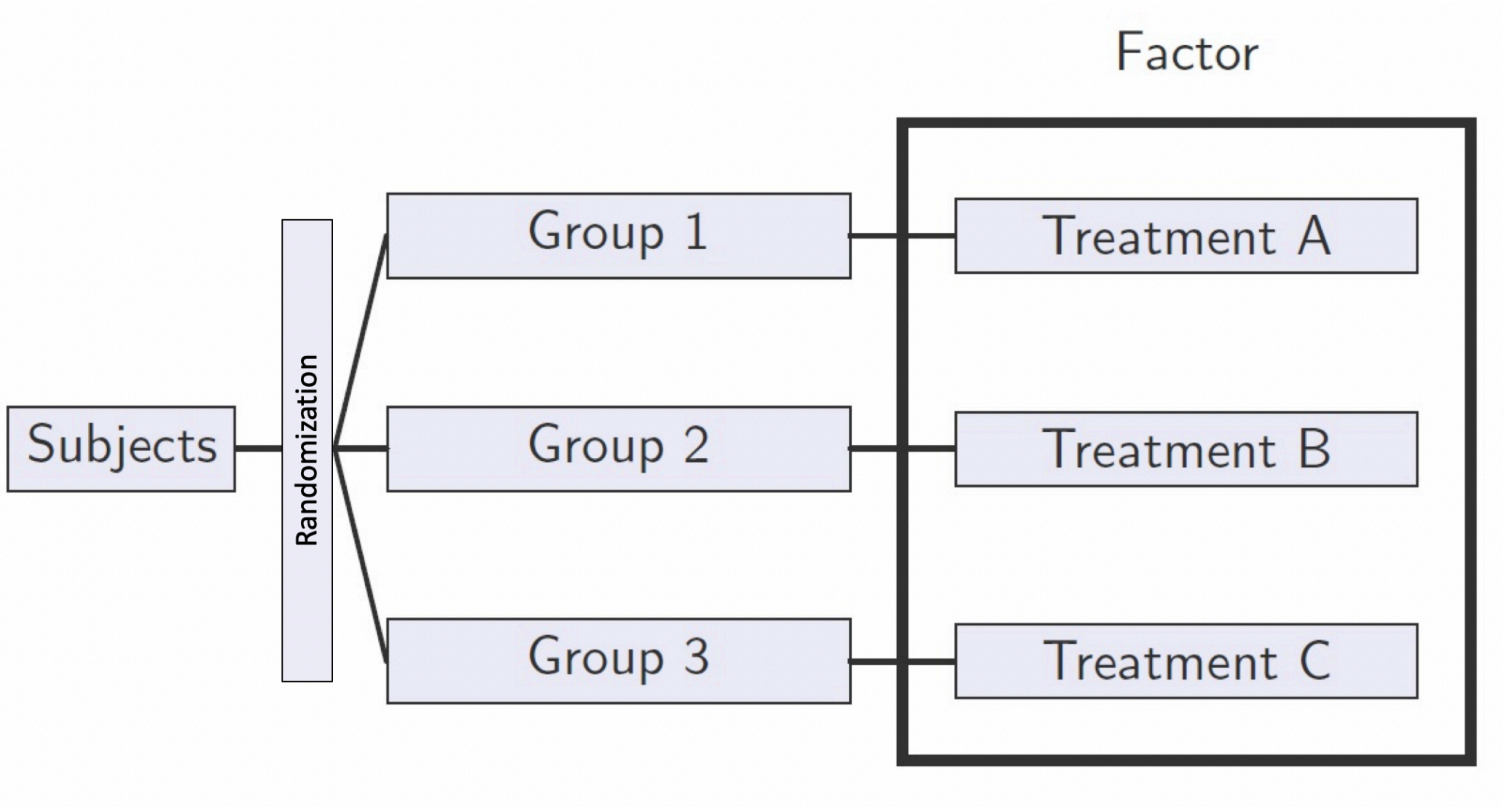
A well-designed experiment can give evidence that the treatment **causes** the response by controlling for **lurking variables**. **Lurking variables** are variables in your study that you have not controlled for but may affect the outcome.





Experiments try to control for as many lurking variables as possible.

Basic Structure of Experiments



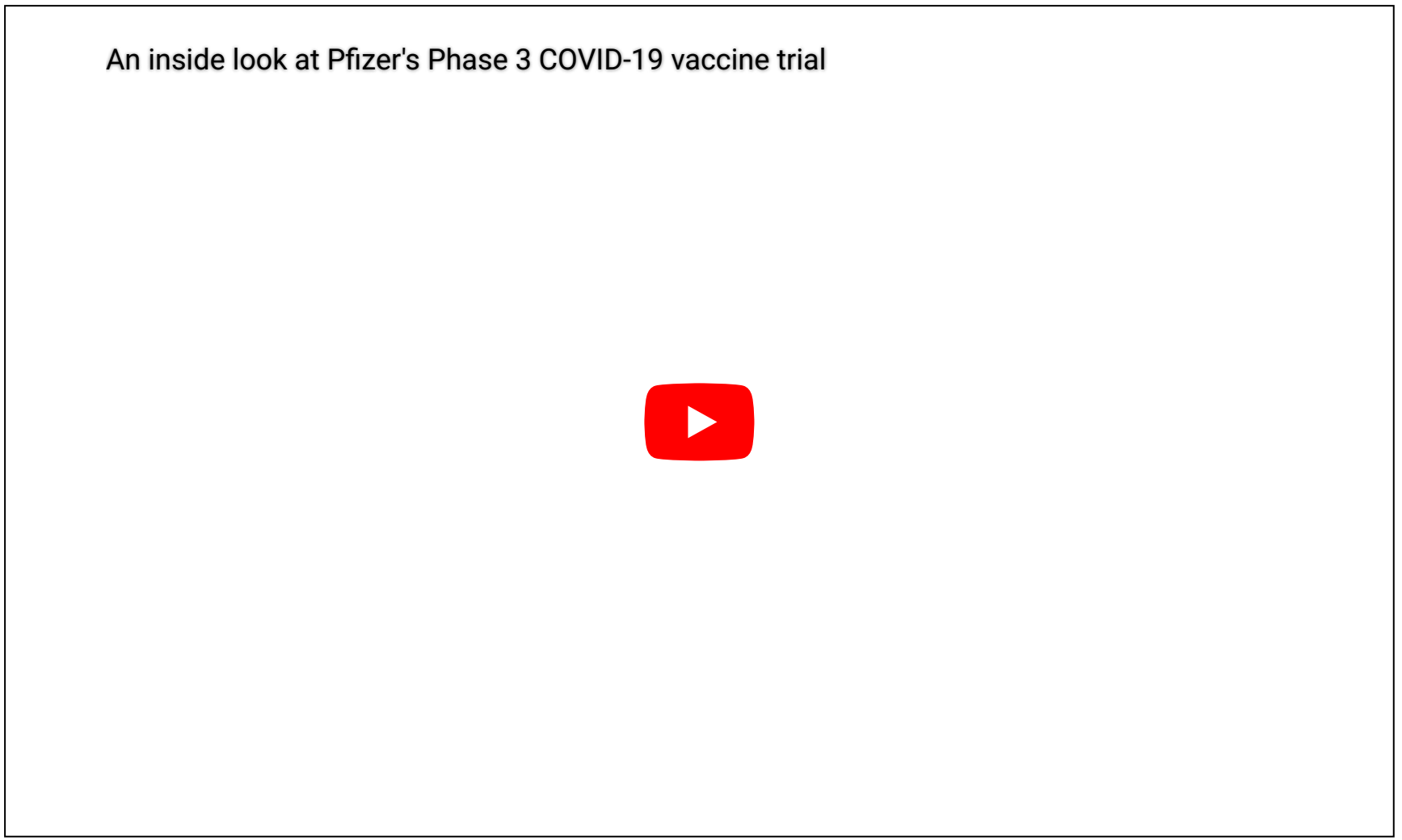
Basic Terminology for Experiments

- **Subject**: Individual on which we are going to measure a variable
- **Response variable (y)**: outcome of the experiment (e.g. damage)
- **Explanatory variable (x)**: variable used to *explain* the response (e.g. number of firefighters)
  - **Factor**: An explanatory variable with a fixed number of values (e.g. 2, 5 and 10 firefighters)
- **Treatment**: the condition or conditions applied to a subject or individual in an experiment (e.g. 5 fire fighters)

Basic Terminology Cont'd

- **Control**: a "treatment" with, supposedly, zero effect
  - **Placebo**: a fake treatment level to account for psychological effects
- **Double blind study**: An experiment where the individual and researcher don't know which treatment is applied.
- **Confounding**: A situation where a lurking variable, in addition to the explanatory variable, is affecting the response

An example: COVID Vaccine Trial



An example: COVID Vaccine Trial

Fill in the following for the Pfizer COVID vaccine study:

- Subject:
- Response variable:
- Explanatory variable:
- Factor:
- Treatment:
- Control:
- Placebo:
- Double blind study:
- Lurking variables:
- Confounded:

An example: COVID Vaccine Trial

Fill in the following for the Pfizer COVID vaccine study:

- Subject: A person (anyone who showed up as part of the trial)
- Response variable: Whether or not a person got COVID
- Explanatory variable: Whether or not a person got the vaccine
- Factor: Yes (only two levels for explanatory variable: vaccine or placebo shot)
- Treatment: Vaccine or placebo shot
- Control: Placebo shot
- Placebo: Yes (placebo shot)
- Double blind study: Yes
- Lurking variables: Contact with other people, living conditions, health condition, age, etc.
- Confounded: Difficult to say, but there is no clear connection between the explanatory variable and any of the lurking variables

Principles of Valid Experiments

1. **Control/Comparison**: control lurking variables by including comparison treatments, using homogeneous subjects; used to measure placebo effect
2. **Randomization**: neutralize effects of lurking variables by randomly assigning subjects to treatments
3. **Replication**: assign more than one subject to each treatment group
4. Double blinding (if possible)

Returning to COVID Vaccine Trial

Did the vaccine study include each of the following? If so, how?

1. Control/Comparison
2. Randomization
3. Replication
4. Double blinding

How would you design a good experiment?

Does requiring someone to sign up for an account with your company increase or decrease purchases?

- Design a valid experiment to answer this question.

Account Requirement Experiment

How did you include each of the following?

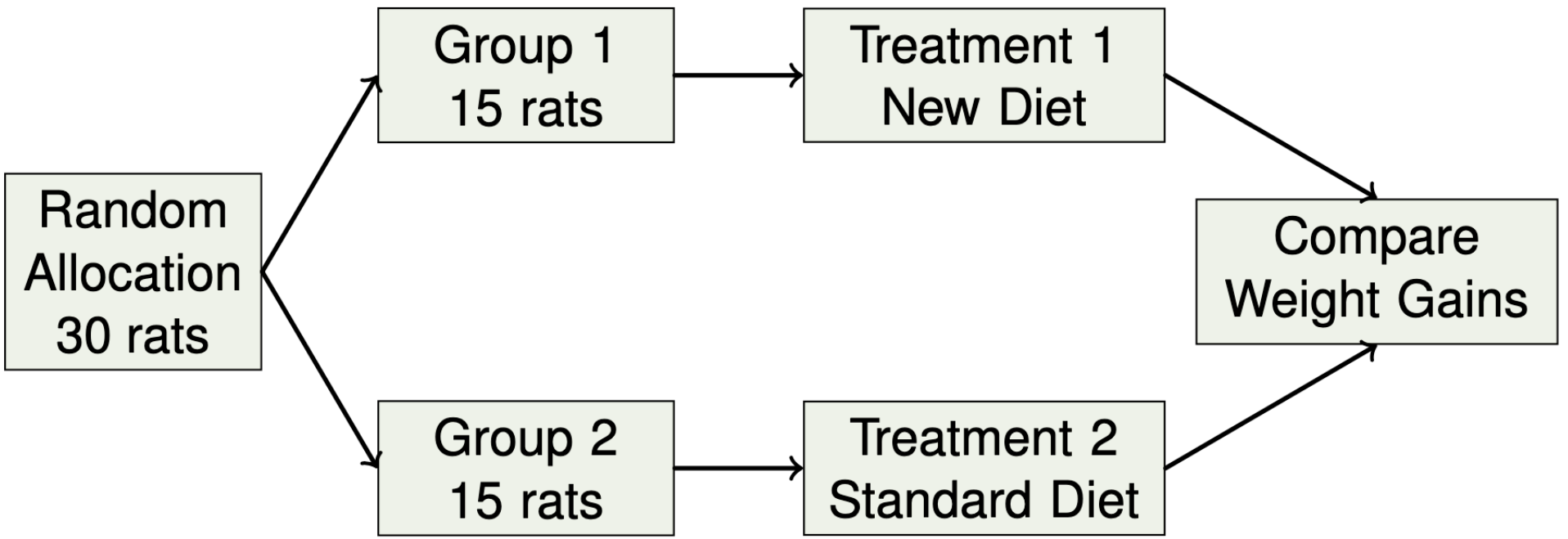
1. Control/Comparison
2. Randomization
3. Replication
4. Double blinding

Note: this is a common type of experiment in data science called “A/B” testing

Main classes of good experiments

1. Randomized controlled experiment
2. Randomized block experiment
    - Matched pairs as a special case

Randomized controlled experiments



Randomly split all subjects into treatment groups.

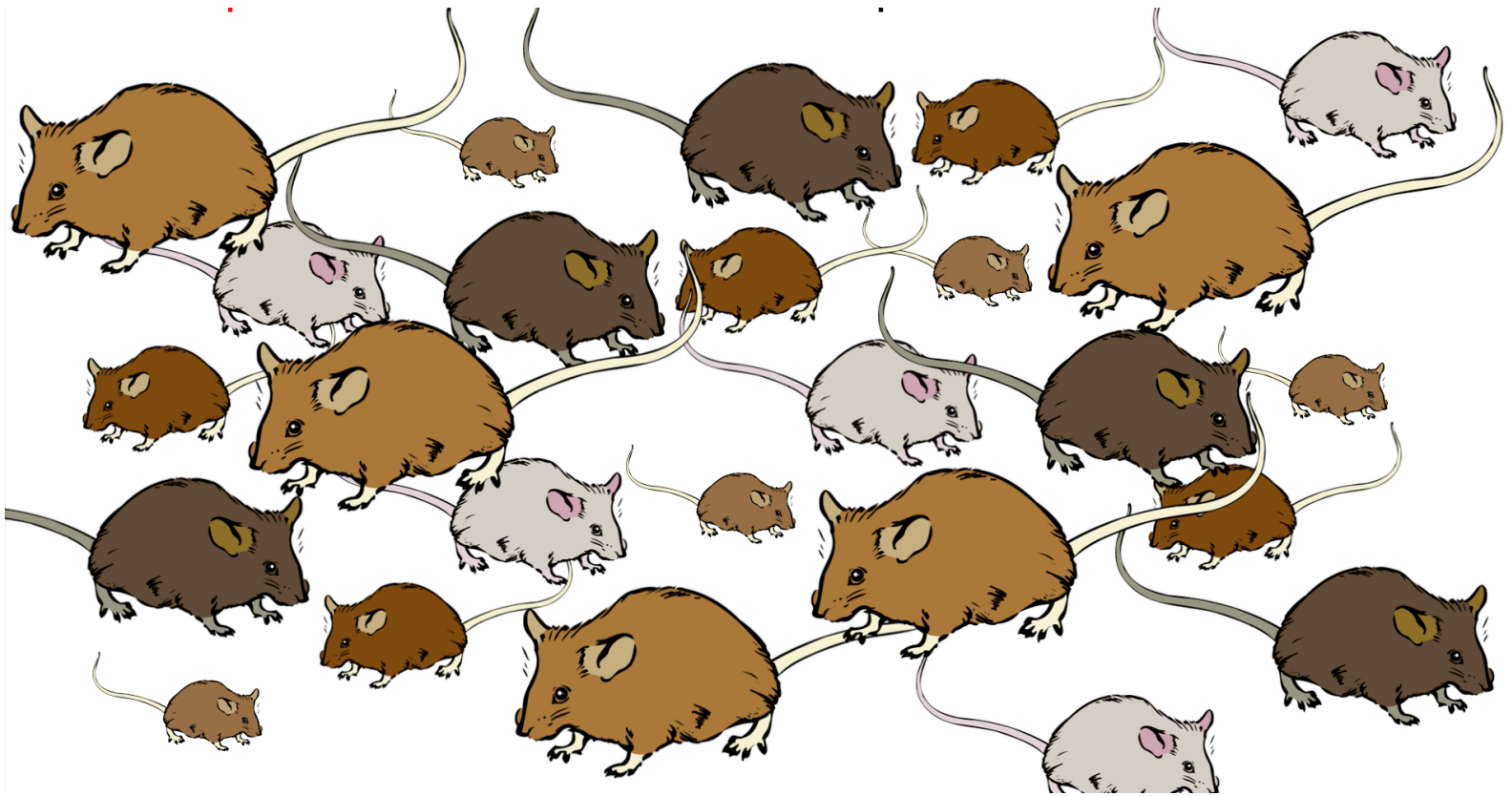
Randomized controlled experiments

Design Principles:

1. Comparison/control: multiple treatments
2. Randomization: used to split into groups
3. Replication: more than 1 rat per group
4. Double blind: maybe

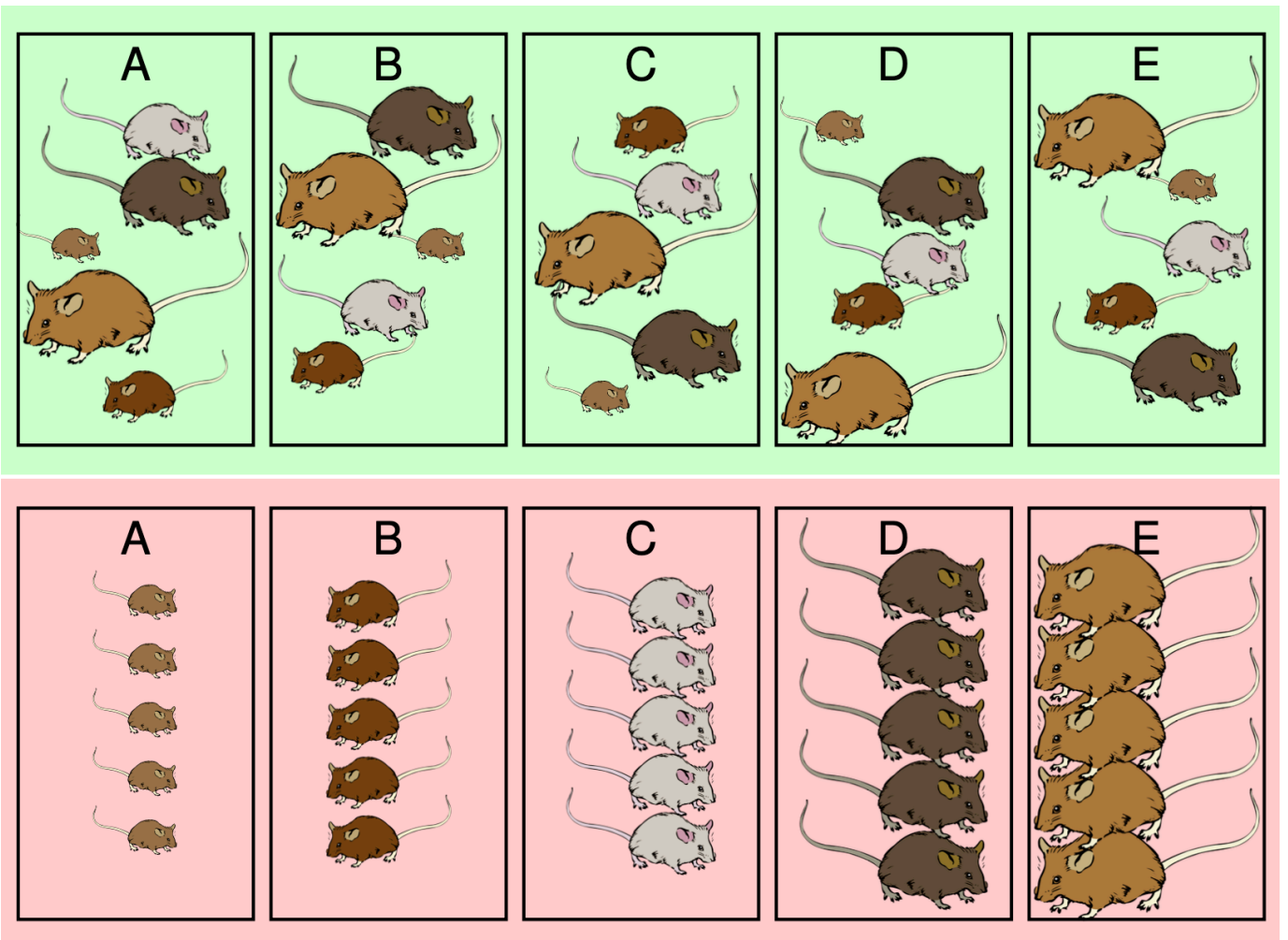
What can go wrong with RCEs?

Hypothetical experiment with rats and a 5 factor explanatory variables (A, B, C, D and E)



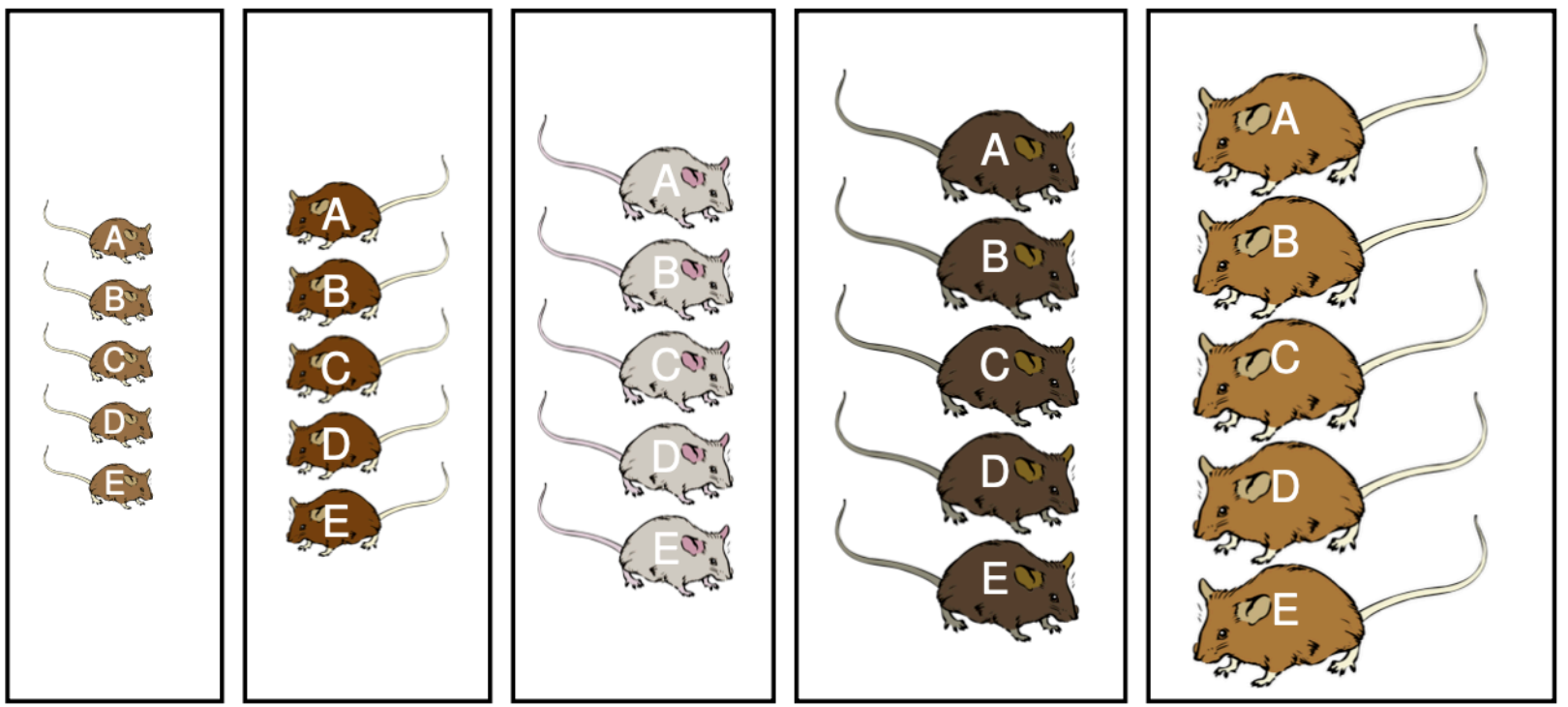
What can go wrong with RCEs?

Randomization outcomes:



Randomized Block Experiment

Solution: separate rats by size *first* then randomize within each size (block = group).



Do I still have all the principles of good experimental design?

RBEs vs RCEs

Randomized Controlled Experiment (RCE):

1. Use when individuals are similar

Randomized Block Experiments (RBE):

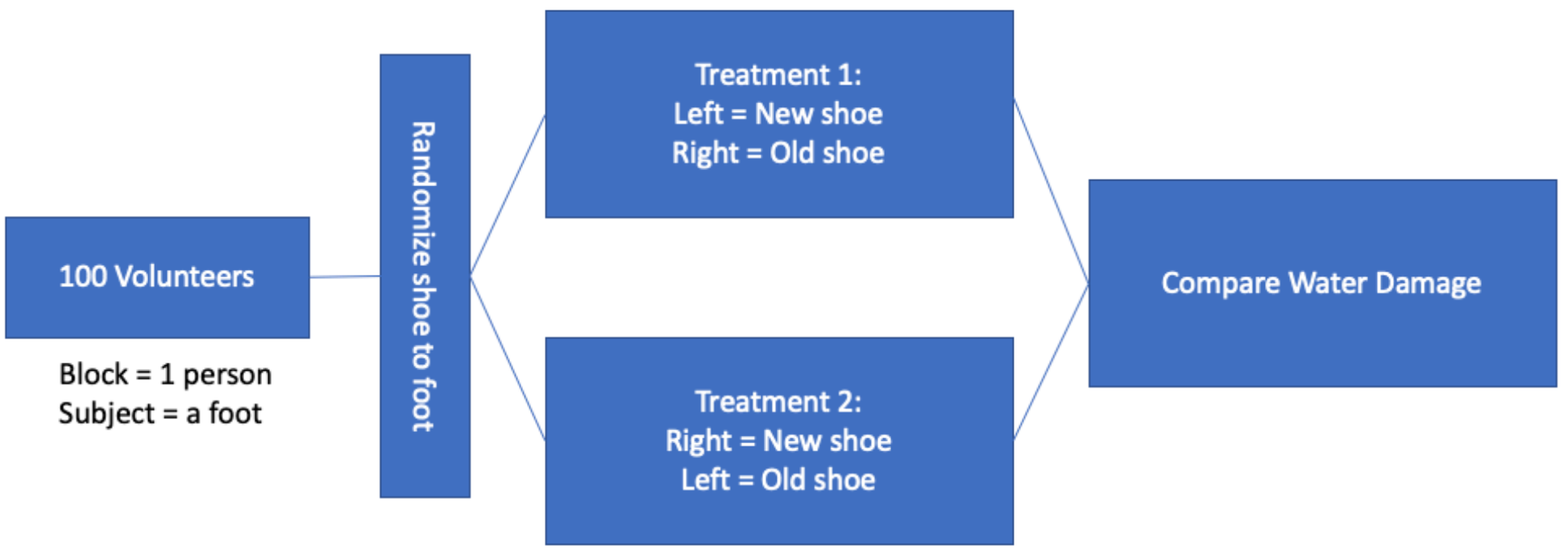
1. Use when the individuals are similar within a block but very different from block to block
2. RBE removes confounding of lurking variables with response variable
3. RBE reduces chance variation by removing variation associated with the lurking (blocking) variable.
4. RBE yields more precise estimates of chance variation which makes detection of statistical significance easier

Matched Pairs Studies

- Explanatory variable: 2 level factor
- Block: 2 subjects who are *very* similar (e.g. twins, same person)
- Randomly assign 1 subject within each block to treatment

Matched Pairs Example

Example: A manufacturer of boots plans to conduct an experiment to compare a new method of waterproofing to the current method. The appearance of the boots is not changed by either waterproofing method. The company recruits 100 volunteers in Seattle (where it rains a lot) to wear the boots as they normally would for 6 months. At the end of the 6 months, the boots will be returned to the company to be evaluated for water damage.



Understanding Check

240 subjects are available for an experiment testing the effects of different diets. Software randomly assigns 60 subjects to Diet 1, 60 subjects to Diet 2, 60 subjects to Diet 3, and 60 subjects to Diet 4. What type of study is this?

a. a randomized controlled experiment

b. a randomized block design, with four blocks

c. a matched pairs design

d. an observational study

e. none of the above

Understanding Check

240 subjects are available for an experiment testing the effects of different diets. Software randomly assigns 60 subjects to Diet 1, 60 subjects to Diet 2, 60 subjects to Diet 3, and 60 subjects to Diet 4. What type of study is this?

a. **a randomized controlled experiment**

b. a randomized block design, with four blocks

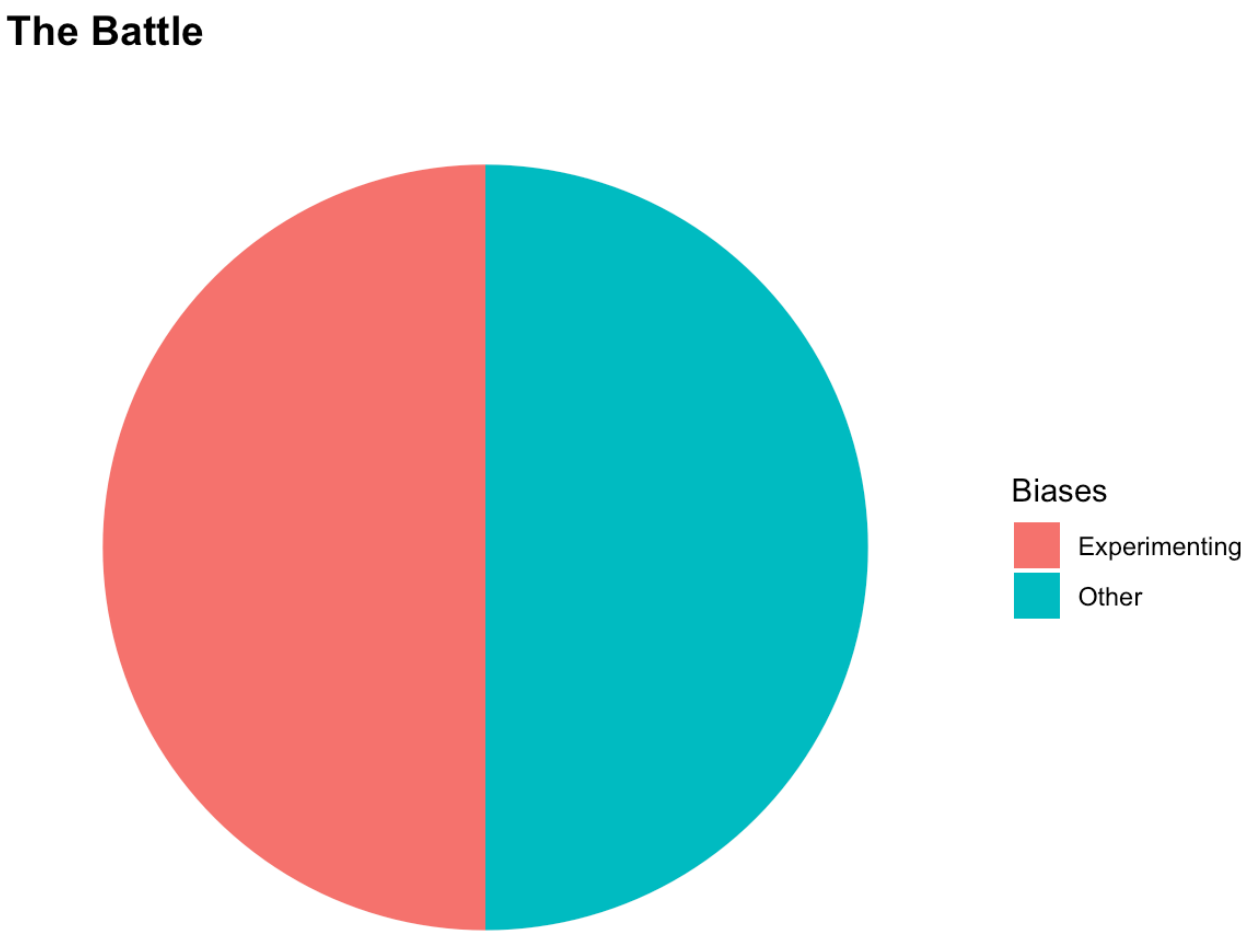
c. a matched pairs design

d. an observational study

e. none of the above

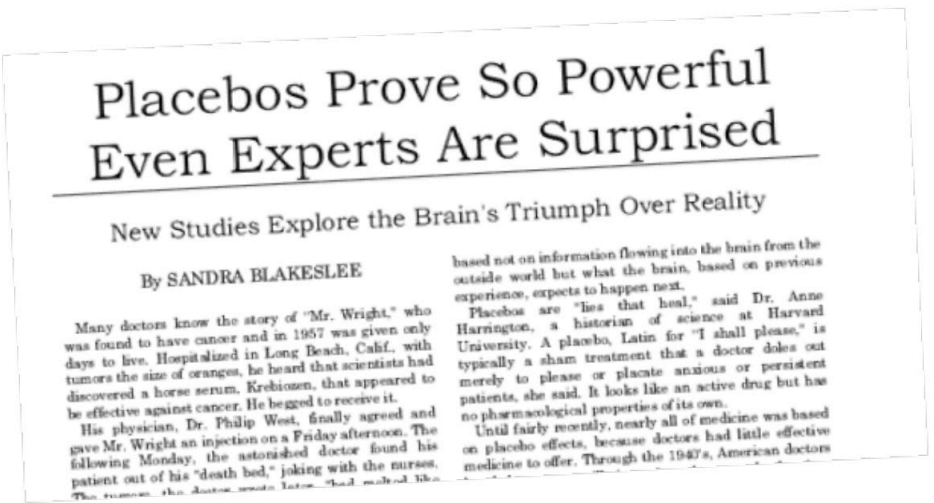
Biases in Experiments

Constructing a valid experiment is only half the battle. We need to be careful about a few things…



Placebo Effect

- Problem: The **placebo effect** is response by human subjects due to the psychological effect of being treated.
- Solution: Use a placebo



Placebos Prove So Powerful Even Experts Are Surprised

New Studies Explore the Brain's Triumph Over Reality

By SANDRA BLAKESLEE

Many doctors know the story of "Mr. Wright," who was found to have cancer and in 1957 was given only days to live. Hospitalized in Long Beach, Calif., with tumors the size of oranges, he heard that scientists had discovered a horse serum, Krebiozen, that appeared to be effective against cancer. He begged to receive it.

His physician, Dr. Philip West, finally agreed and gave Mr. Wright an injection on a Friday afternoon. The following Monday, the astonished doctor found his patient out of his "death bed," joking with the nurses.

based not on information flowing into the brain from the outside world but what the brain, based on previous experience, expects to happen next.

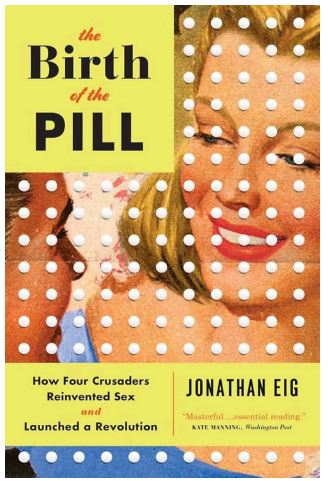
Placebos are "lies that heal," said Dr. Anne Harrington, a historian of science at Harvard University. A placebo, Latin for "I shall please," is typically a sham treatment that a doctor doles out merely to please or placate anxious or persistent patients, she said. It looks like an active drug but has no pharmacological properties of its own.

Until fairly recently, nearly all of medicine was based on placebo effects, because doctors had little effective medicine to offer. Through the 1940's, American doctors

New York Times October 13, 1998

The Birth of the Pill by Jonathan Eig

Researchers wanted to test a theory that the side effects women were experiencing from birth control were psychosmastic. To test this, they created a simple experiment:



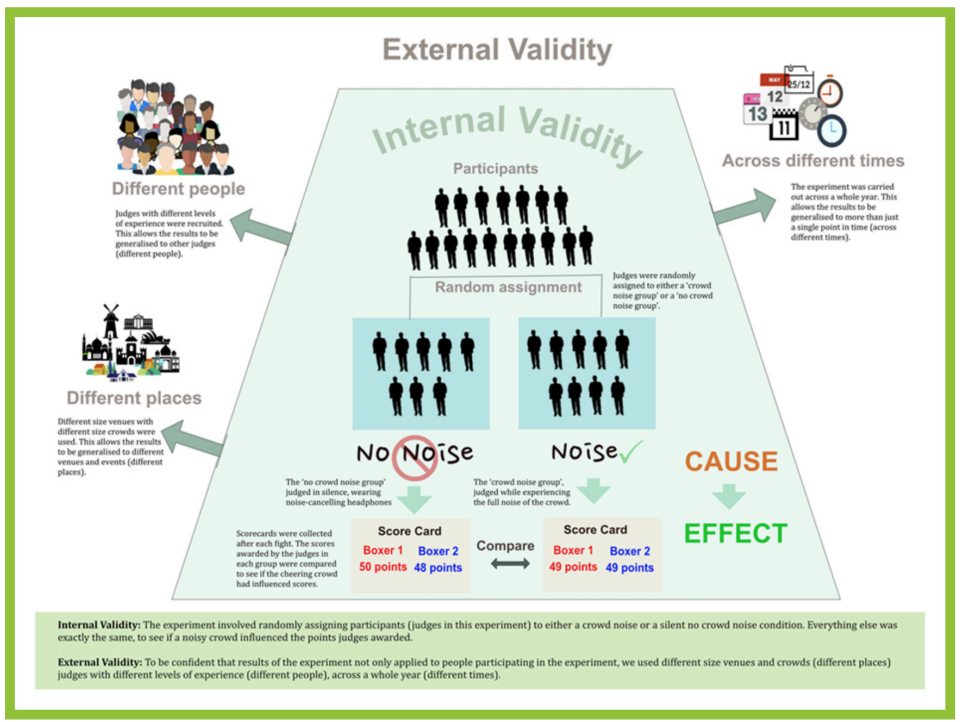
- Group 1 was given the drug with the usual warnings
- Group 2 was given a placebo and the same warnings as the first group
- Group 3 was given the drug with no warnings about the side effects
    - Side Effect Results: Group One 23%, Group Two 17%, Group Three 6%

Diagnostic Effect

- Problem: Diagnosis of subjects biased by preconceived notions about effectiveness of treatment
- Solution: Blind the diagnoser

Lack of Realism

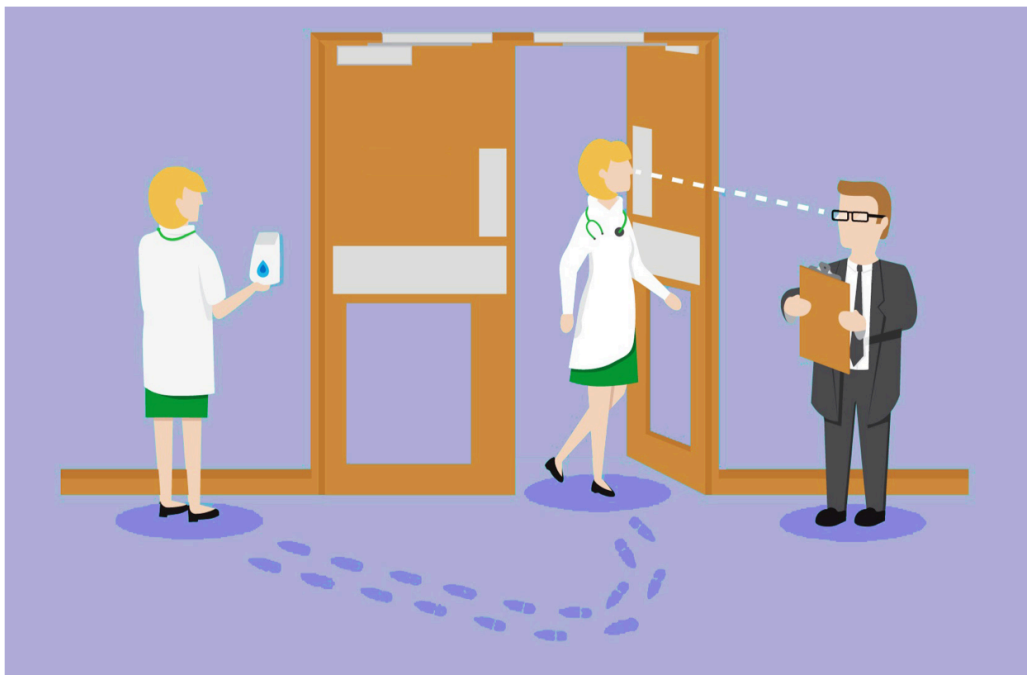
- Problem: Sometimes experiments can’t apply to real life.
- Solution: Keep it real!



https://kids.frontiersin.org/articles/10.3389/frym.2017.00013

Hawthorne Effect

- Problem: people in an experiment behave differently from how they would normally behave
- Solution: Hidden observation (if ethical)



https://www.vitalacy.com/post/hawthorne-effect-hand-hygiene

Non-compliance

- Problem: People don’t do what they are supposed to do
- Solution: You can’t make them

Key Terminology

- Causation
- Lurking Variables
- Subject
- Response variable
- Explanatory variable / factor
- Treatment
- Control
- Placebo
- Double blind
- Placebo effect
- Diagnostic Bias
- Data Ethics
- Randomized Controlled Experiment
- Randomized Block Experiment
- Matched Pairs Experiment