

Human-Computer Interaction

Experimental Research: An Introduction

Professor Bilge Mutlu

Today's Agenda

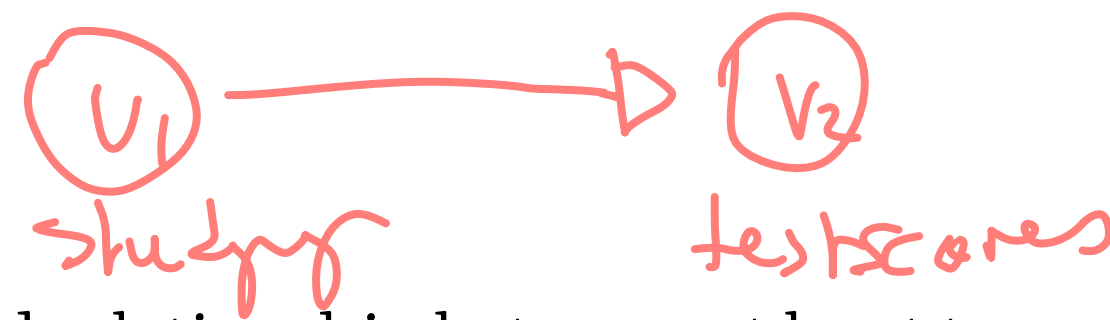
- » Topic overview: *Experimental Research: An Introduction*
- » Hands-on Activity: *Reverse Engineering Experimental Design Choices*

What is a hypothesis?

Definition: An idea that proposes a tentative explanation about a phenomenon or a narrow set of phenomena observed in the natural world.

> The two primary features of a scientific hypothesis are falsifiability and testability (proposed by Karl Popper).¹

¹Brittanica



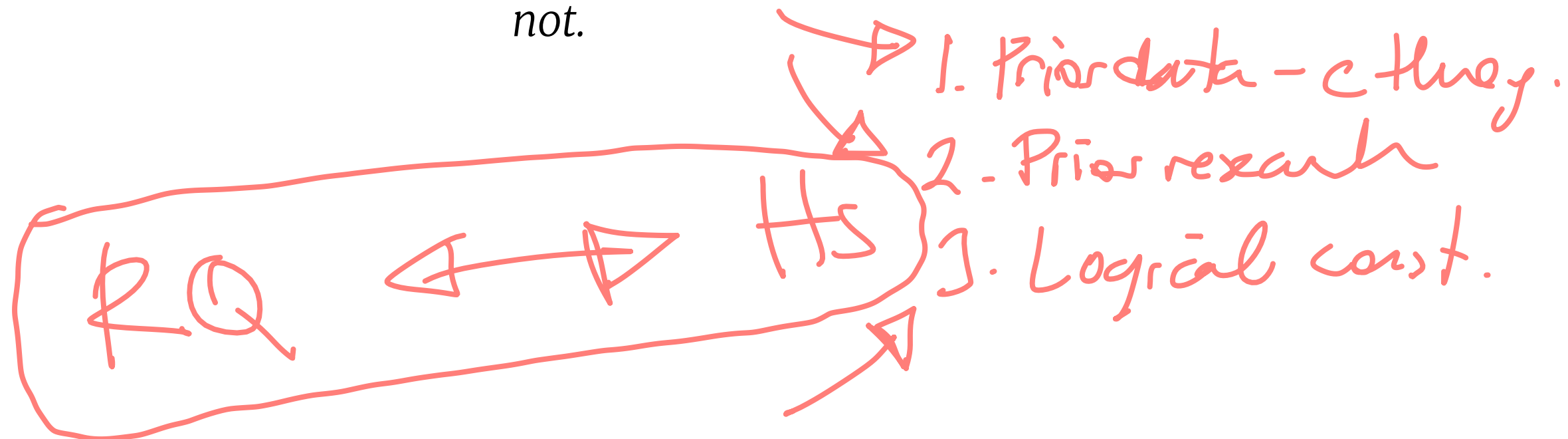
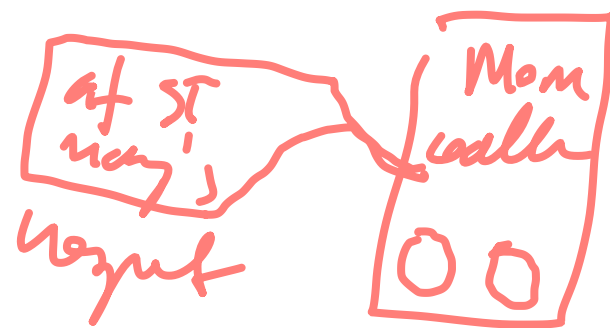
A more operational definition

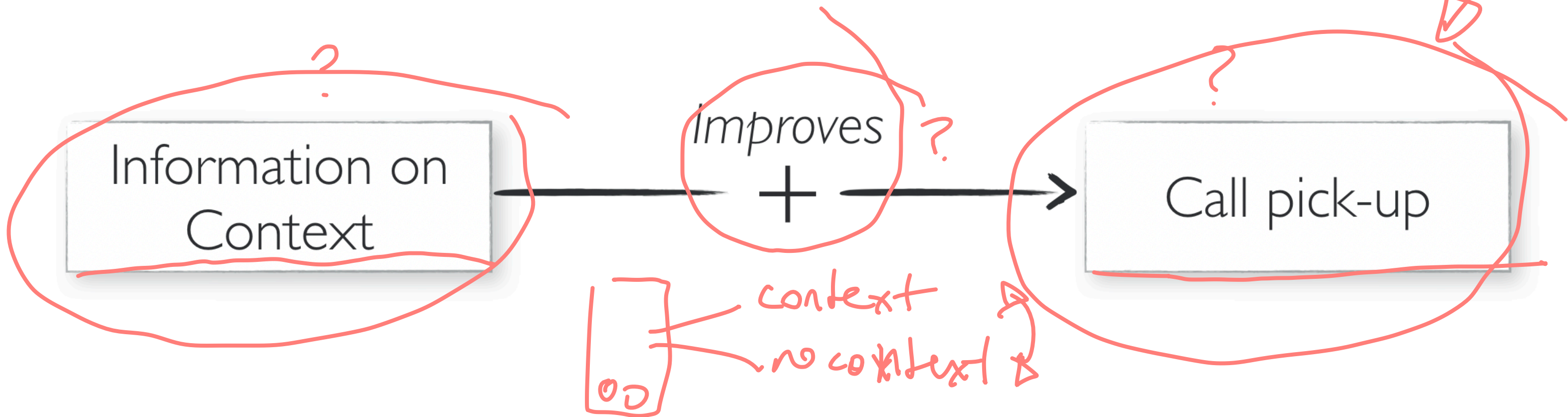
A statement of the predicted or expected relationship between at least two variables (e.g., an independent and a dependent variable).

A well-formulated hypothesis should provide an provisional, testable answer to a *research question*.

Question: How does having information on the context of a caller affect whether the receiver picks up the call?

Hypothesis: Receivers will be more likely to pick up a call when they have information on their callers' context than they will be when they do not.





Good hypotheses should be:

1. **Testable**, such that manipulating *independent variables* and measuring *dependent variables* should be possible
2. **Falsifiable** with the data obtained from the experiment
3. **Parsimonious**, representing a prediction in the simplest form
4. **Precise** such that the researcher can operationalize it
5. **Useful** to inform existing or new theory

How do we think about experimental variables?

An experiment is ^{an} empirical journey set to establish relationships among *variables*—ideas in the conceptual domain² represented as mathematical abstractions. Five key types of variables:

1. Independent variable: what is being manipulated

2. Dependent variable: what is being measured

3. Control variable: what is held constant 18 - 65

4. Random variable: what is allowed to vary randomly

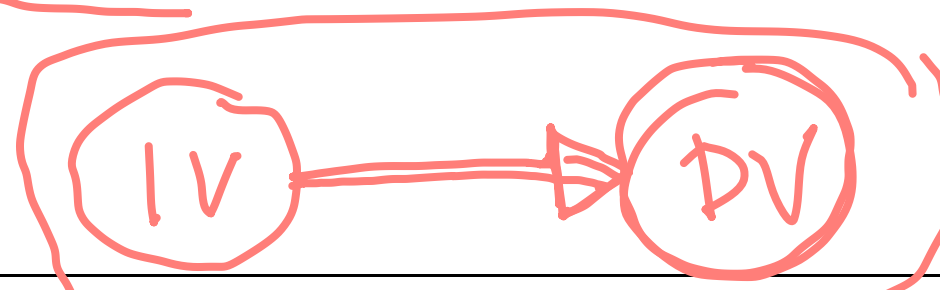
5. Confounding variable: what correlates with IV/DV

3 domains

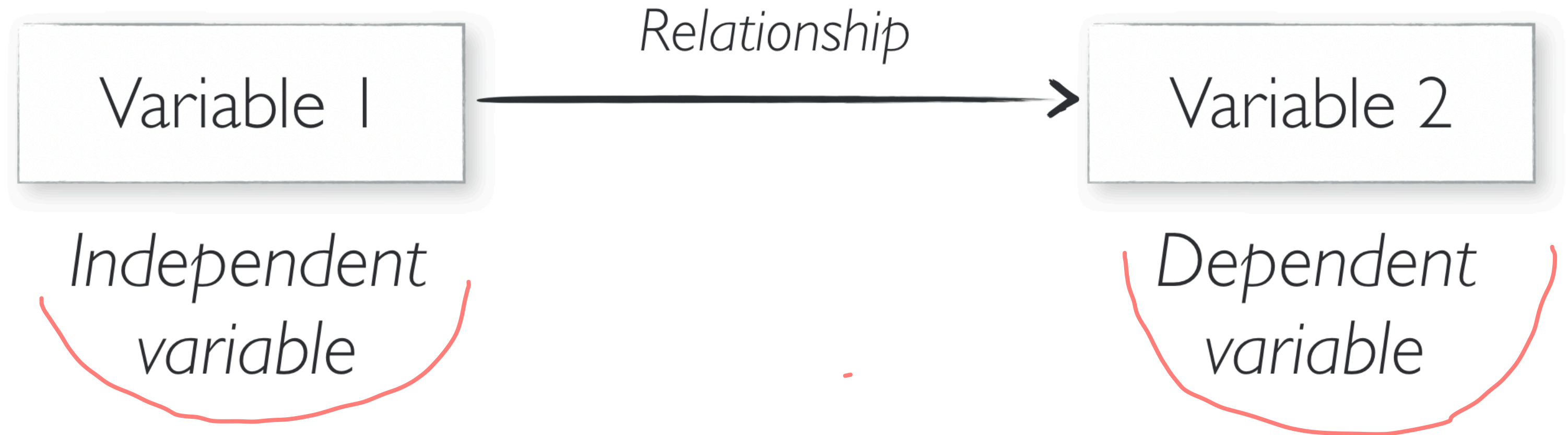
— conceptual

— substantive

— methodological

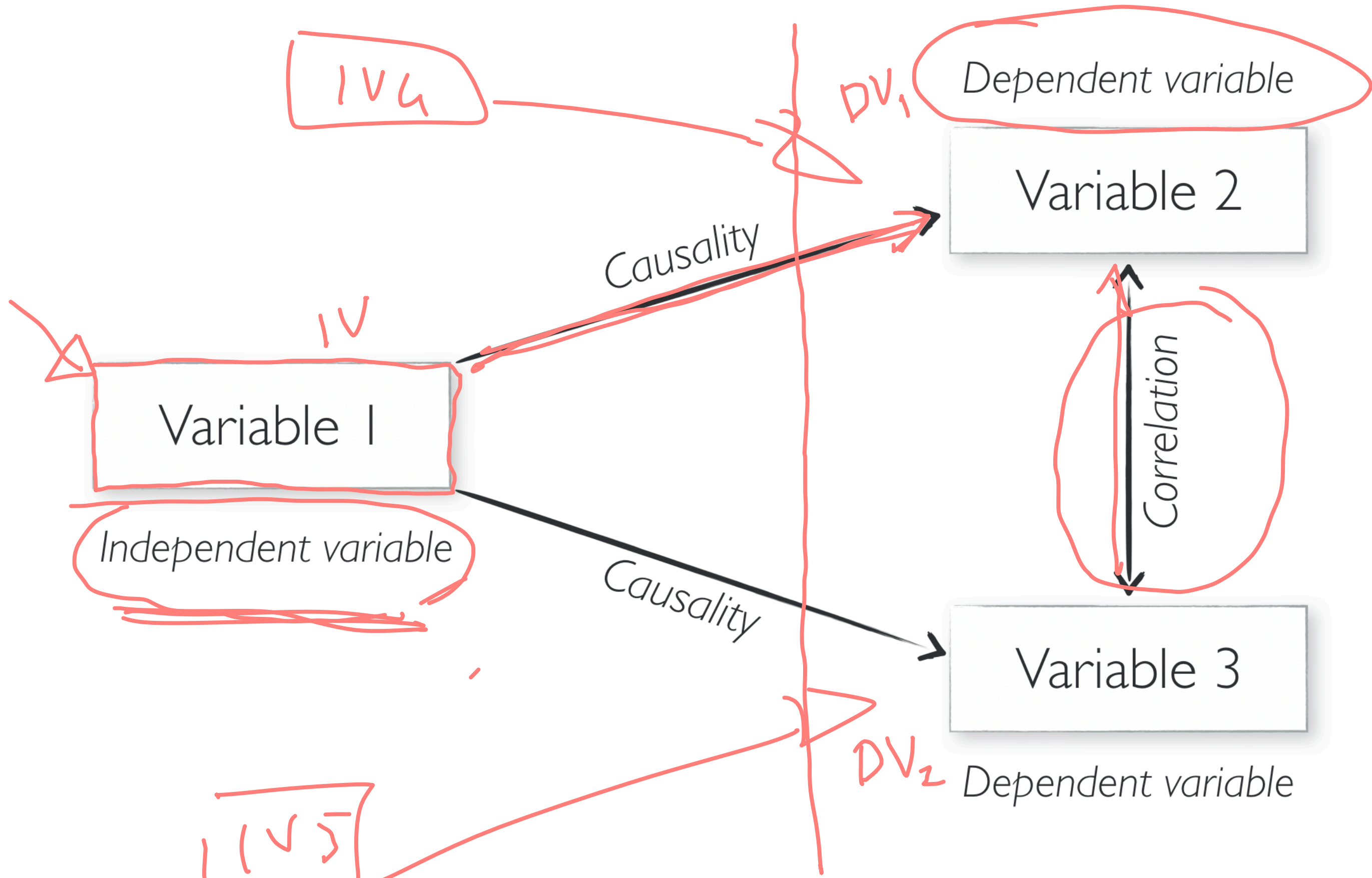


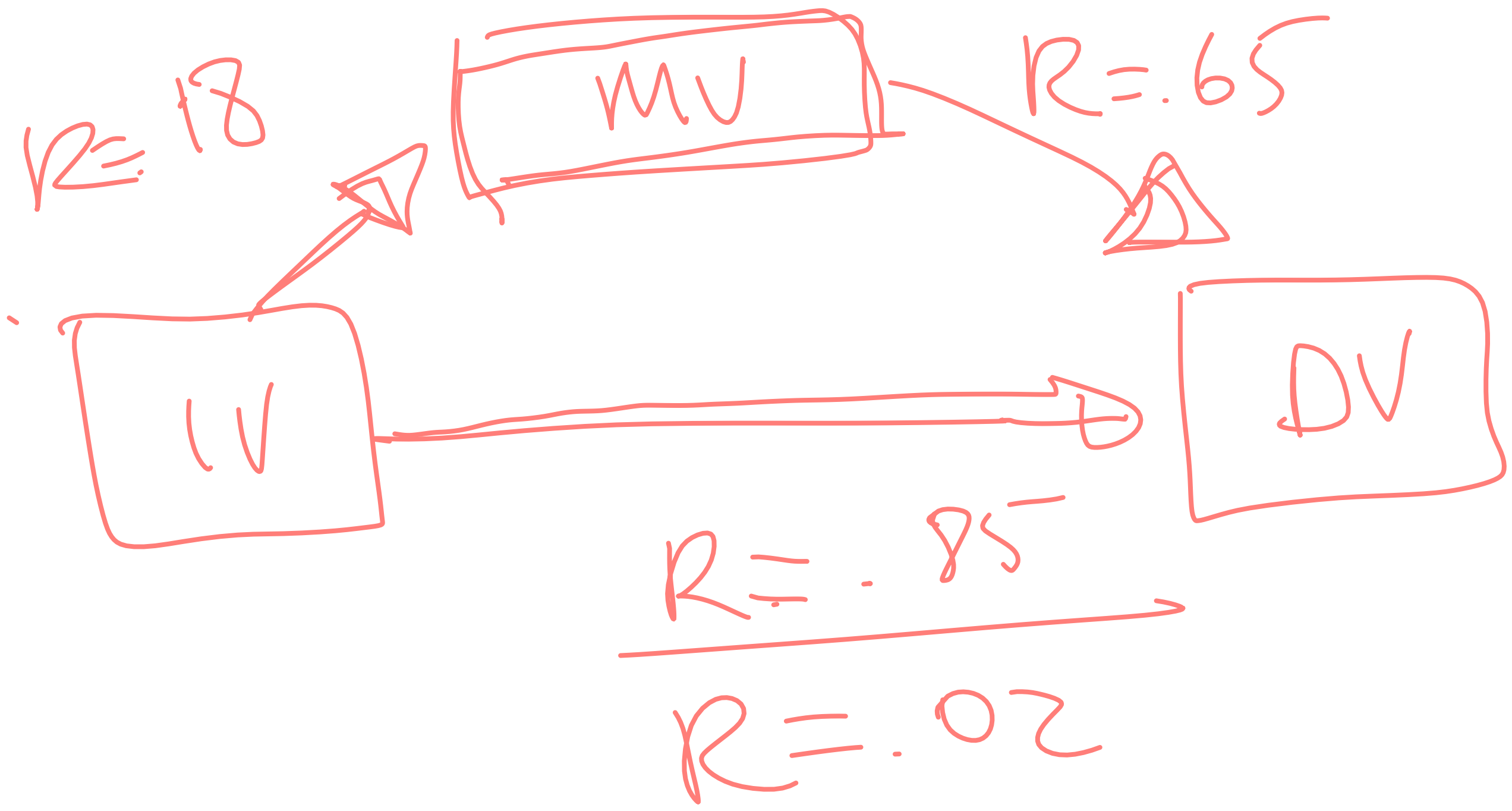
² McGrath, J. E. (1995). Methodology matters: Doing research in the behavioral and social sciences. In *Readings in Human-Computer Interaction* (pp. 152-169). Morgan Kaufmann.



What kinds of relationships are we interested in?

- » **Causal relationships:** one variable (DV) depends on and is affected by another (IV).
- » **Correlational relationships:** two variables are affected by a third variable in the same direction.

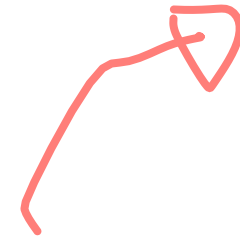
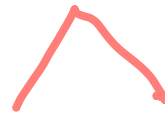
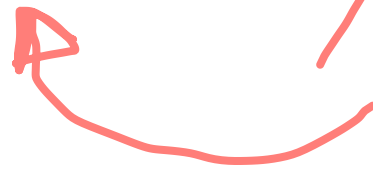
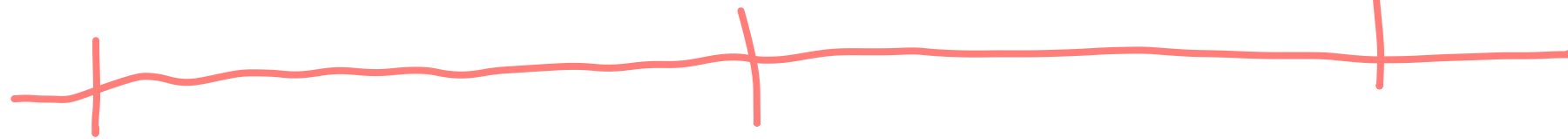


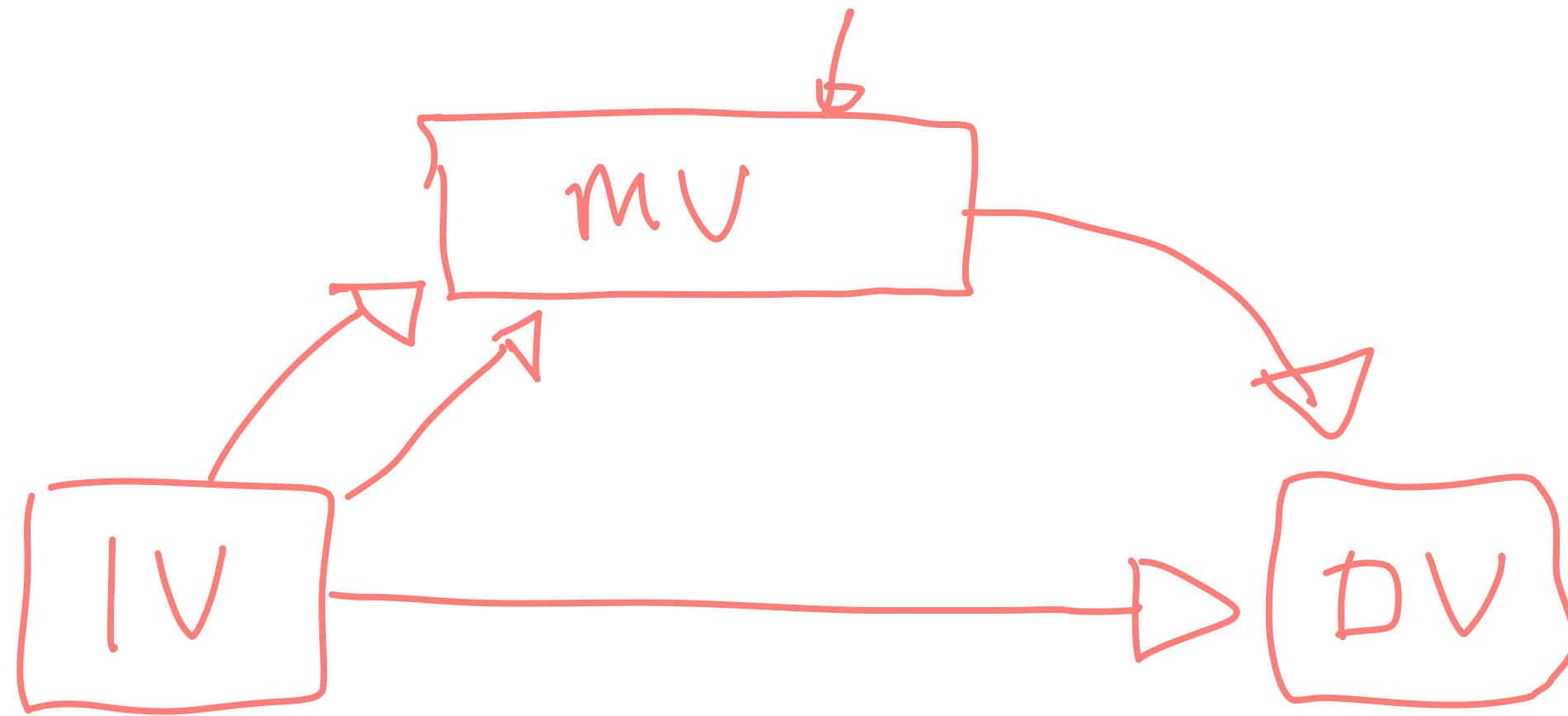


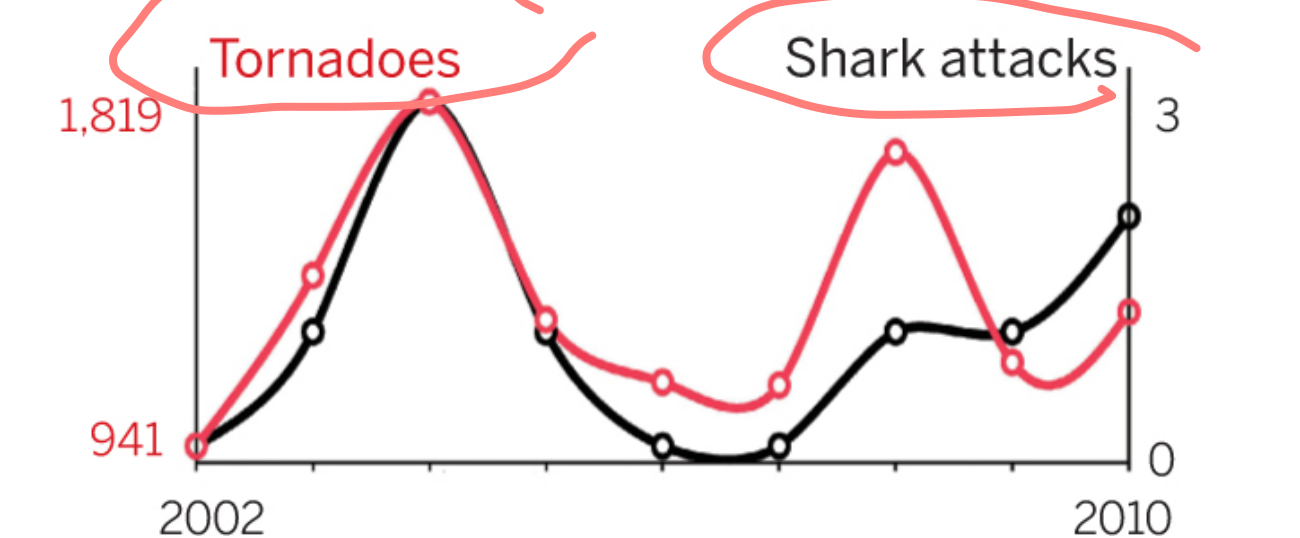
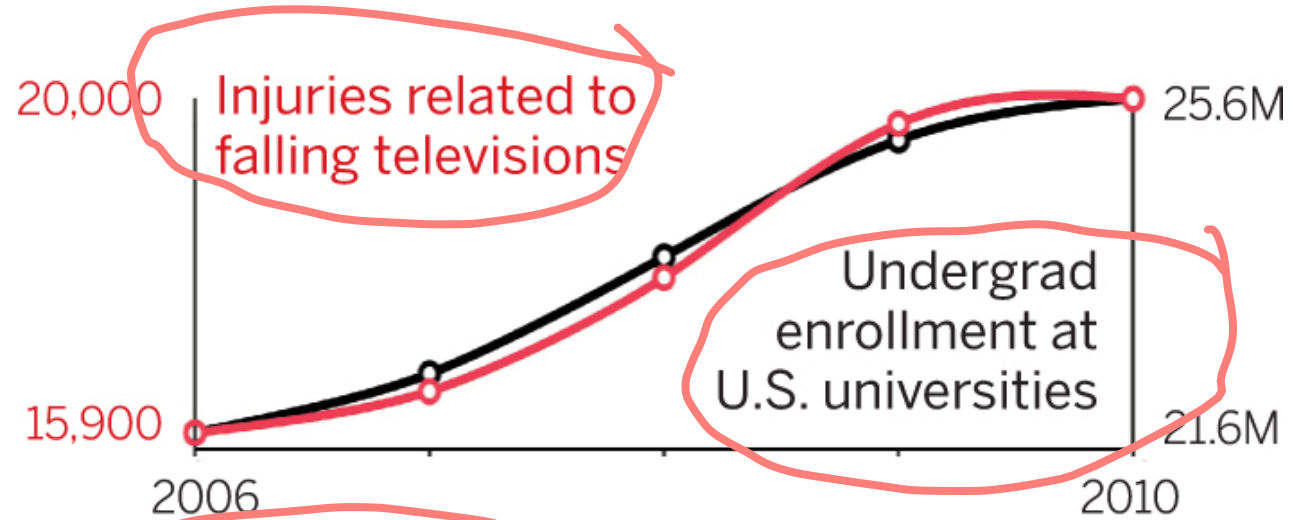
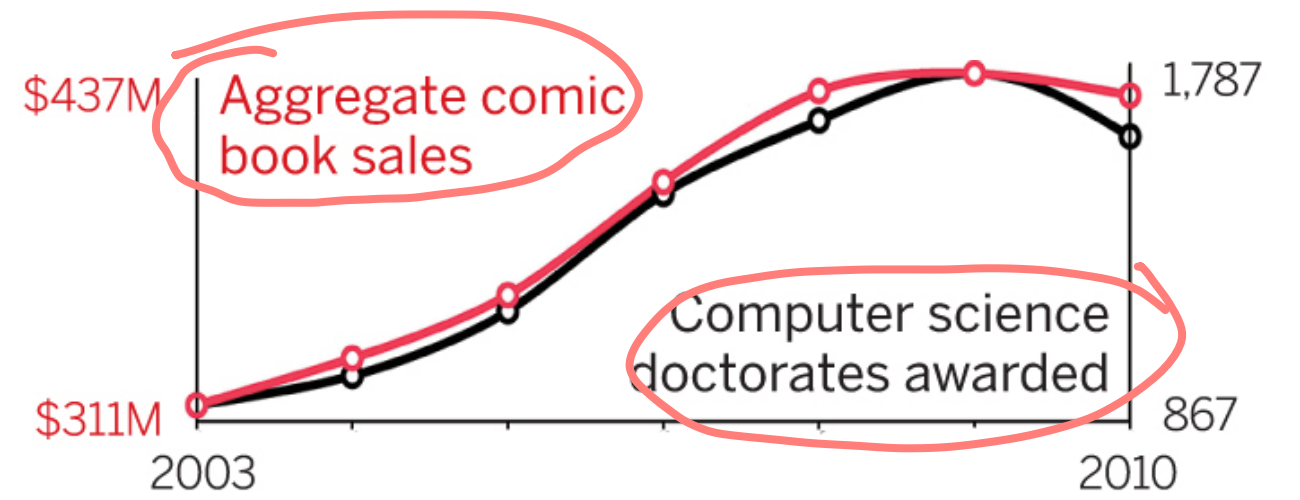
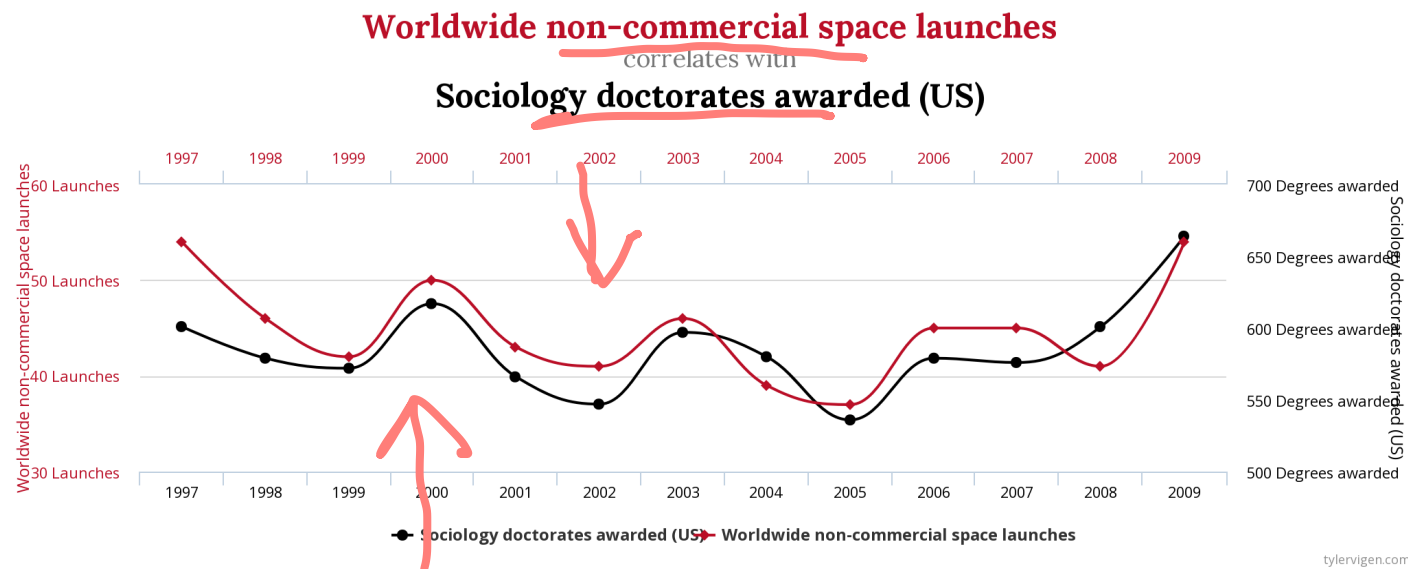
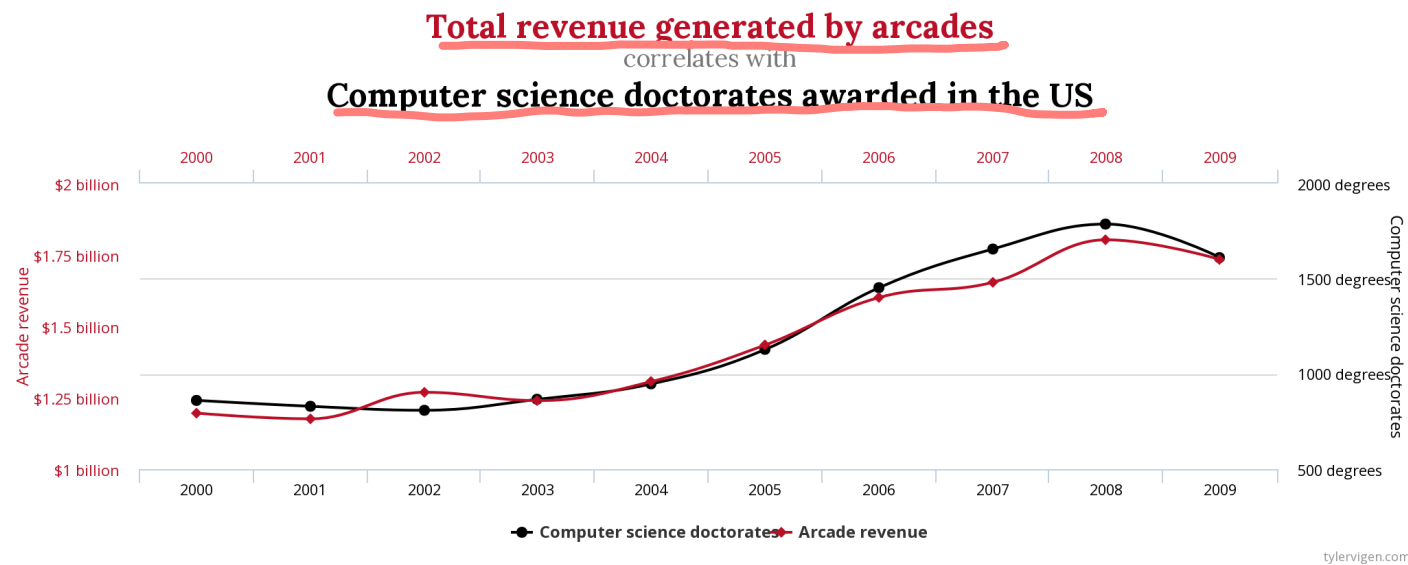
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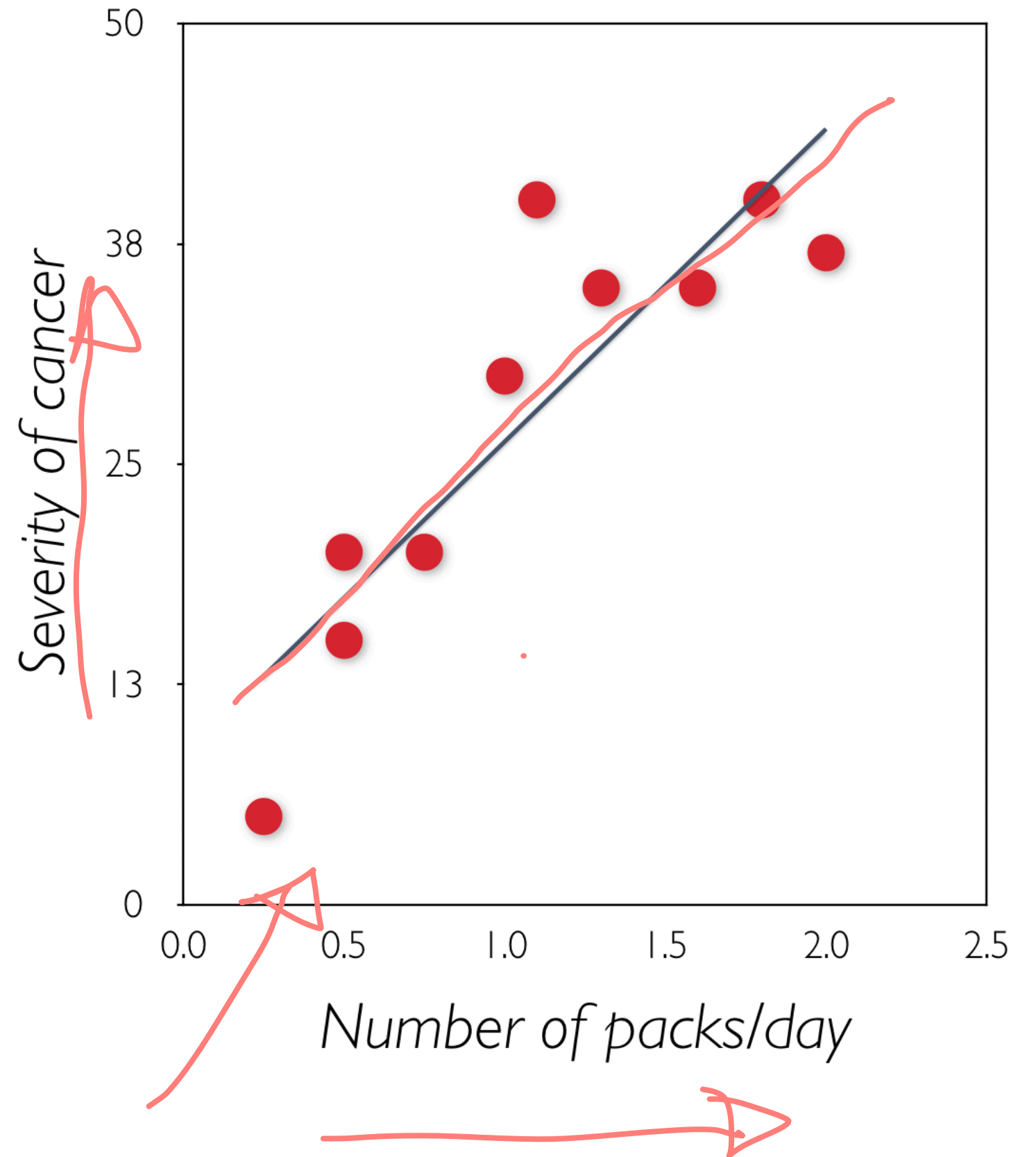
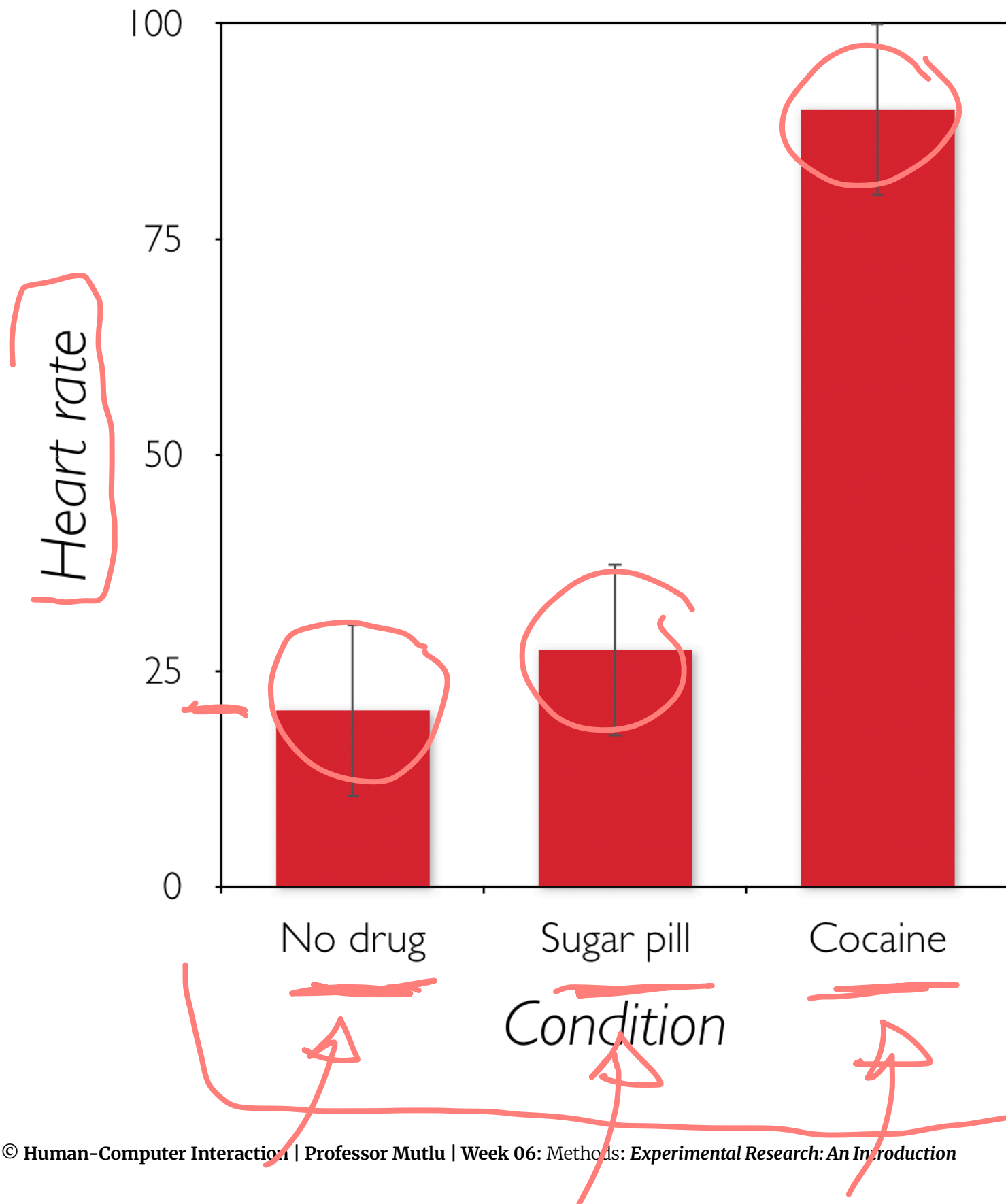






³ Left: Tyler Vigen: Spurious correlations

⁴ Right: Books et al., 2015, Spurious correlations



How do we think of variables in designing experiments?

By answering the following questions:

1. Do we know all the variables involved? <
2. Can we control independent variables of interest? <
3. Can we measure all variables? <

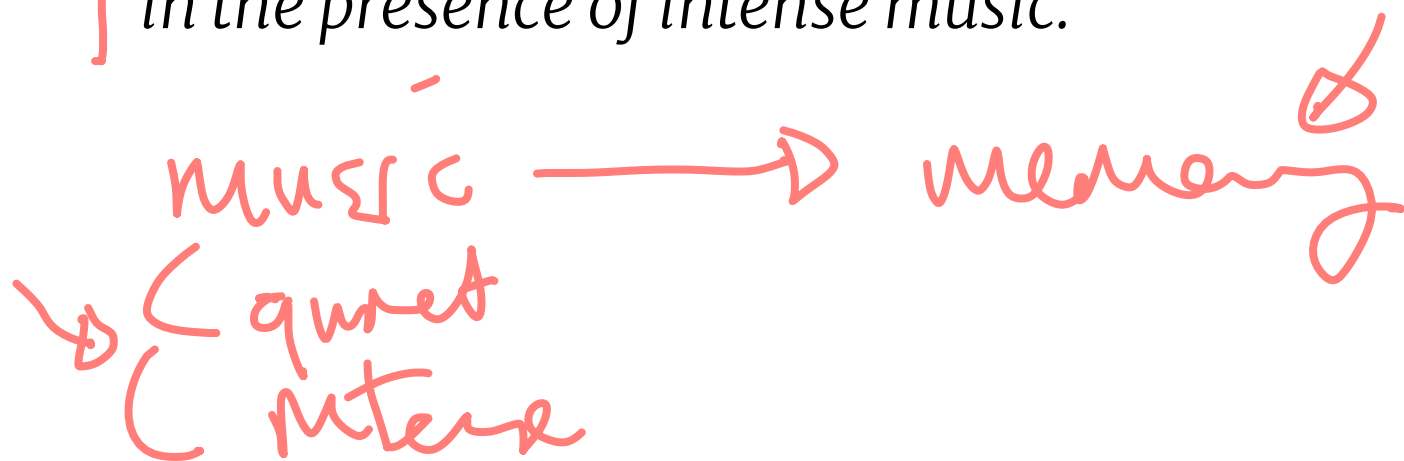
If the answers are:

Yes. Yes. Yes.

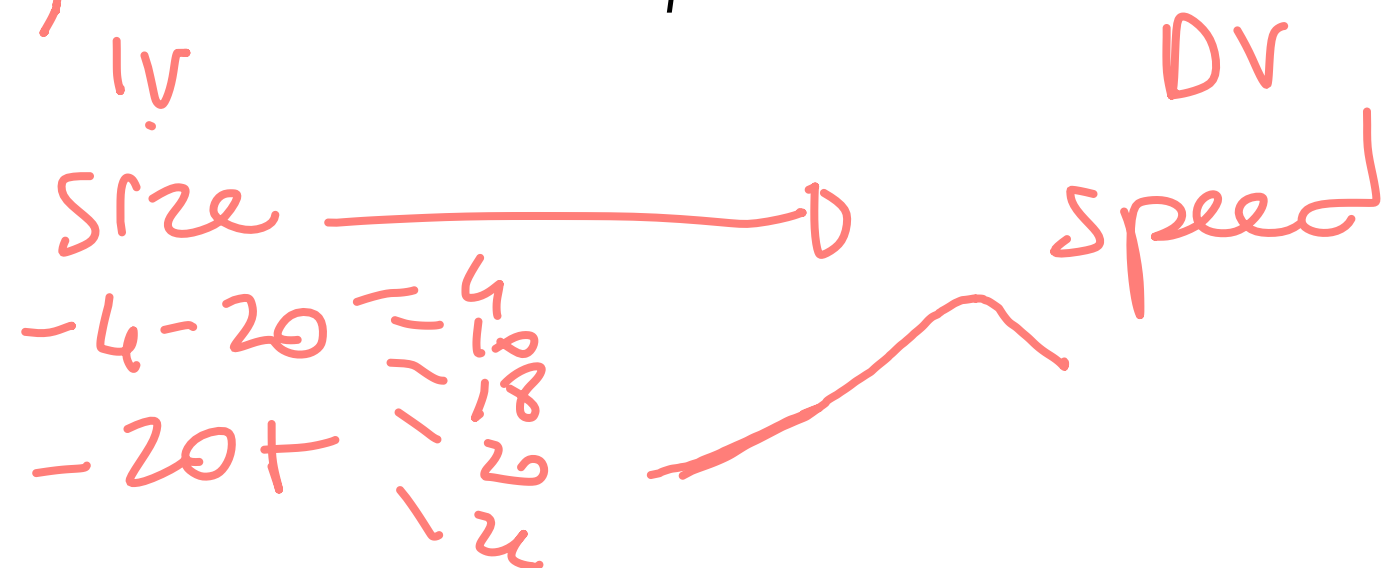
We are designing a true experiment where independent variables are manipulated, dependent variables are measured, and the hypothesis is a cause-effect statement.

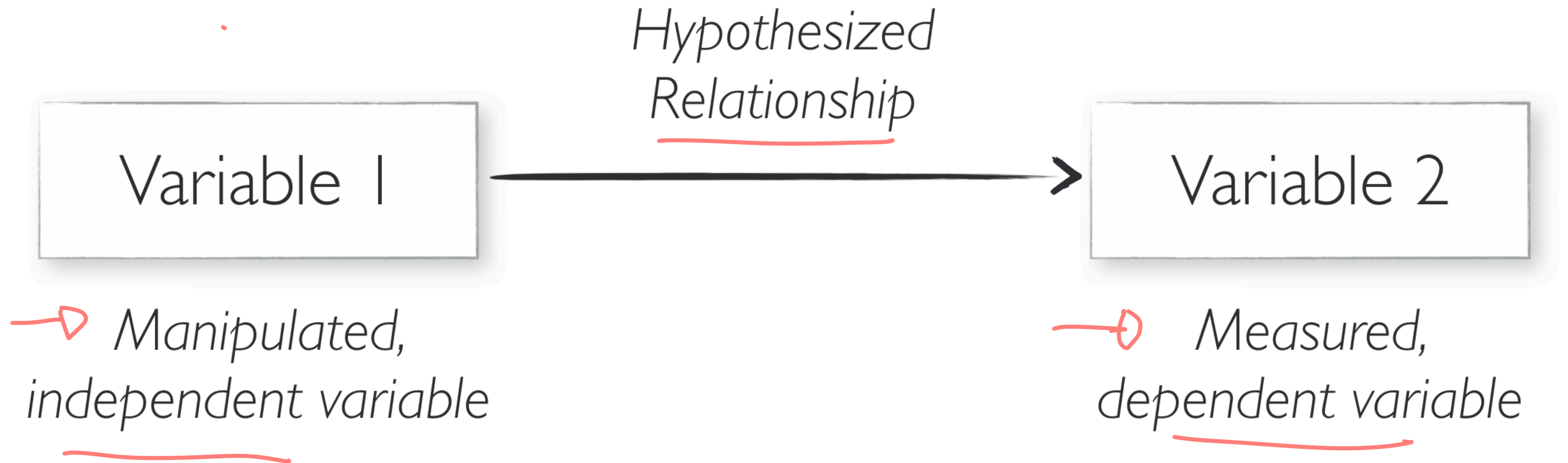
Example hypotheses:

Students will remember more items from a word list if they learn the list in the quiet, rather than in the presence of intense music.



Reading speed (words/minute) will change with font size, increasing as font size is increased from 4 point to 20 point, but decreasing as font size is increased above 20 point.





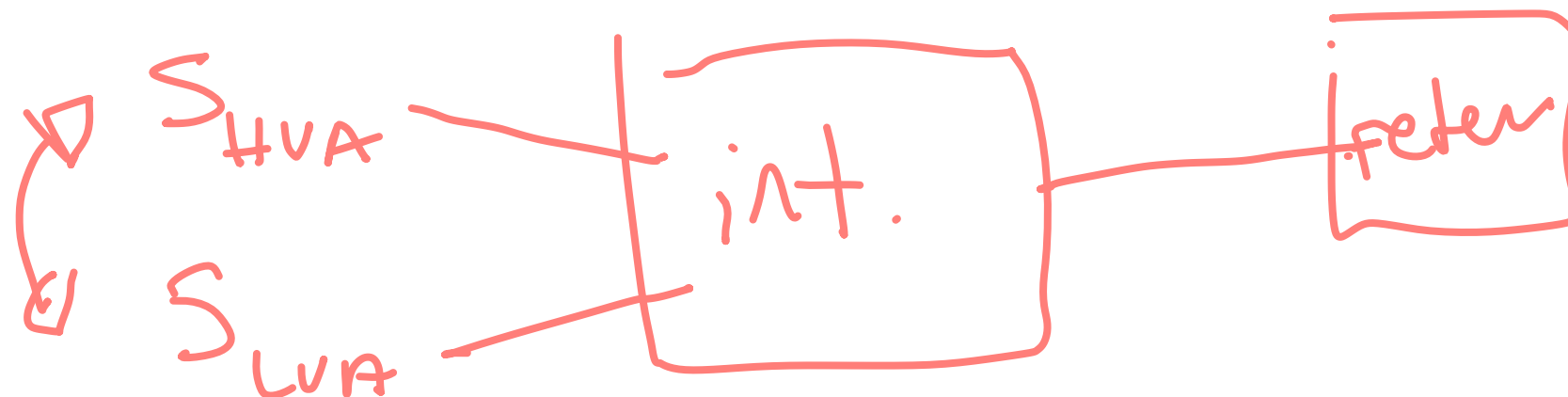
If the answers are:

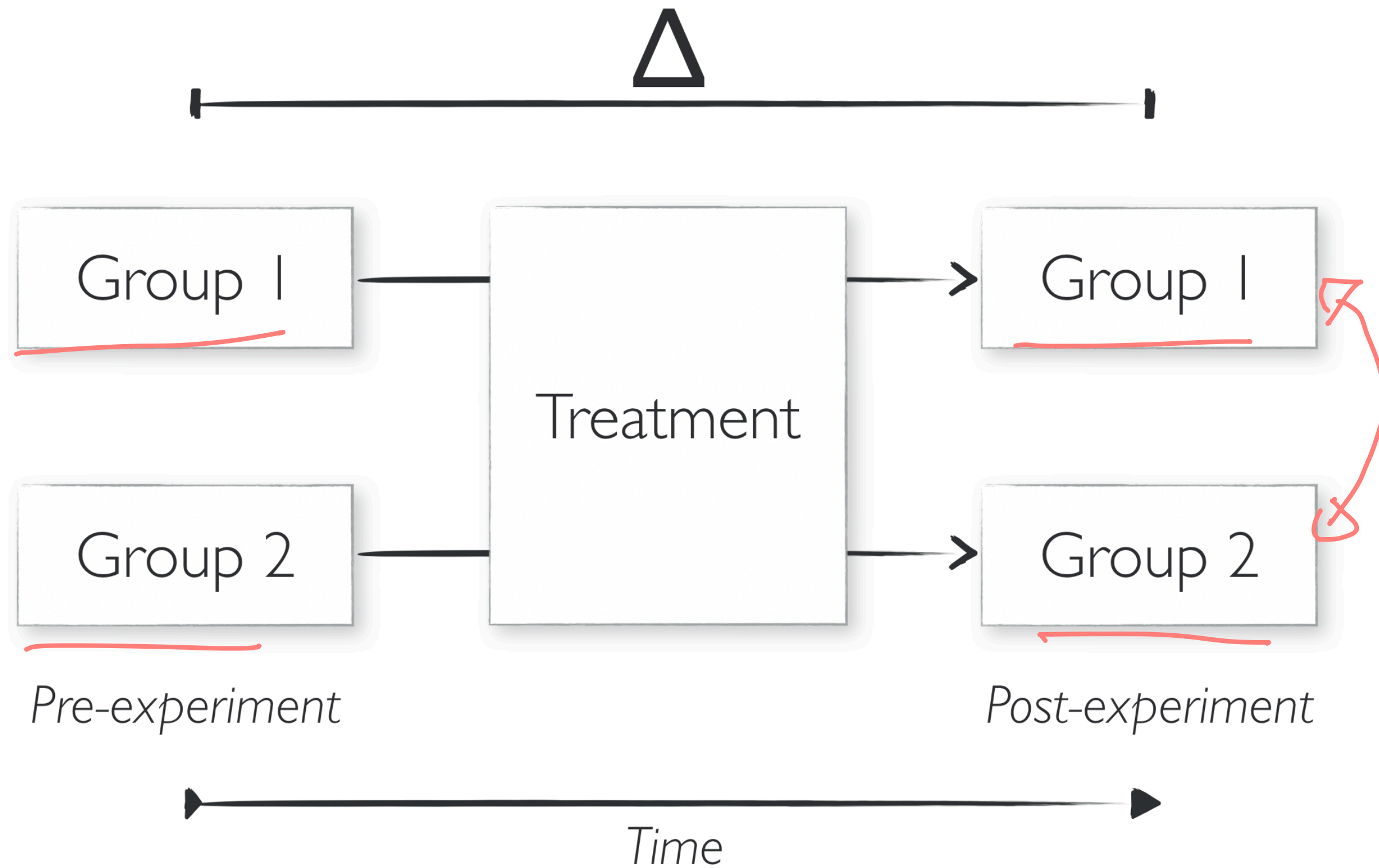
Yes. No. Yes.

We are designing a **quasi experiment** where controlling independent variables or random assignment is not practical or possible and where we separate participants based on some characteristics (e.g., expertise, verbal ability) and measure them before and after an intervention.

Example hypothesis:

Students with high verbal ability will show higher vocabulary retention after the second-language-learning intervention than students with low verbal ability.





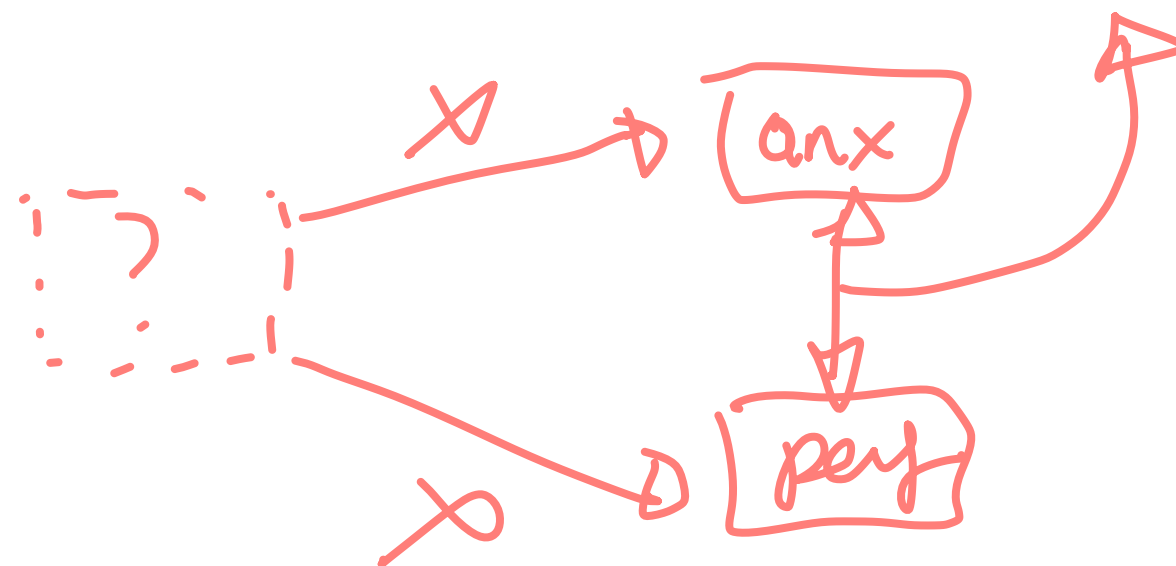
If the answers are:

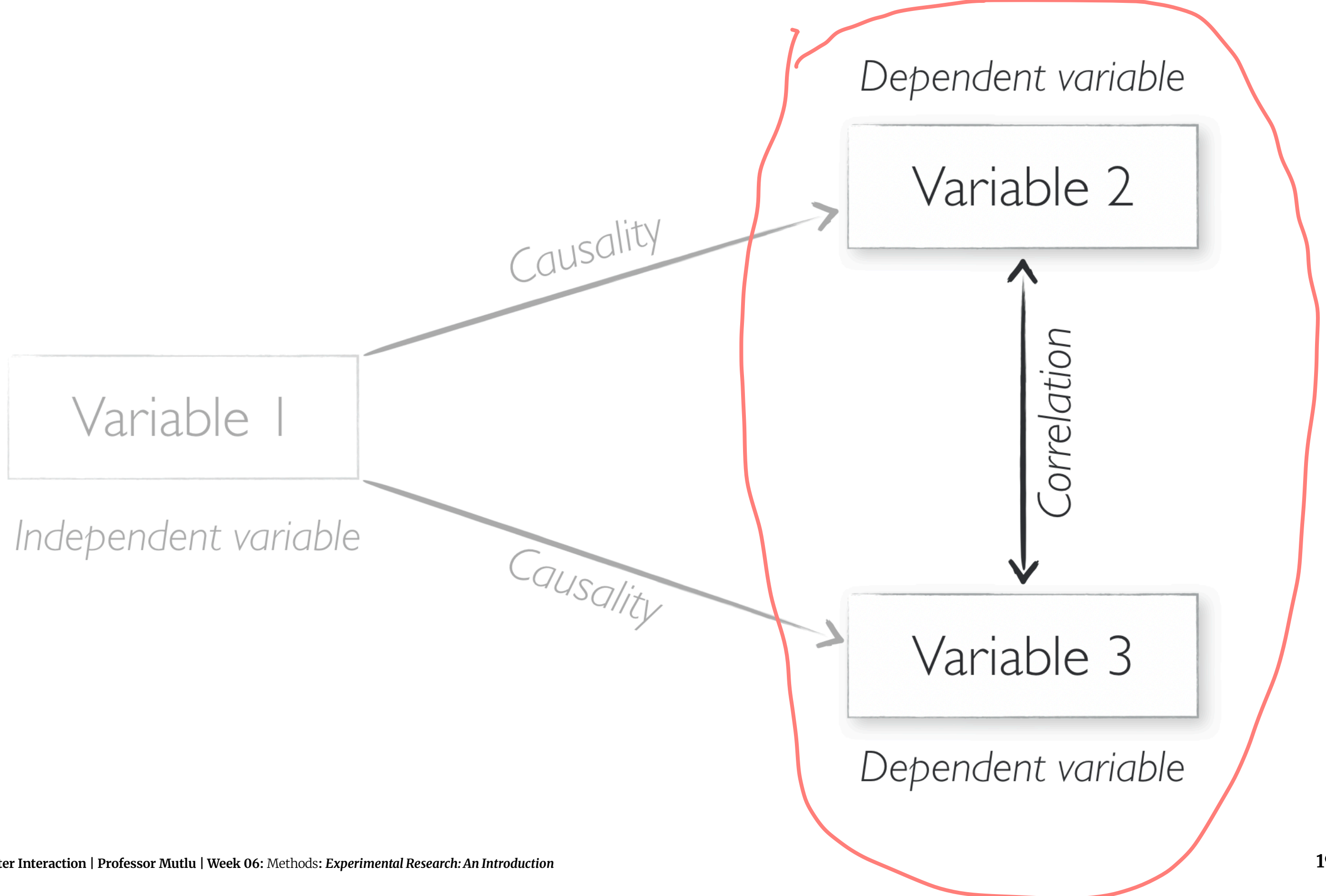
No. Yes/no. Yes.

We are designing a correlational study that examines the relationships among dependent variables such as individual traits, behavior, outcomes and the hypotheses are specific statements about these relationships.

Example hypotheses:

We will observe a strong positive correlation between test-taking anxiety and test-taking performance.



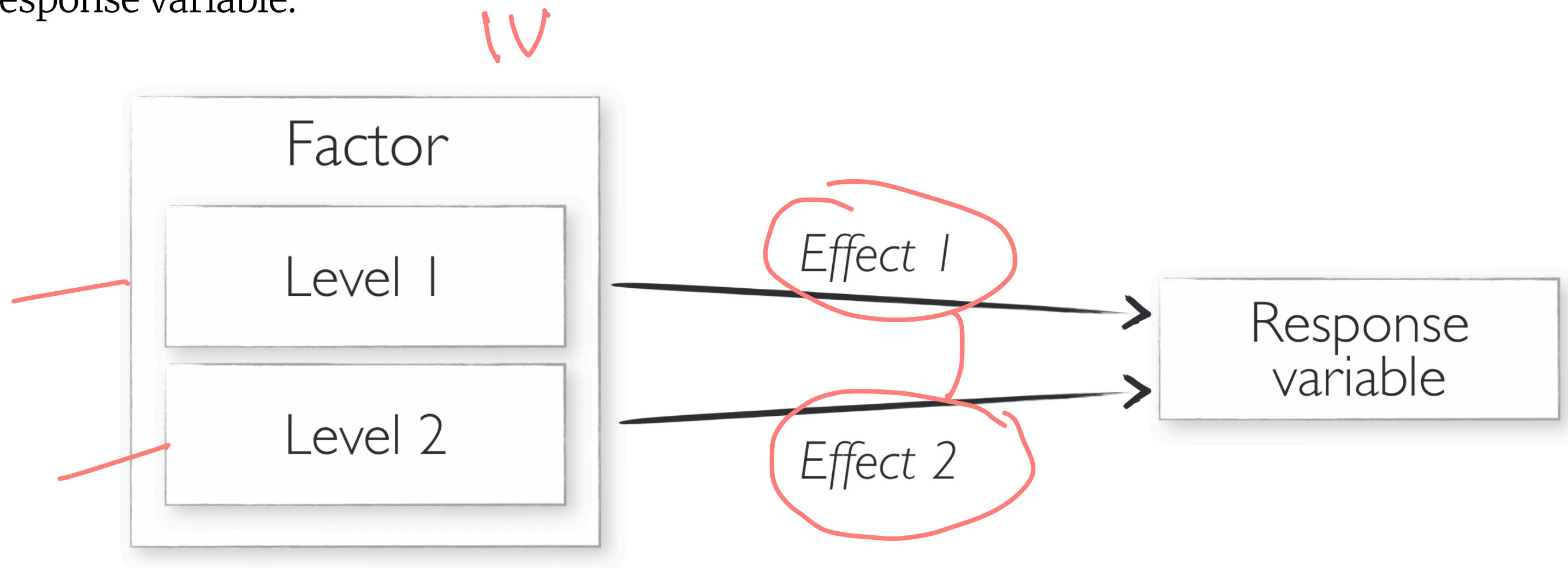


Independent and dependent variables are also called factors and response or outcome.



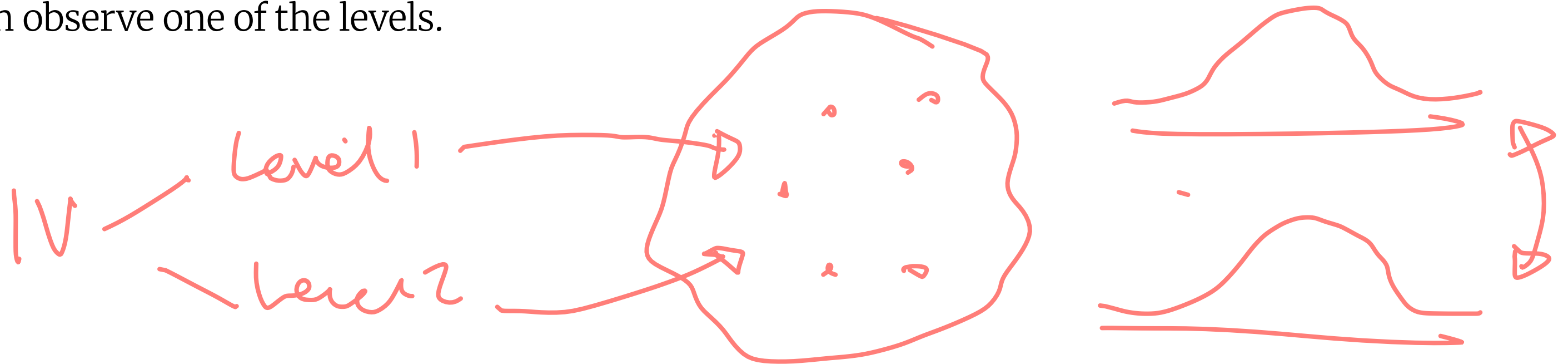
How do we perform random assignment of the factor to a population?

We create multiple **levels** of the factor (also called **experimental conditions**), e.g., interface 1 vs. interface 2; low verbal ability vs. high verbal ability; novice vs. expert. The independent *variable* takes different values. We measure and compare the differential effects of the different levels on the response variable.

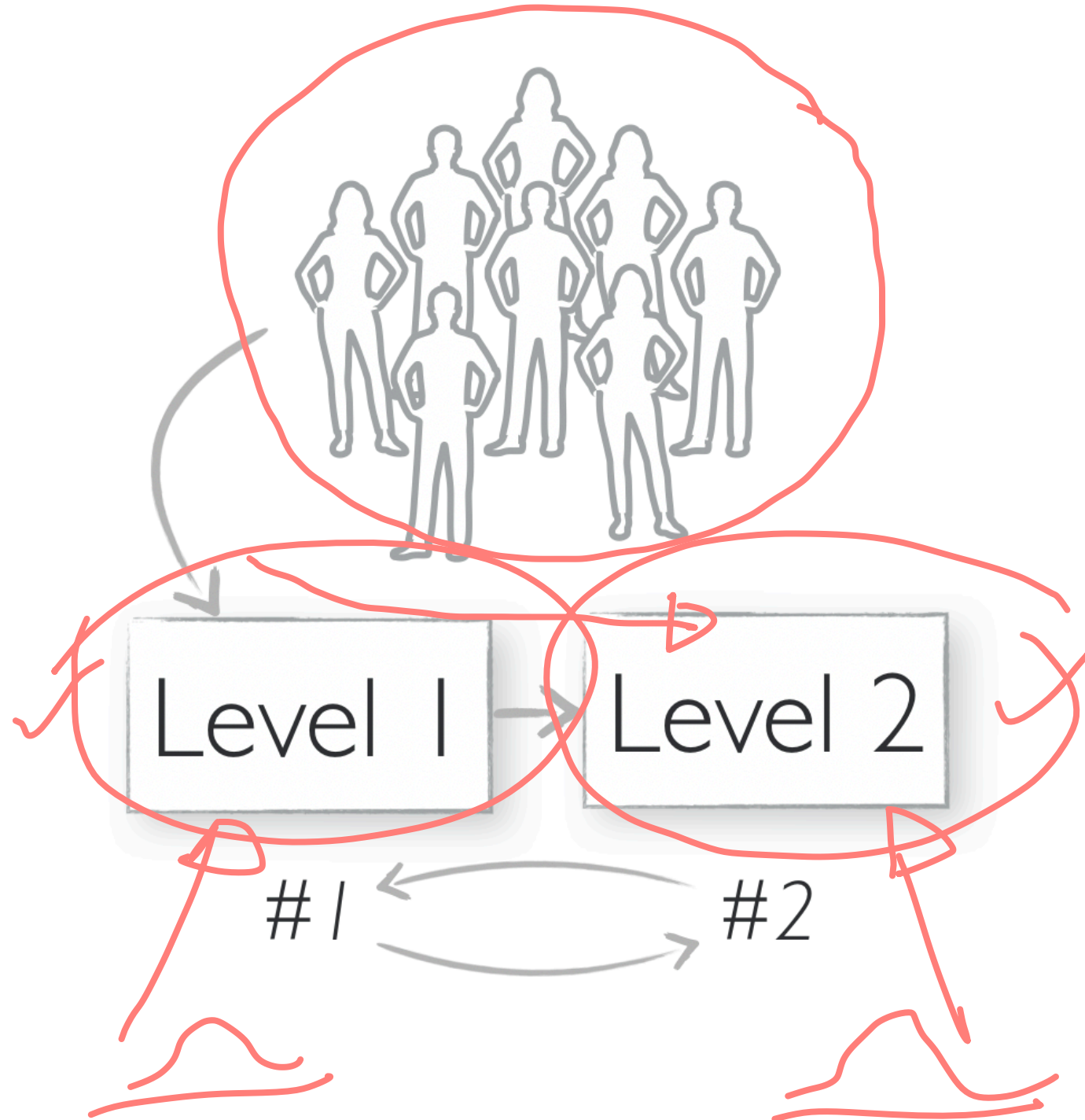


Each level of the factor needs to be assigned to a sub-population. This assignment can be done in two ways:

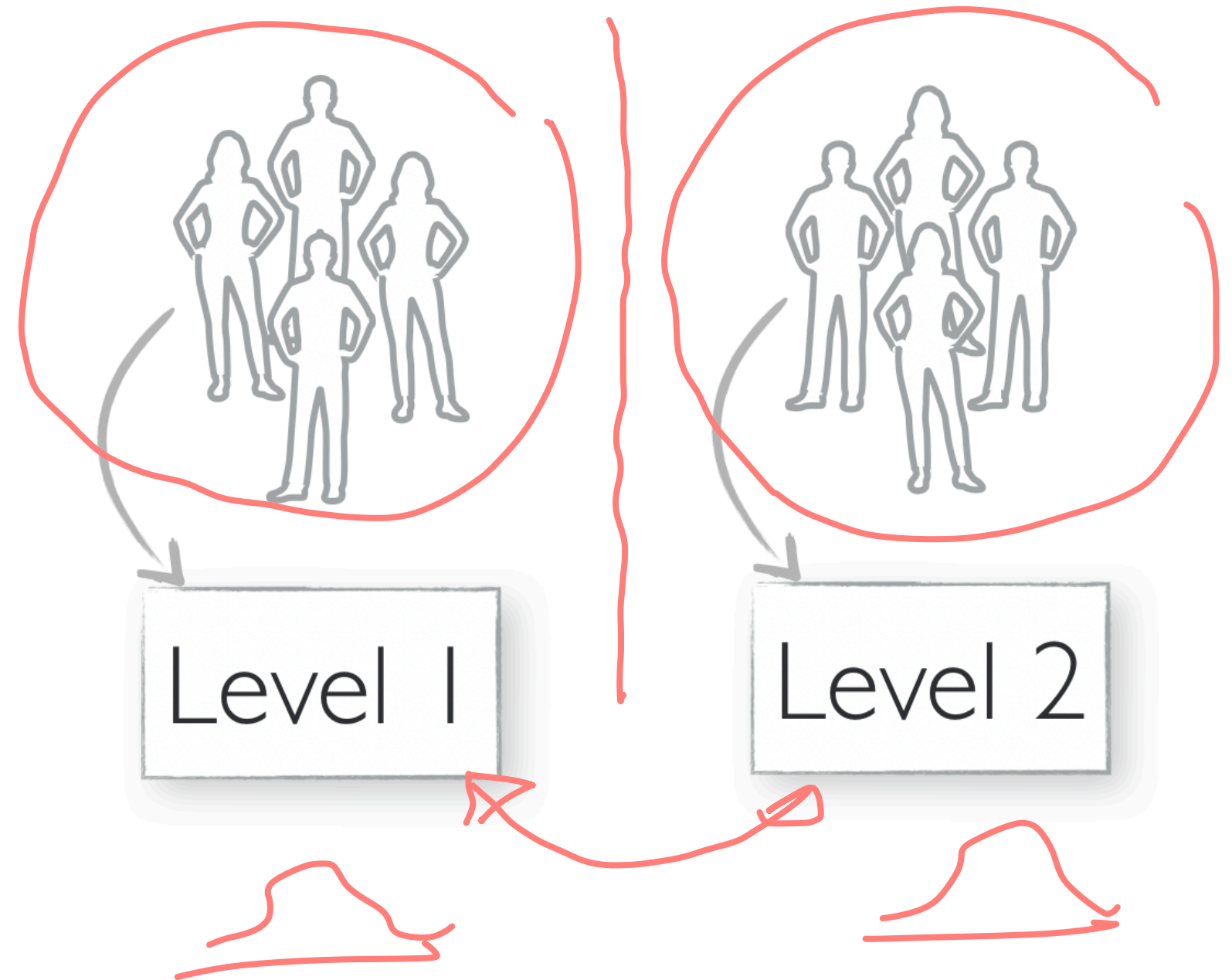
1. Within-participants assignment, where all participants will observe each level in a specified order.
2. Between-participants assignment, where mutually exclusive subgroups of the population will each observe one of the levels.



Within-participants



Between-participants

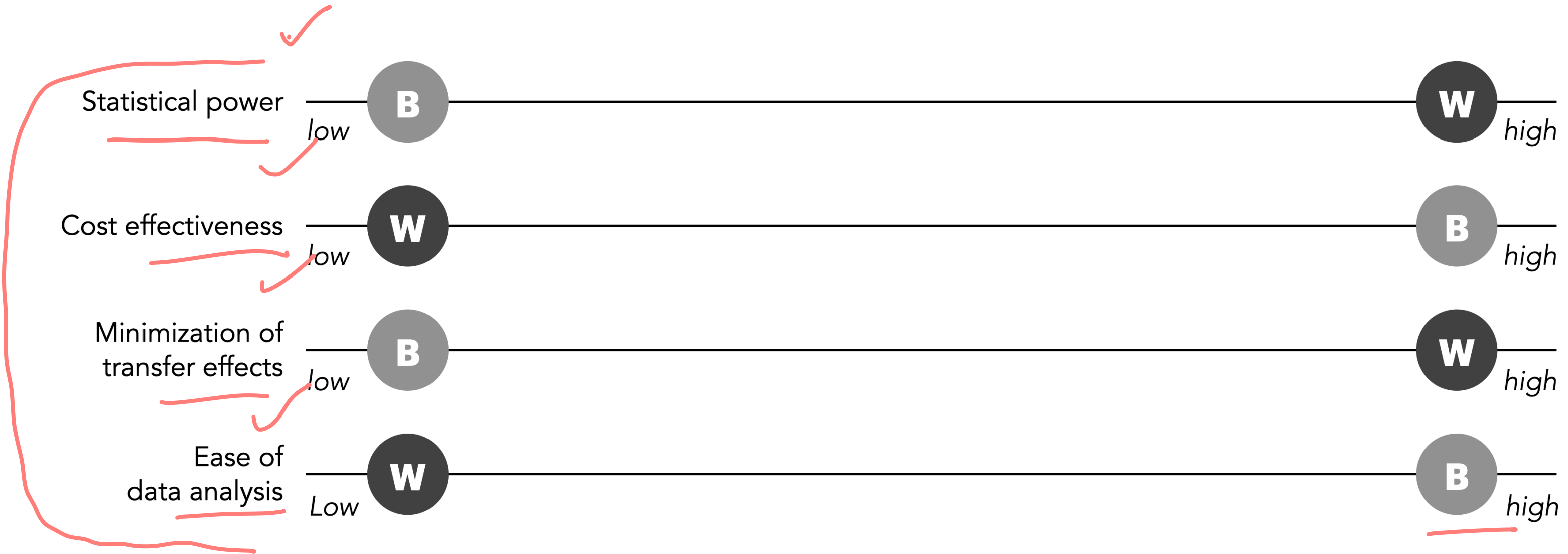


Within-participants designs:

1. Offers higher statistical power
2. Takes more time
3. Suffers from transfer effects
4. Data analysis can be more complex

Between-participants designs:

1. Minimizes transfer effects
2. Requires larger samples
3. Offers less power
4. Easier to analyze data



What if I have multiple factors?



Experiments can involve manipulating **single** or **multiple** independent variables (factorial designs).

Factorial designs:

1. Examine multiple variables at once
2. Analyze interactions
3. Will require larger samples

In general, factorial designs are more efficient but also more demanding.

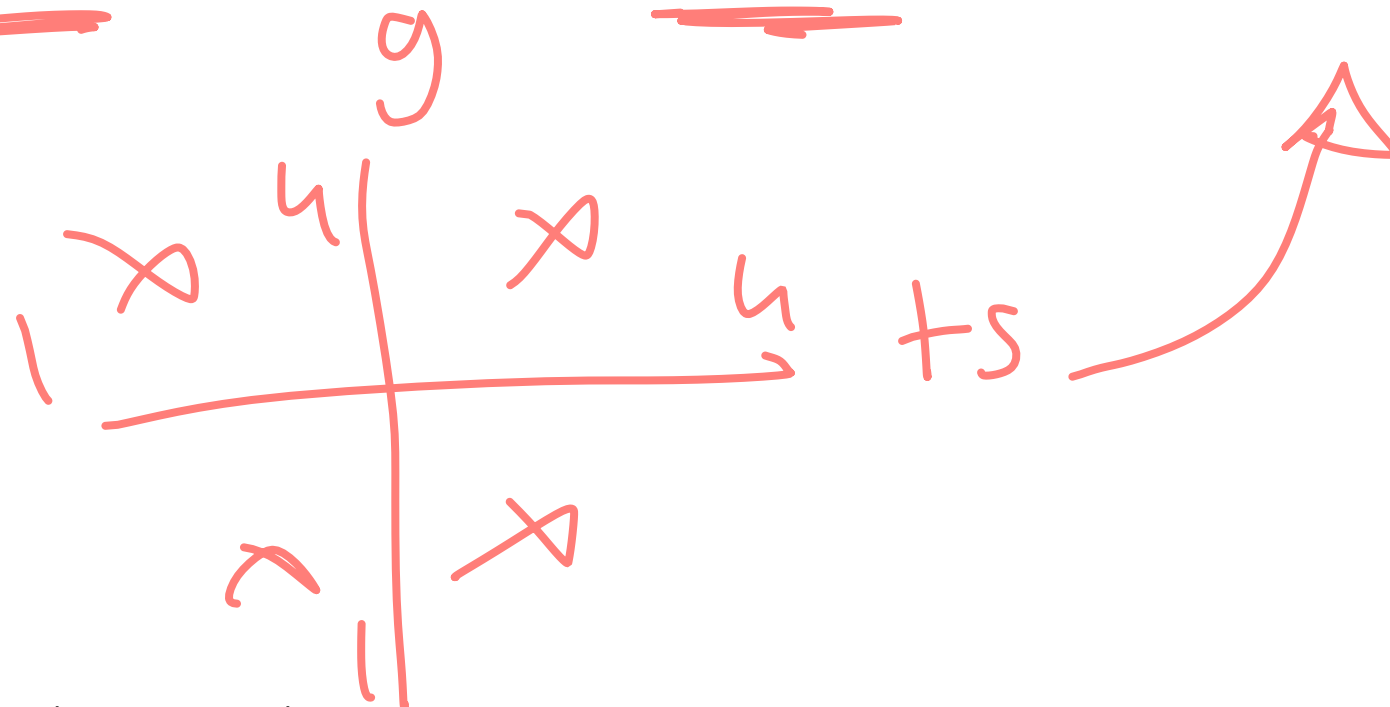
How does gaming and technology savviness affect perceptions of robots?

Single-factor experiment (2 two-population experiments):

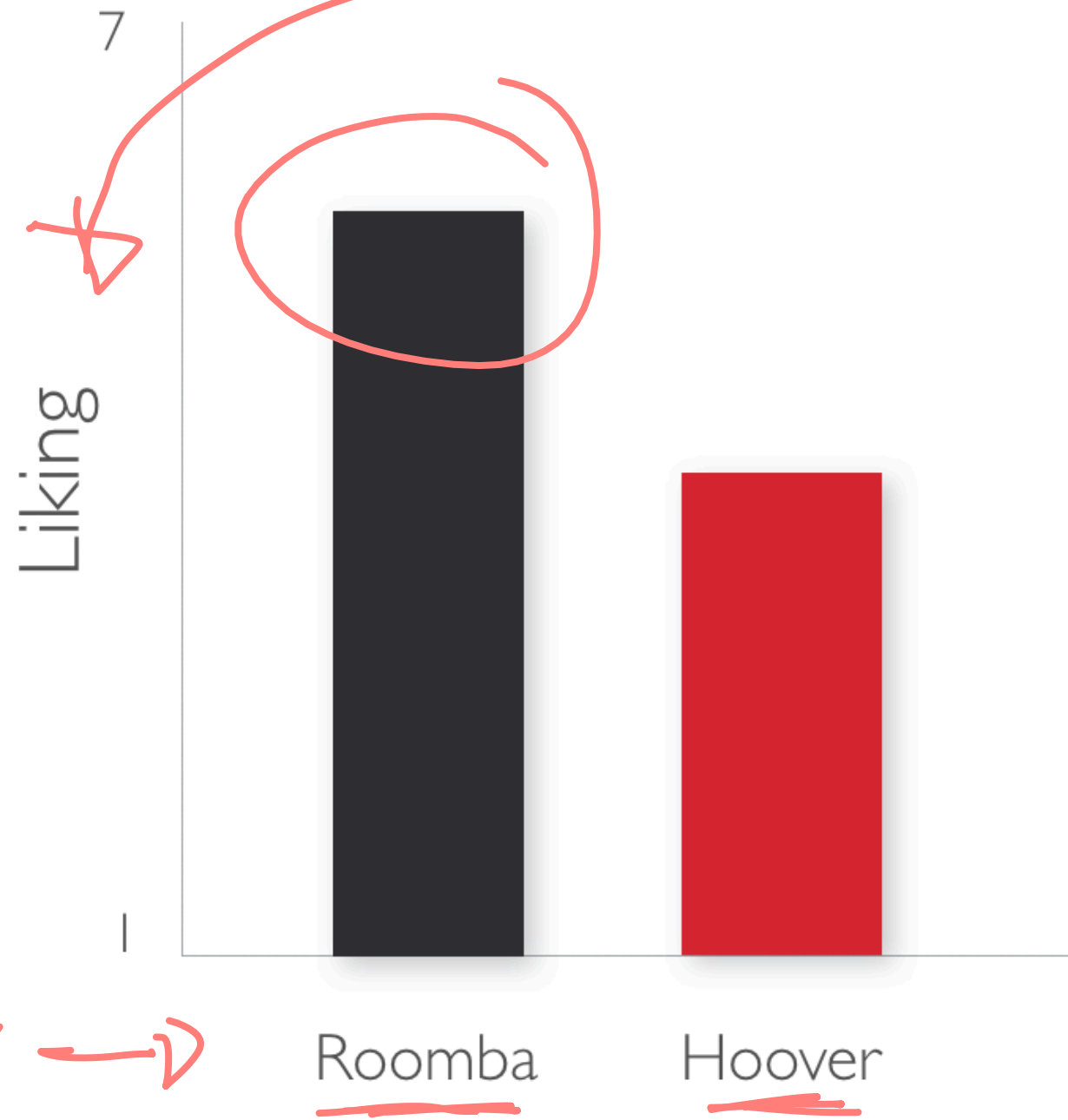
- » Experiment 1: low/high gaming → perceptions of robots
- » Experiment 2: low/high tech savviness → perceptions of robots

Factorial experiment (1 four-population experiment):

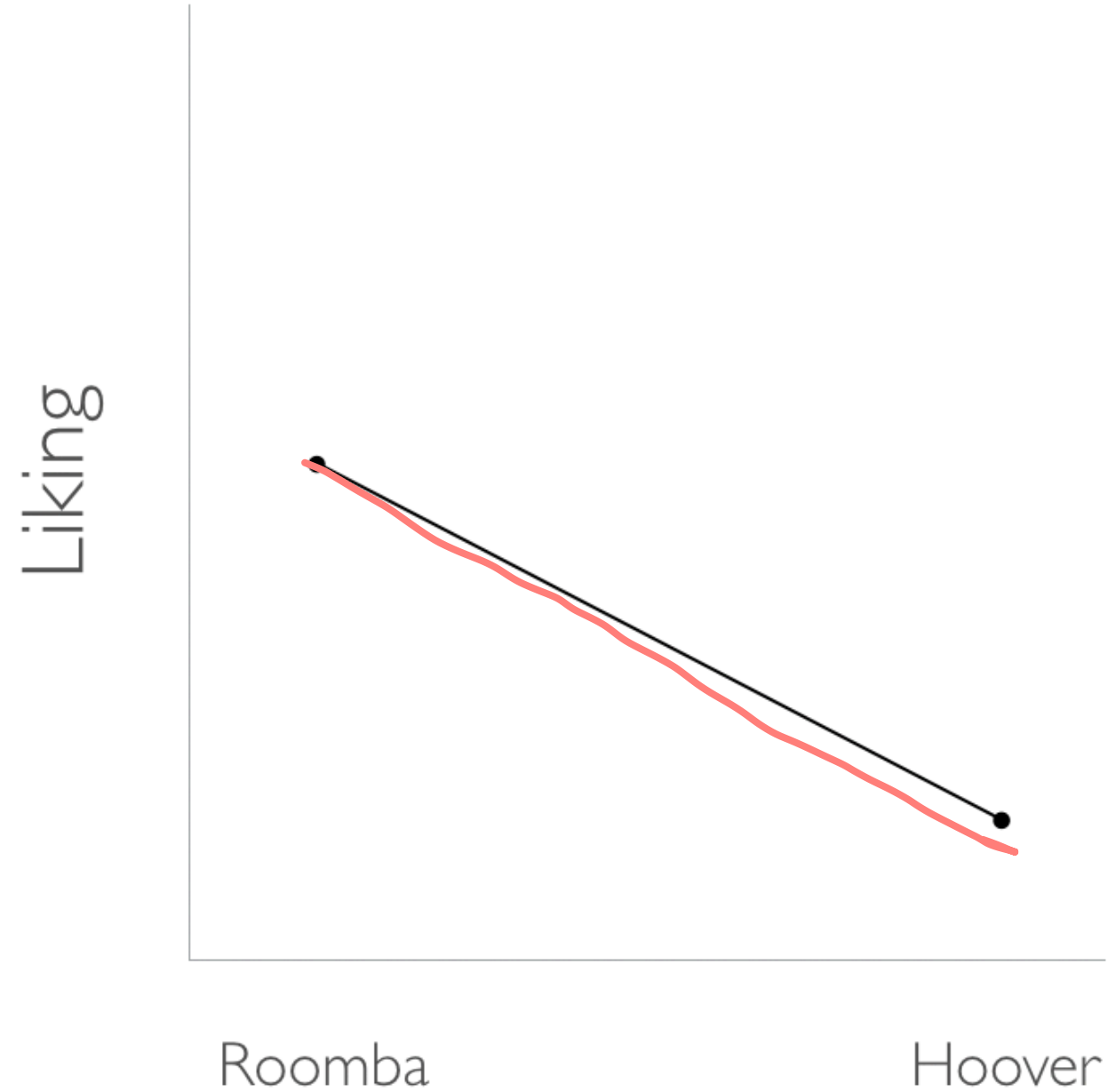
- » low/high gaming × low/high tech savviness → perceptions of robots



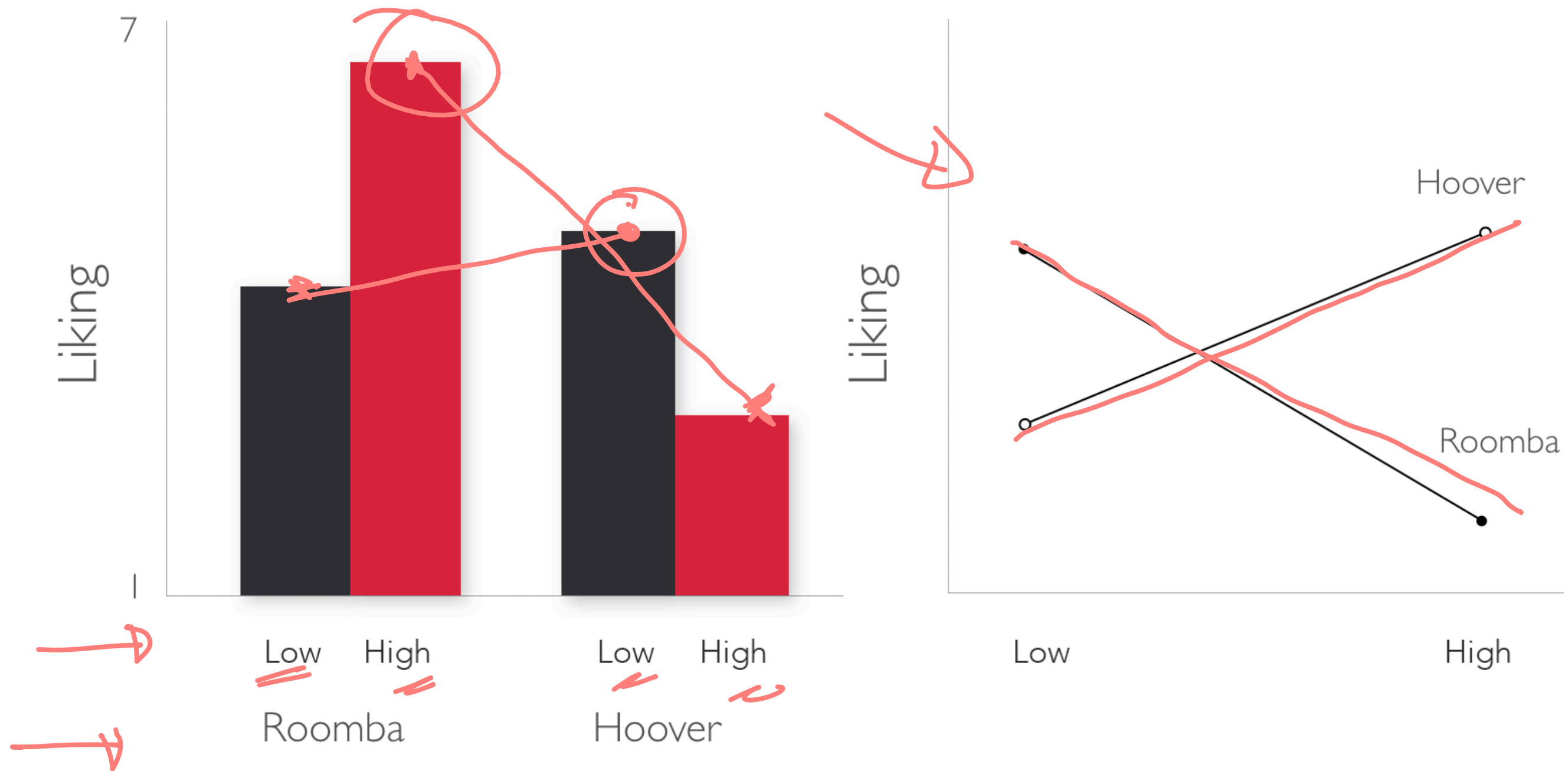
A main effect is the effect of a single factor on the response variable.



vacuum type →



An **interaction effect** is the interaction among multiple factors over the response variable.



How do we achieve random assignment?

➤ **Random sampling** and **assignment** are critical for experimental validity and generalizability. To minimize *selection bias* or *experimental bias*, we need to:

1. Choose participants randomly from the population
2. Assign participants randomly to experimental conditions

Methods for random assignment: random assignment at arrival, counterbalancing, matching



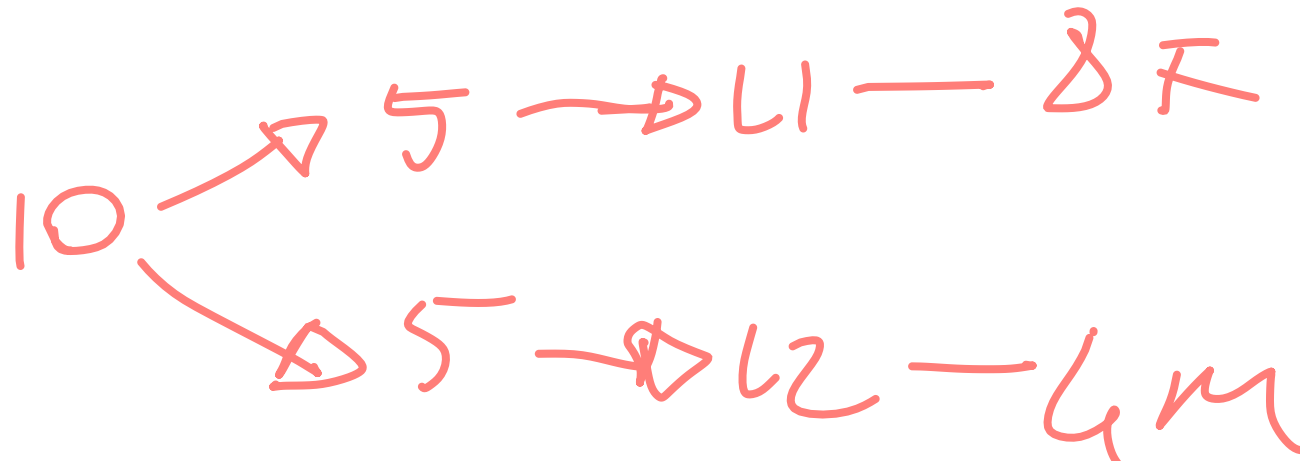
How do we assign randomly at arrival?

1 2 3 4 5 6 7 8 9 10, ten participants, *between-participants* design

7 4 8 6 9 | 1 2 10 3 5 → **Level 1** [7 4 8 2 9], **Level 2** [1 6 10 3 5]

L1 | L2
L2 L1 L2 L1 L2 L2 L1 L1 L1 L2

AA . .



HHH HHH HHH

L1 L2 L2 L2 L2 L1 L2

How do we balance order in within-participants designs?

> Counterbalancing involves randomizing the order in which participants observe different levels across individuals to minimize transfer effects.

Transfer effects result from observing earlier levels affecting participant performance/behavior in later levels due to learning, fatigue, etc.

Transfer effects can be linear, where observing each level changes user behavior/performance to the same extent, or non-linear, where different levels have different effects on user behavior/performance (e.g., most of the learning taking place in the first trial).

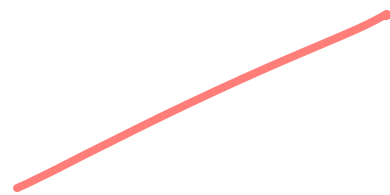
Counterbalancing can address linear and non-linear transfer effects.



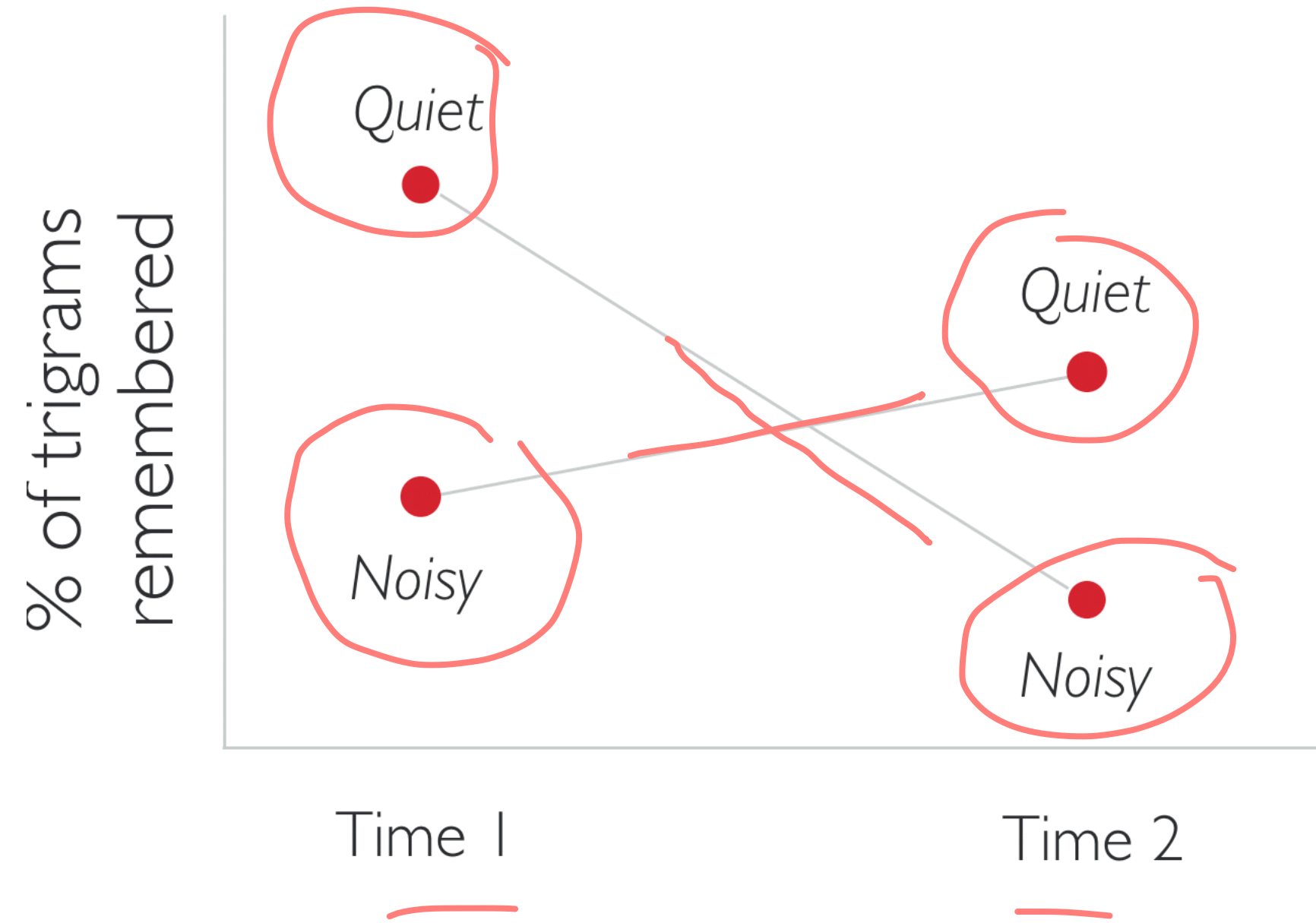
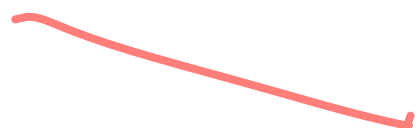
Counterbalancing cannot address **asymmetrical** transfer effects, where total magnitude of transfer effects are different across different orderings of levels (e.g., people sticking with a strategy they choose).

A between-participants design is a better fit to situations with asymmetrical transfer effects.

L1 → L2



L2 → L1



- ① - order randomization →
- ② - statistical center →

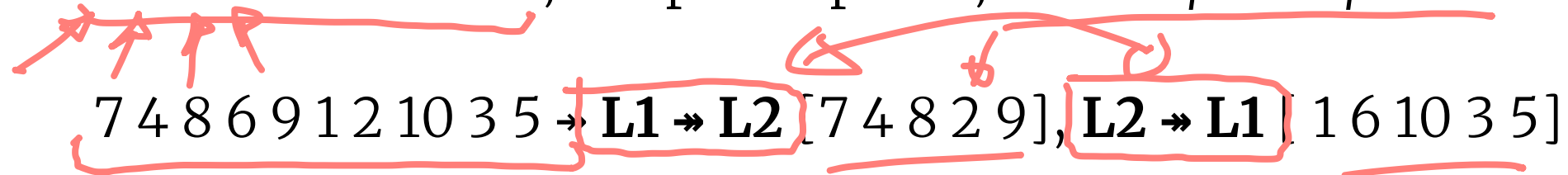


PID	Level	Order
1	L_1	B_1
1	L_2	B_1
1	L_3	B_1
1	L_3	B_1
1	⋮	B_1
1	⋮	B_1

The 'Order' column is circled in red. A red arrow points from the circled 'Order' header to the circled 'Order' values. There is a large red scribble at the bottom of the table.

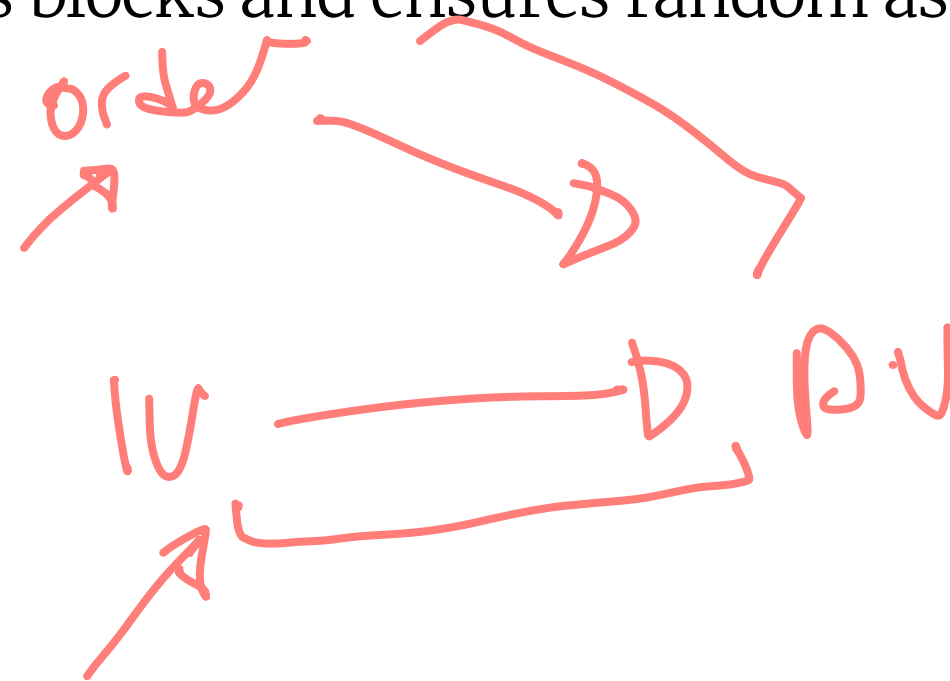
How do we do counterbalancing?

1 2 3 4 5 6 7 8 9 10, ten participants, *within-participants* design

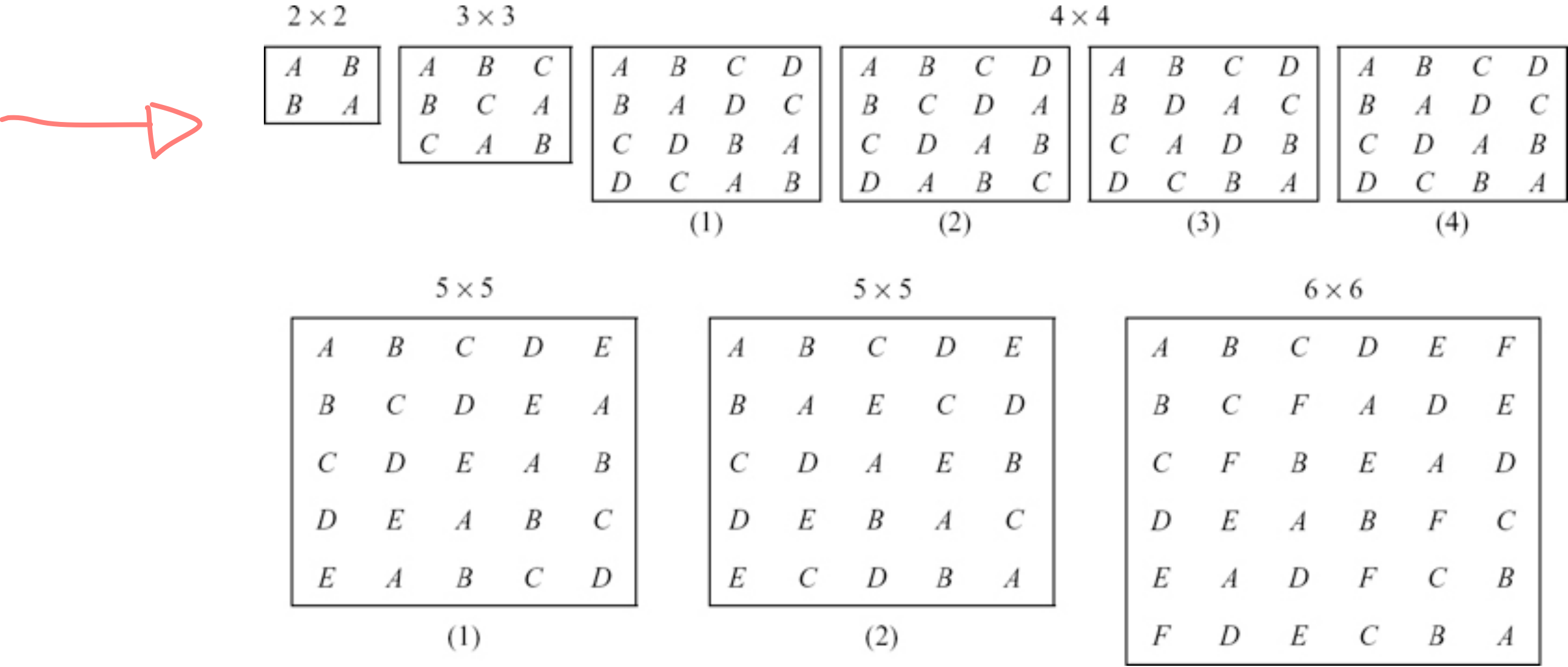


L2 → L1, L1 → L2, L2 → L1, L1 → L2, L2 → L1, L2 → L1, L1 → L2, L1 → L2, L1 → L2, L2 → L1

This is an example of a process called **blocking** or **randomized block design** where the experimenter defines blocks and ensures random assignment of conditions for each block.



The latin square design is special type of blocking where unique ordering of levels appear once within each cell of an $n \times n$ block.⁵



⁵Kirk, 2013, Experimental Design: Procedures for the Behavioral Sciences

How do we minimize experimental bias?

Blinding, where stakeholders are intentionally kept naive to experimental conditions, ensures that knowledge of experimental conditions do not affect the behavior/performance of participants or experimenters.

Single-blind designs: when participants are not told what condition is being administered..

Double-blind designs: when participants or researchers are not told what condition is being administered.



Questions?