

MODULE 2

CENTRAL TENDENCY

OUTLINE

- 1 Central tendency: Mean, median, and mode
- 2 Statistical properties of the mean
- 3 Between-group application: Smoking cessation clinical trial
- 4 Within-subjects application: Age and Body Satisfaction
- 5 Study questions

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5

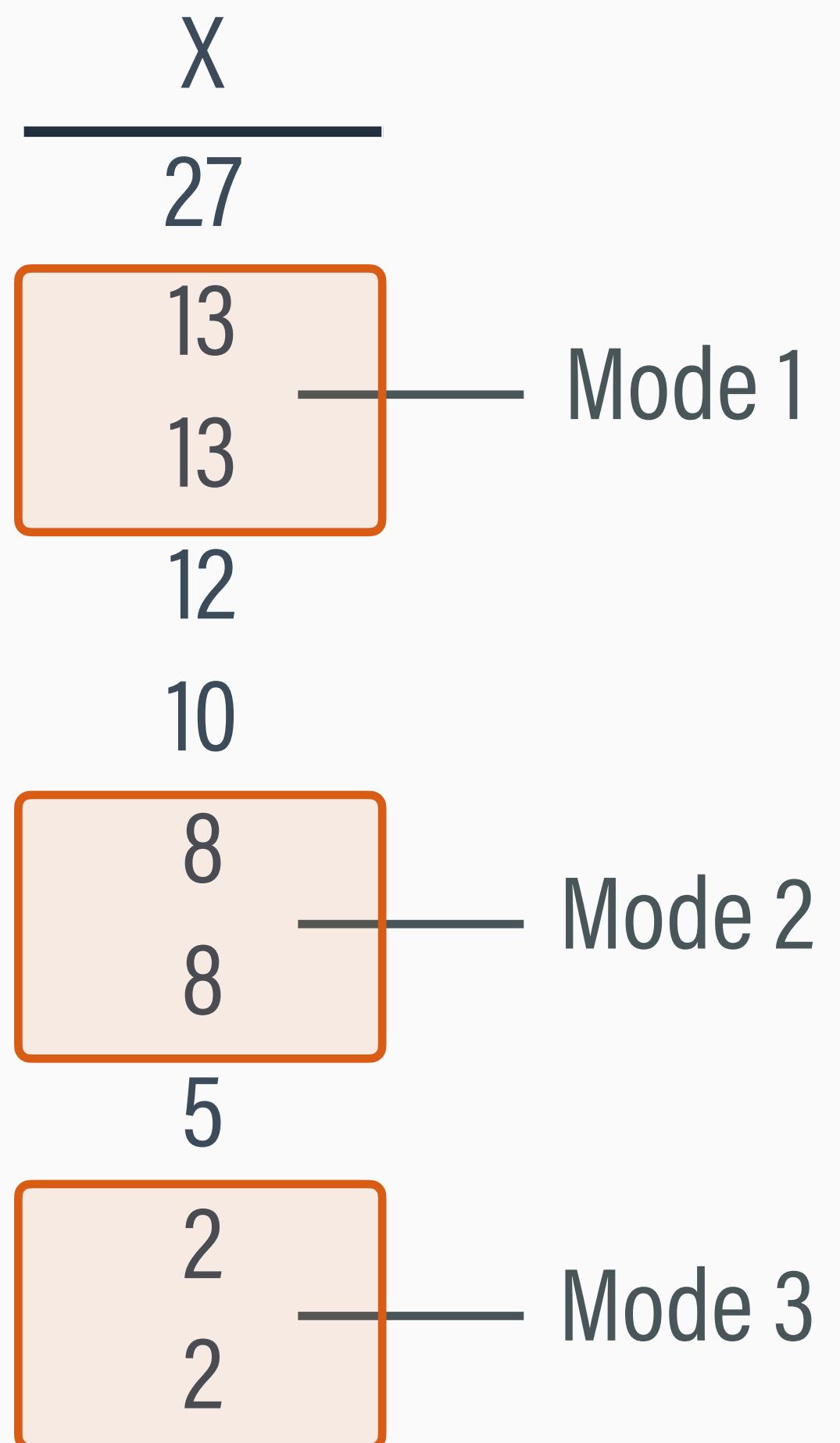
Study questions

CENTRAL TENDENCY

- Central tendency = the center of the distribution = a single value that is “typical” of the entire sample
- Three different definitions of center: mean (average score), median (middle score), and mode (most common score)
- We focus on the mean, as applications of the median and mode are uncommon in psychology research

THE MODE

- The mode is the most common score
- The only measure of central tendency for categorical variables
- Not useful for continuous variables because there can be multiple modes (e.g., 13, 8, and 2)

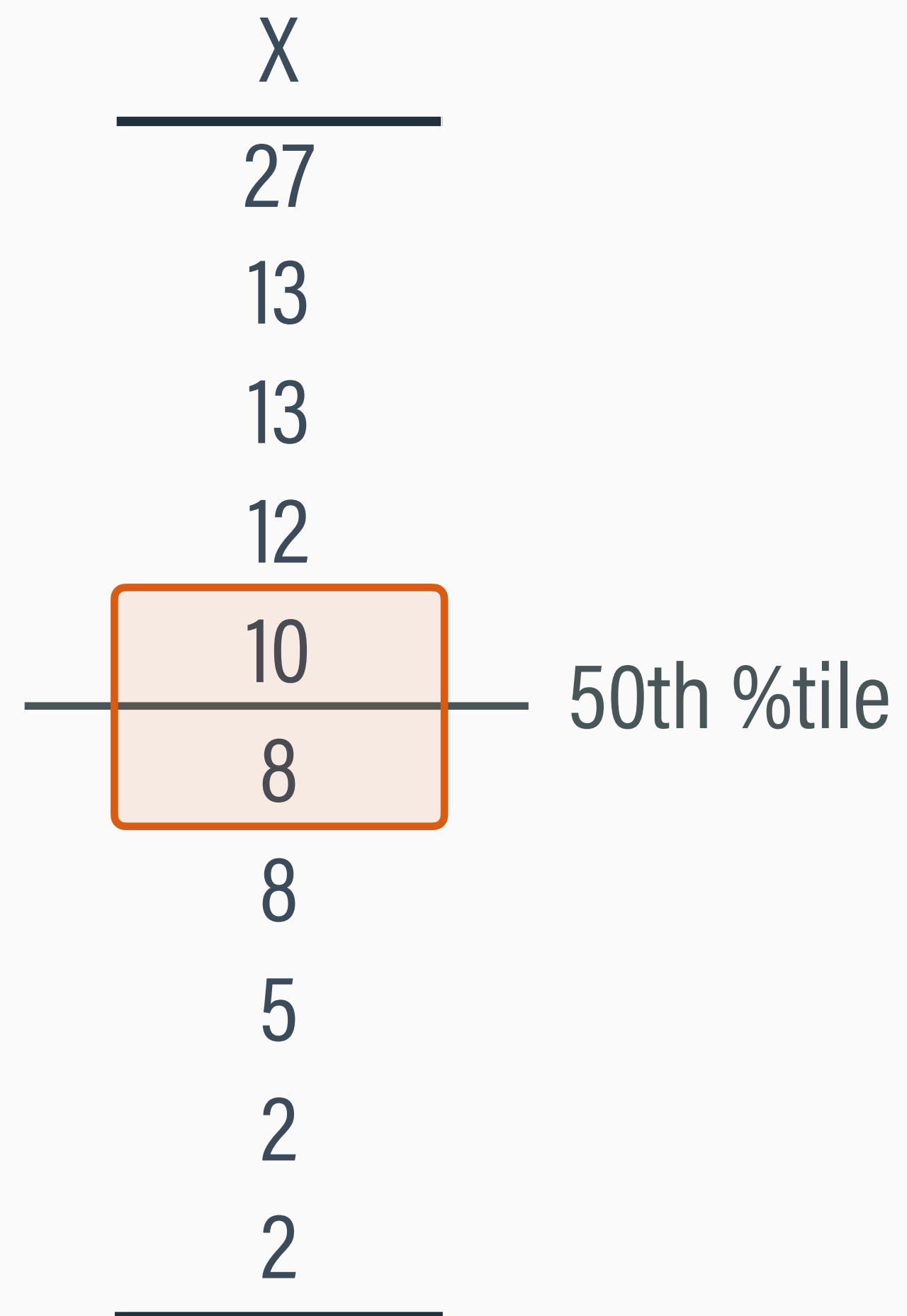


THE MEDIAN (50TH PERCENTILE)

- The **median** is the score that divides the distribution in half (half of the scores are above and below the median)

1. Rank scores then find the middle value
2. If even number, average the two middle scores

$$\text{median} = \frac{8 + 10}{2} = 9$$



THE MEAN (ARITHMETIC AVERAGE)

- The mean is the most common measure of central tendency for numeric variables in psychological research
- Among other things, psychology researchers use the mean to test hypotheses, compare groups, and examine trends over time
- The mean has desirable statistical properties that make it preferable (e.g., theorems that quantify the difference between a sample mean and the true population mean)

THE SAMPLE MEAN

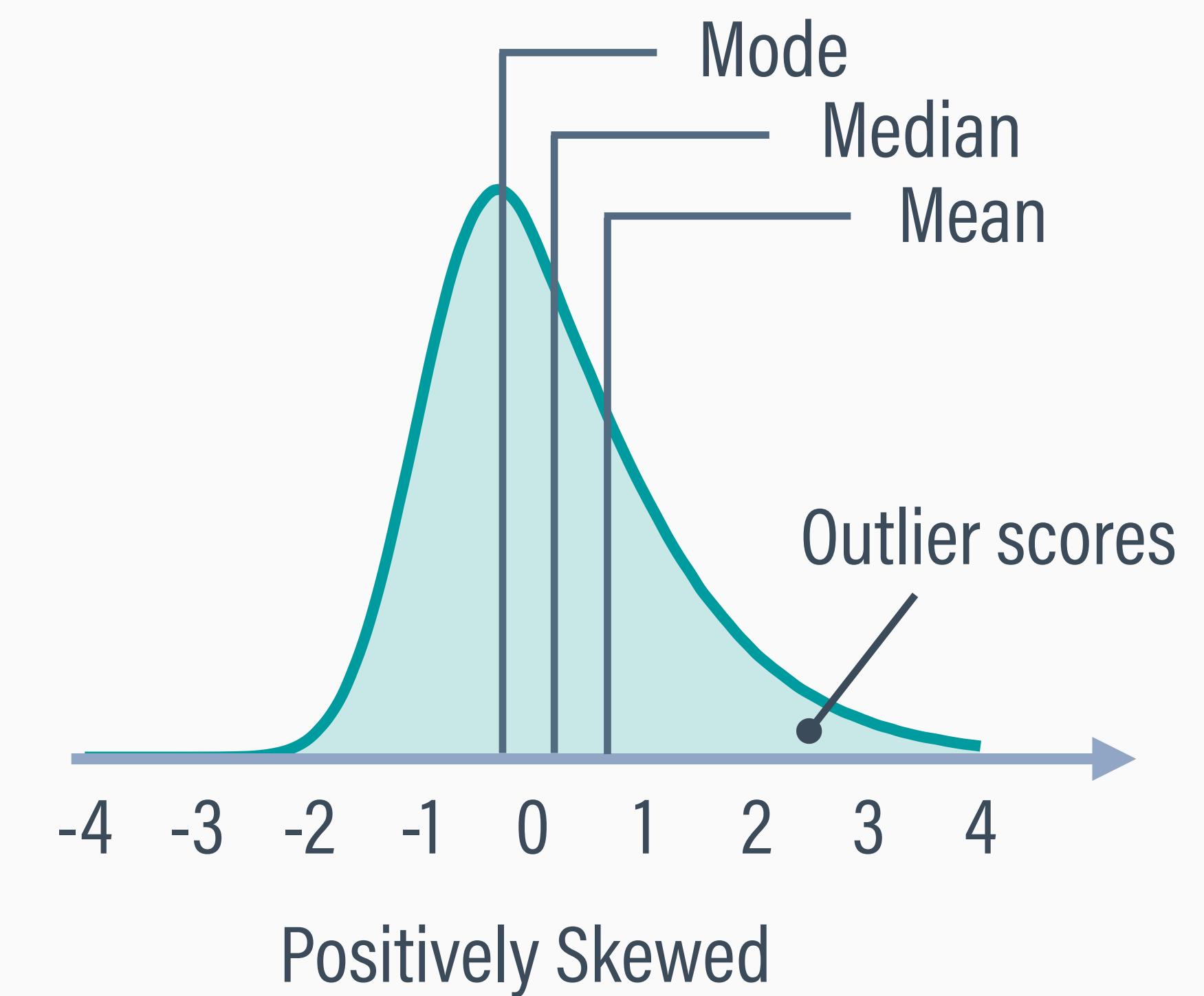
- The arithmetic **mean** adds up scores and divides by the number of scores (the sample size, N)
- Conceptually, the mean distributes the total amount of the variable (the sum) equally across all sample members (N)

$$\bar{X} = \frac{\text{sum all scores}}{\text{number of scores}} = \frac{\sum X}{N}$$
$$= \frac{12 + 2 + 8 + 13 + 27 + 5 + 13 + 8 + 10 + 2}{10} = 10$$

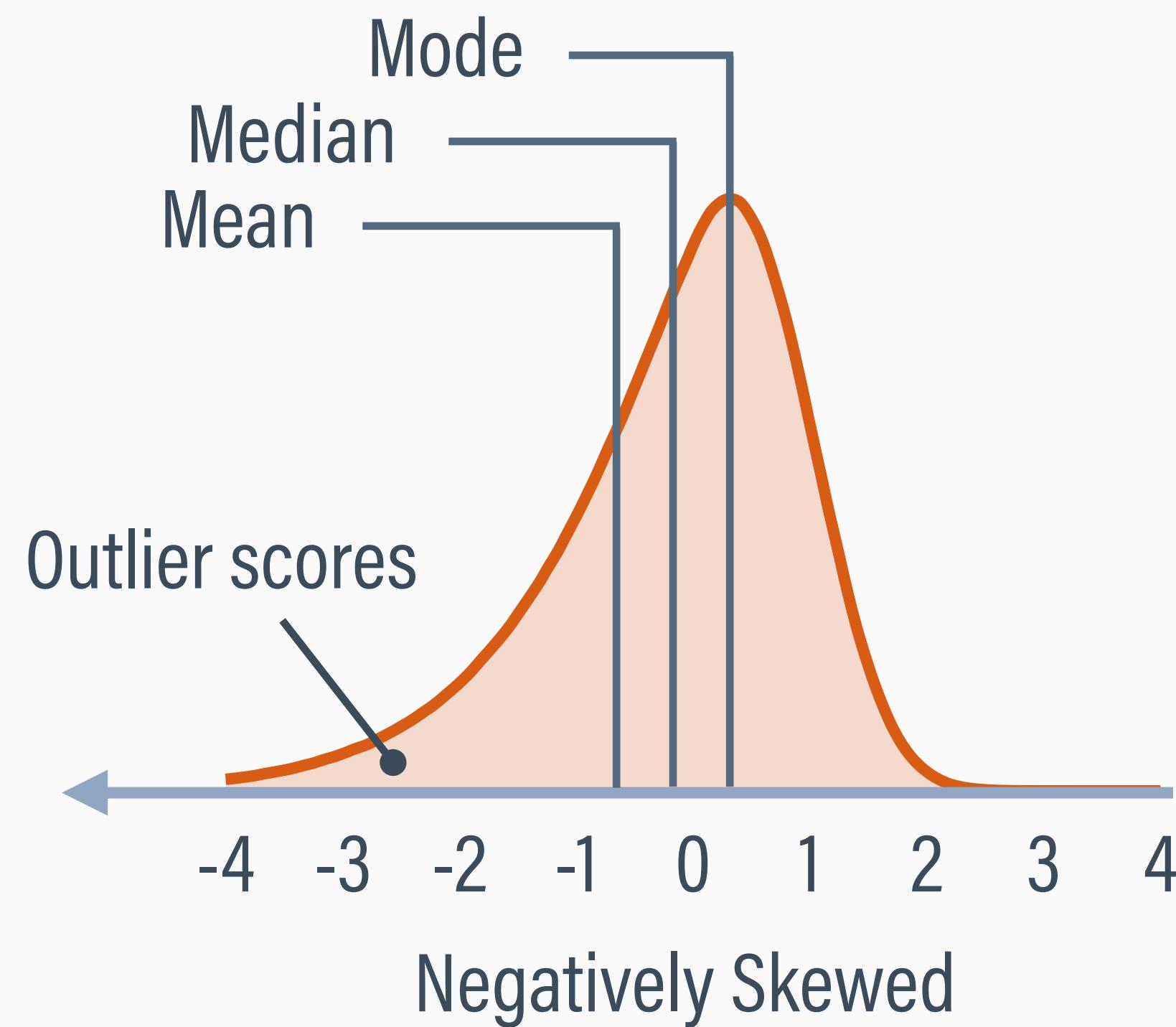
X
12
2
8
13
27
5
13
8
10
2
<hr/>
Sum = 100

CENTRAL TENDENCY IN SKEWED DISTRIBUTIONS

- Positively skewed distributions have extreme high scores in the right tail
- The high outlier scores contribute to the mean, pulling it toward the upper tail
- The mode is at the peak, the median cuts the distribution in half



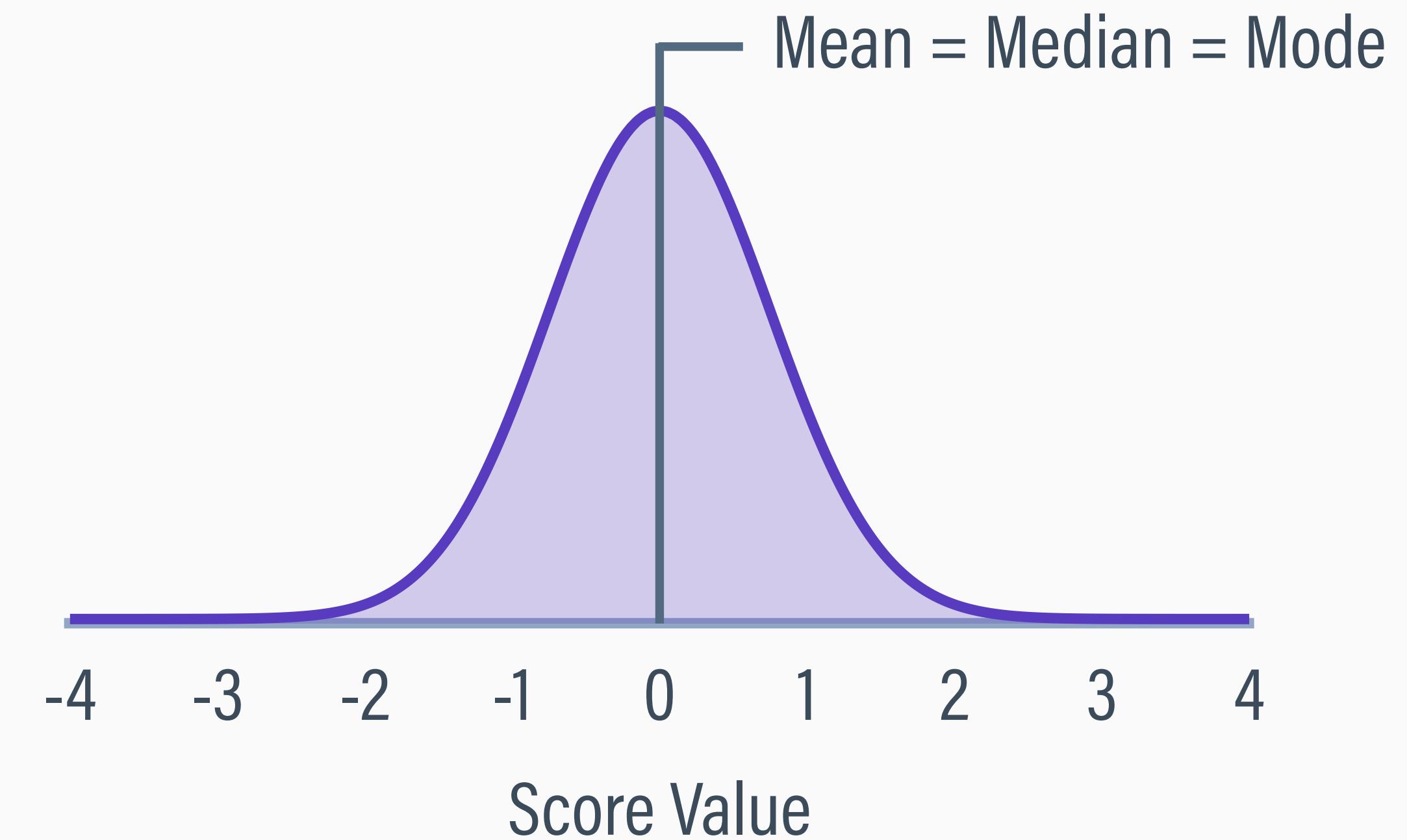
CENTRAL TENDENCY IN SKEWED DISTRIBUTIONS



- Negatively skewed distributions have extreme low scores in the left tail
- The low outlier scores contribute to the mean, pulling it toward the lower tail
- The mode is at the peak, the median cuts the distribution in half

CENTRAL TENDENCY IN SYMMETRIC DISTRIBUTIONS

- Extreme scores exist in both tails
- High and low outliers cancel out
- All three measures of central tendency are equal (or approximately so)



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IMPORTANT TERMINOLOGY

Participants

Population = all possible participants who share an attribute of interest

Statistic

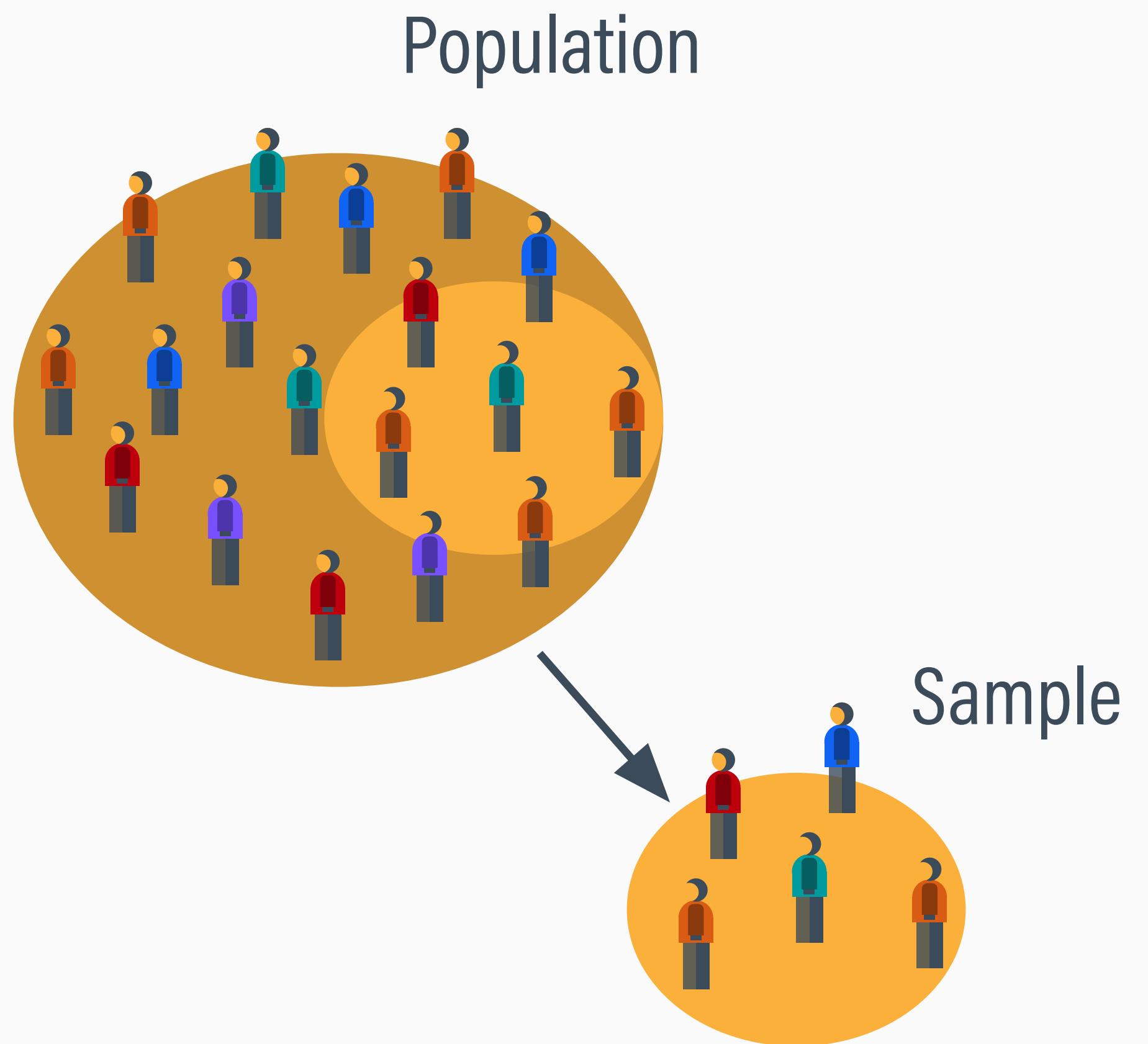
Parameter = a hypothetical statistic computed using the full population

Sample = the subset of people who participated in the study

Estimate = an observed statistic computed from the sample data

POPULATIONS VS. SAMPLES

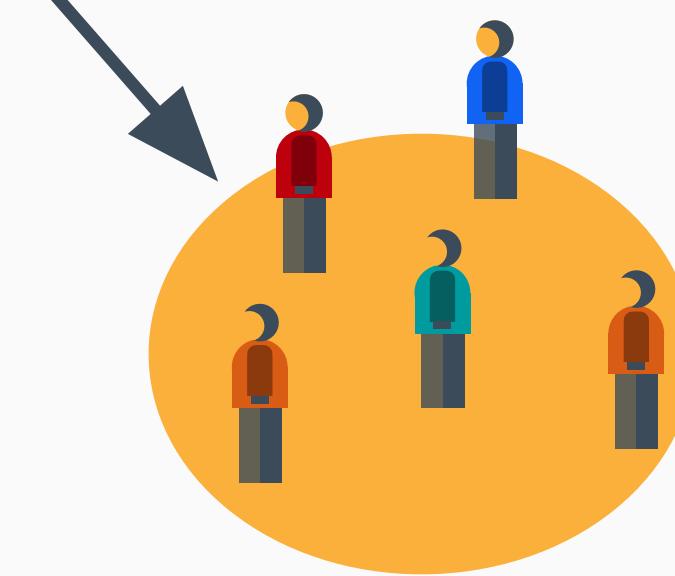
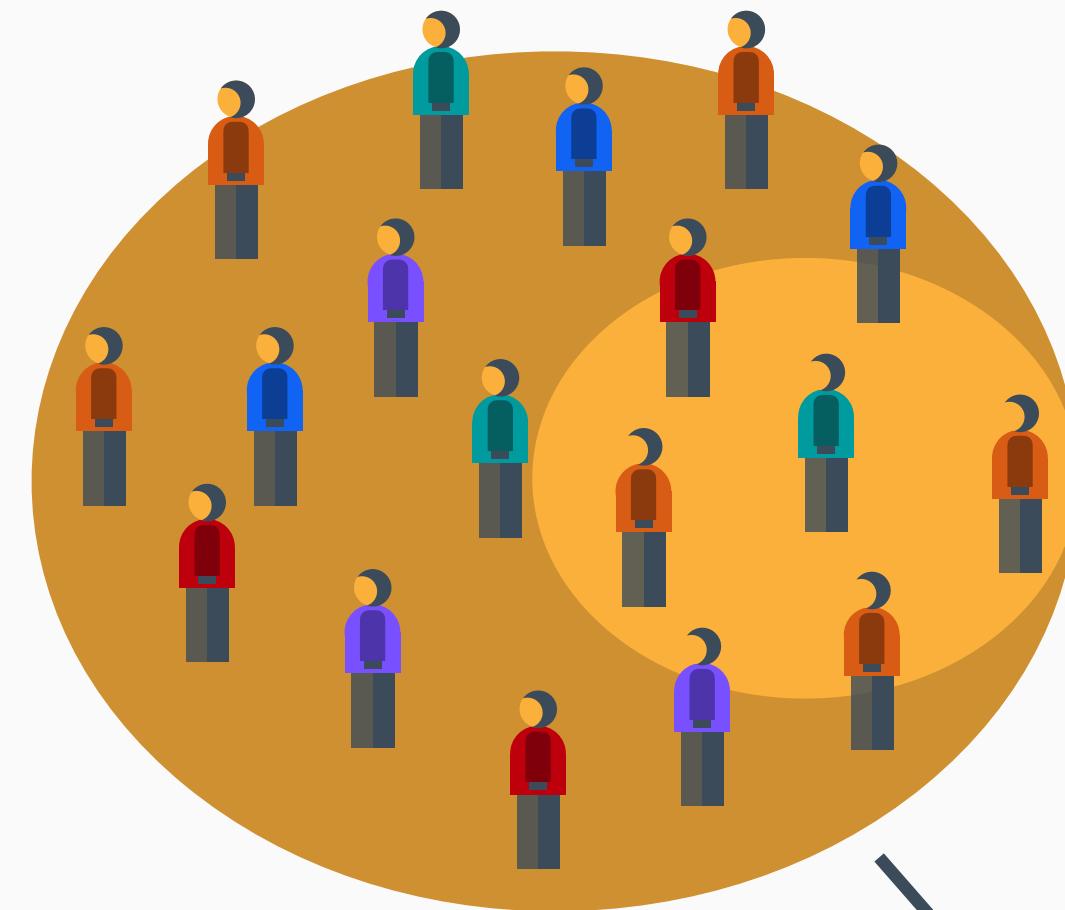
- A population is the entire group of individuals that are of interest in a study
- Researchers almost exclusively work with a smaller subset called a sample
- The usual goal is use a sample statistic as a best guess about the population statistic



PARAMETERS VS. ESTIMATES

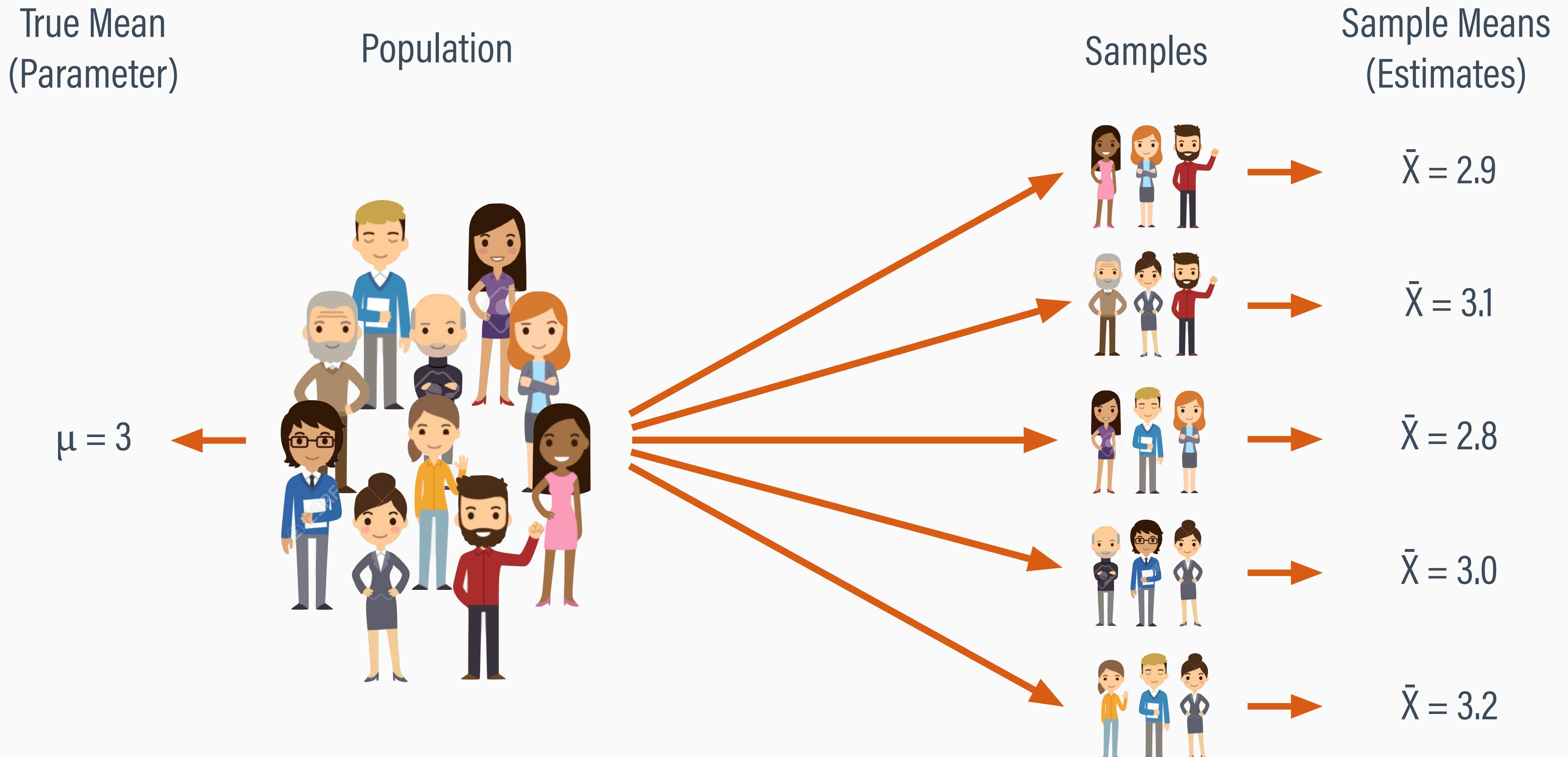
- The Greek letter μ denotes the true population-level mean (the parameter)
- The Roman letter \bar{X} references a sample mean (an estimate)
- Ideally, the sample mean will be close to the true mean, but it will always differ

Population mean = μ



Sample mean = \bar{X}

SAMPLE MEANS DIFFER FROM THE TRUE MEAN

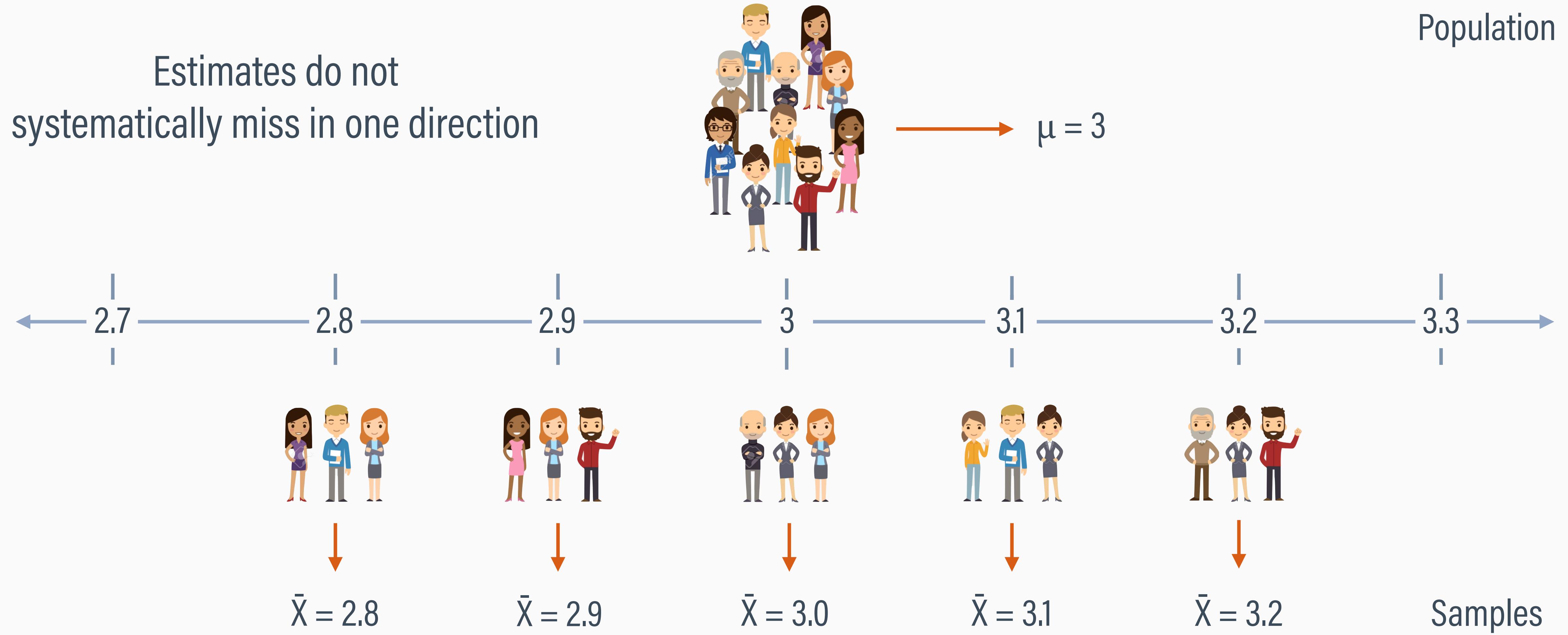


UNBIASEDNESS OF SAMPLE MEAN

- Each sample contains different individuals, so \bar{X} will vary from sample to sample
- Some sample means will overestimate μ , some will underestimate it, and others will be very close to μ
- The sample mean is an unbiased estimate of the true population mean: on average (across many samples), it doesn't systematically miss in one direction

UNBIASED ESTIMATES

Estimates do not
systematically miss in one direction





In small groups of two or three, each of you should run the R code below, which draws a random sample of $N = 100$ scores from a population with a true mean of 3. Discuss how your sample means differ from the true mean of 3. Were they higher or lower? On average, about how much did they differ from the true mean?

```
mysample <- rnorm(n = 100, mean = 3, sd = 1)
mysample
hist(mysample)
cat("My sample mean = ", mean(mysample))
```

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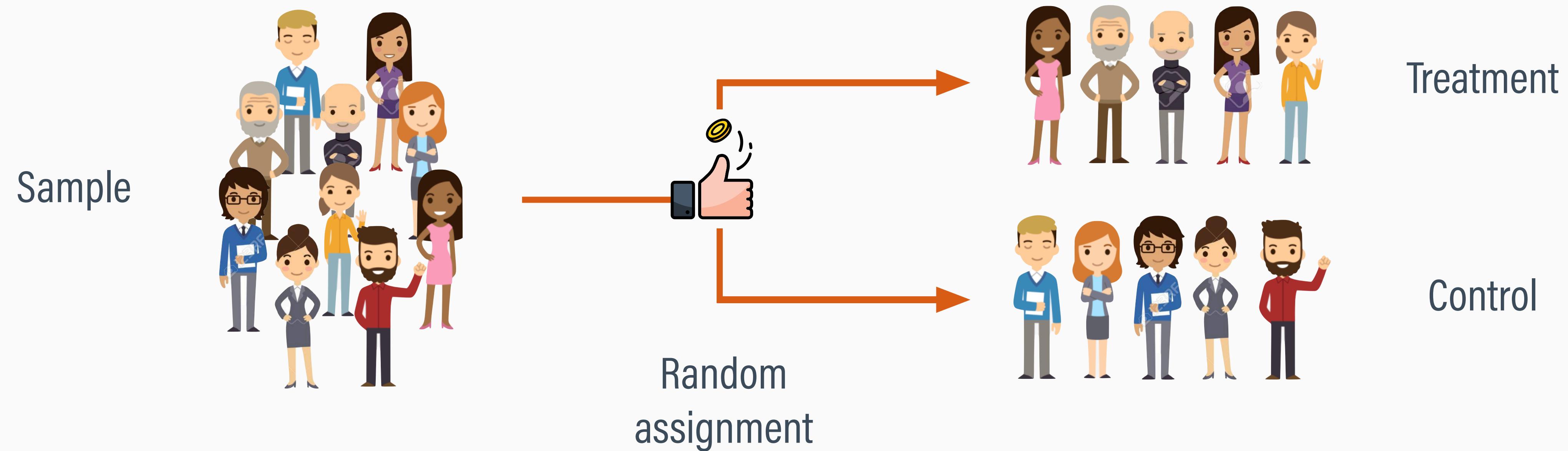
Study questions

BETWEEN-GROUP RESEARCH DESIGNS

- A **between-group research design** seeks to compare two or more groups of participants
- Unlike the within-group design, each condition is comprised of different participants
- The classic example is a randomized experiment with a treatment and control group, but groups can reflect any qualitative characteristic (e.g., sociodemographic)

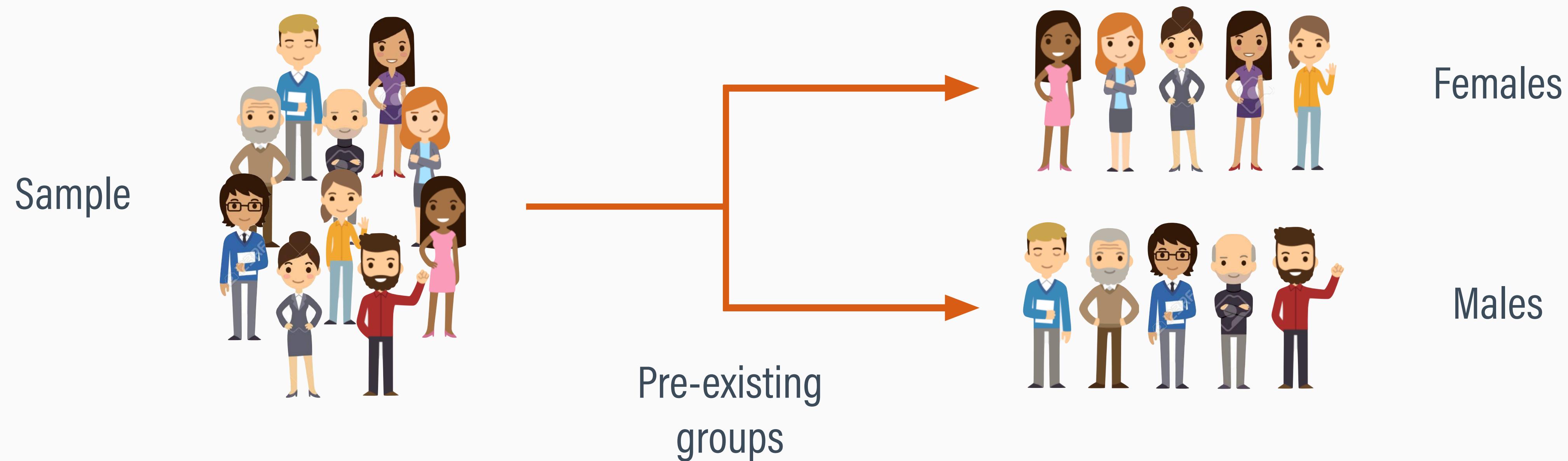
EXPERIMENTAL APPLICATION

- Participants are randomly assigned to either a treatment or a control condition



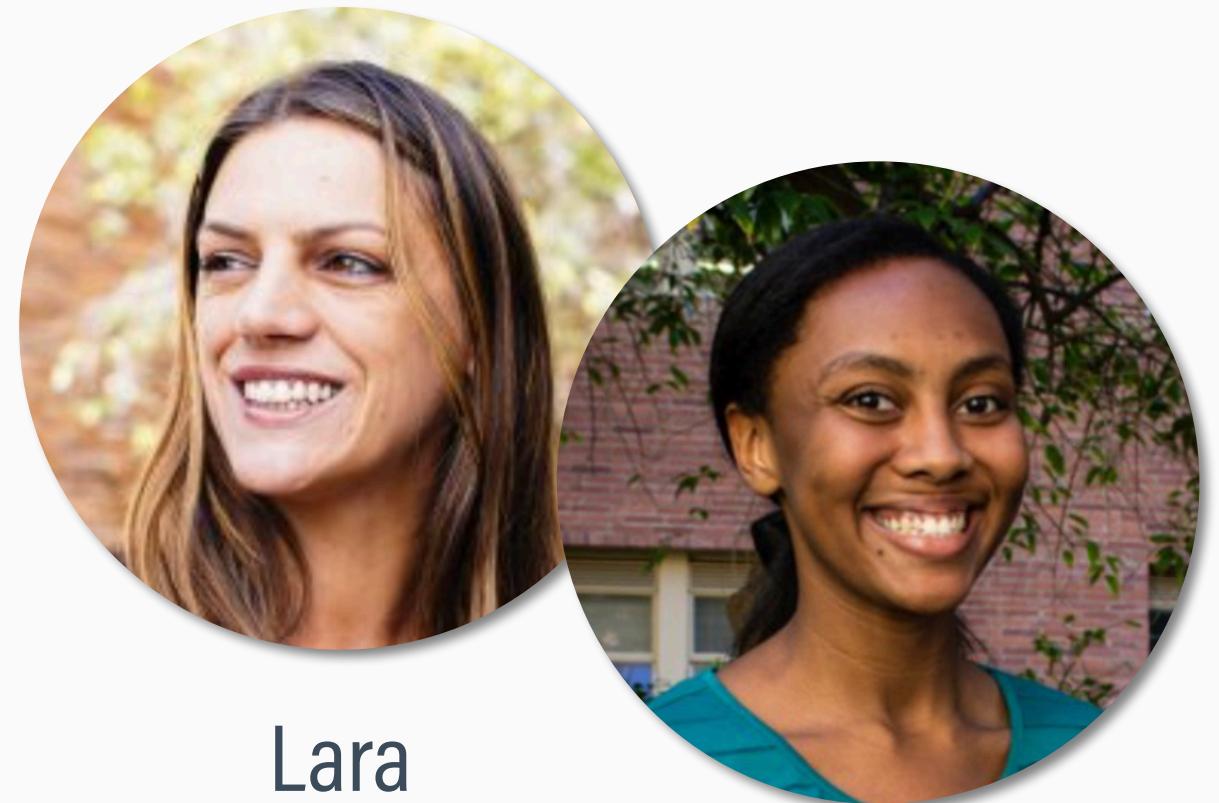
NON-EXPERIMENTAL APPLICATION

- Participants divide into subgroups based on a shared qualitative characteristic



SMOKING AND DRINKING CESSATION TRIAL

Pharmacological treatments that can concomitantly address cigarette smoking and heavy drinking stand to improve health care delivery for these highly prevalent co-occurring conditions. This superiority trial compared the combination of varenicline and naltrexone against varenicline alone for smoking cessation and drinking reduction among heavy-drinking smokers.



Lara
Ray

ReJoyce
Green

Ray, L.A., Green, R., Enders, C., et al. (2021). Efficacy of combining varenicline and naltrexone for smoking cessation and drinking reduction: A randomized clinical trial. *American Journal of Psychiatry*, 178, 818–828.

KEY VARIABLES



Breath (alveolar) carbon monoxide

A measure of carbon monoxide in the lungs. Breath carbon monoxide is a biomarker of smoking behavior common in clinical trials. Higher scores reflect more frequent smoking.

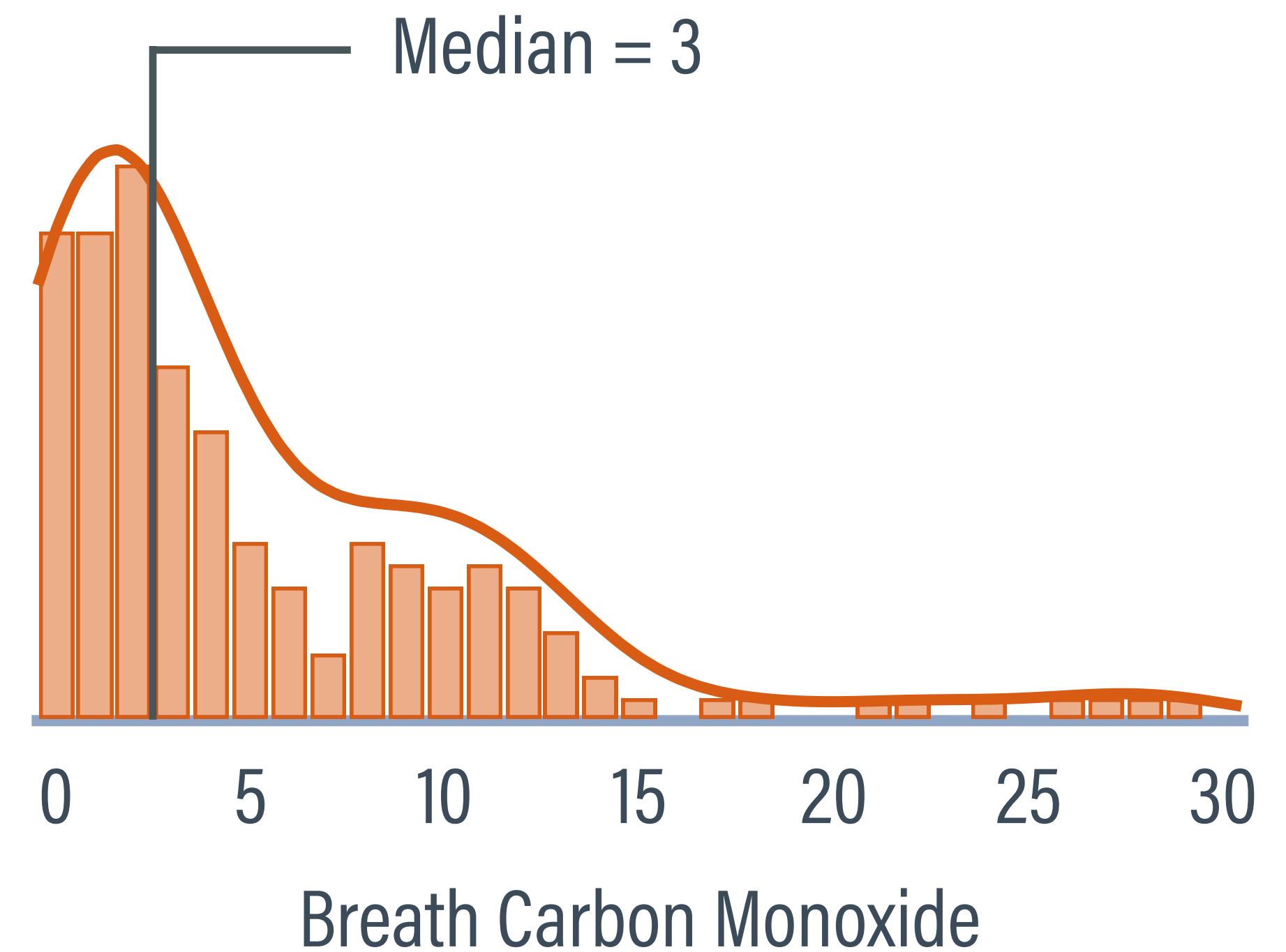


Medication arm

Participants were randomly assigned to receive one of two meds: varenicline plus naltrexone or varenicline plus placebo pills

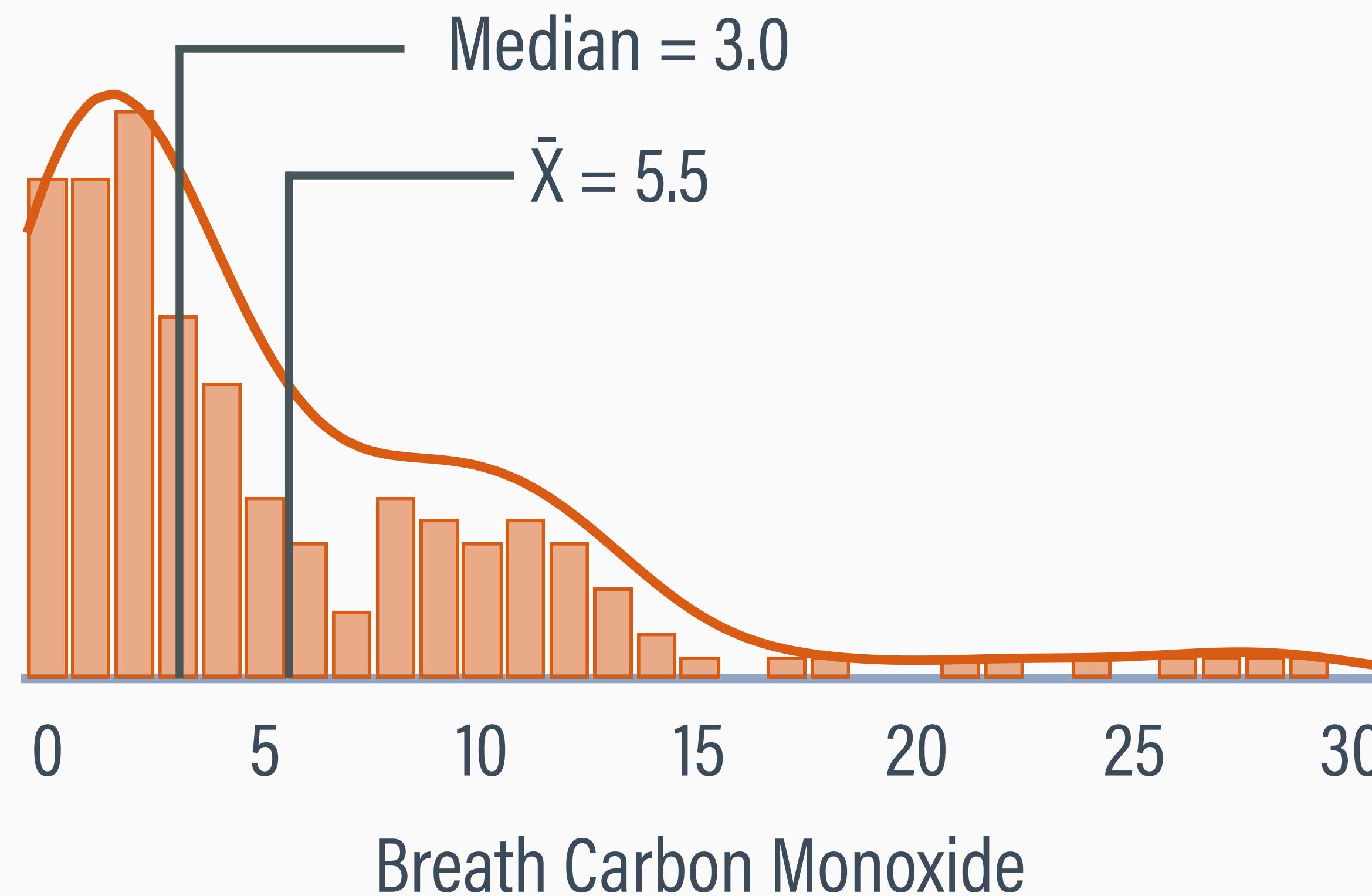


The median breath CO reading at the eight-week follow-up is 3.0. In small groups of two or three, discuss whether the sample mean is higher, lower, or about the same as than the median. Provide a rationale.



MEAN VS. MEDIAN

- High CO values in the upper tail pull the mean above the median



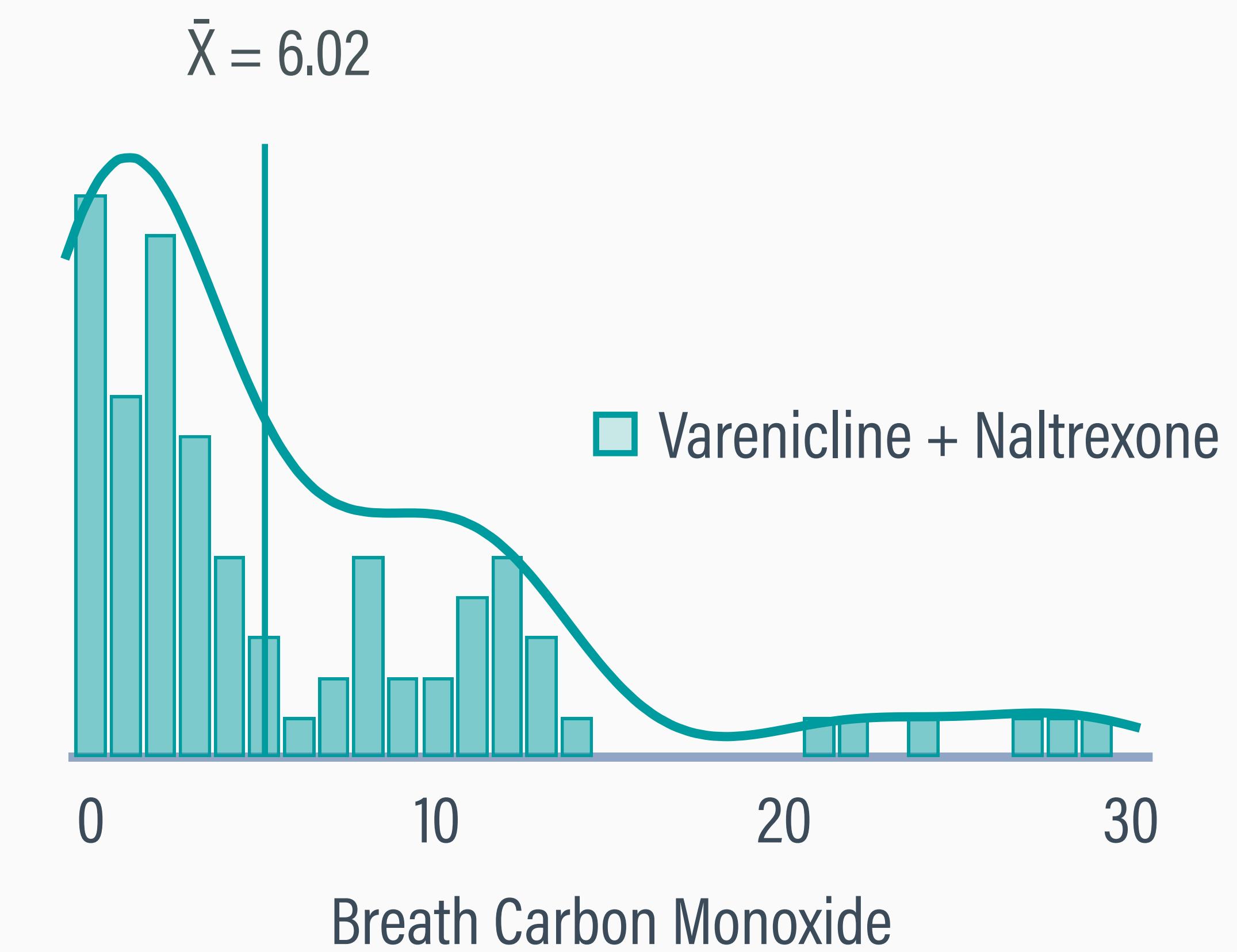
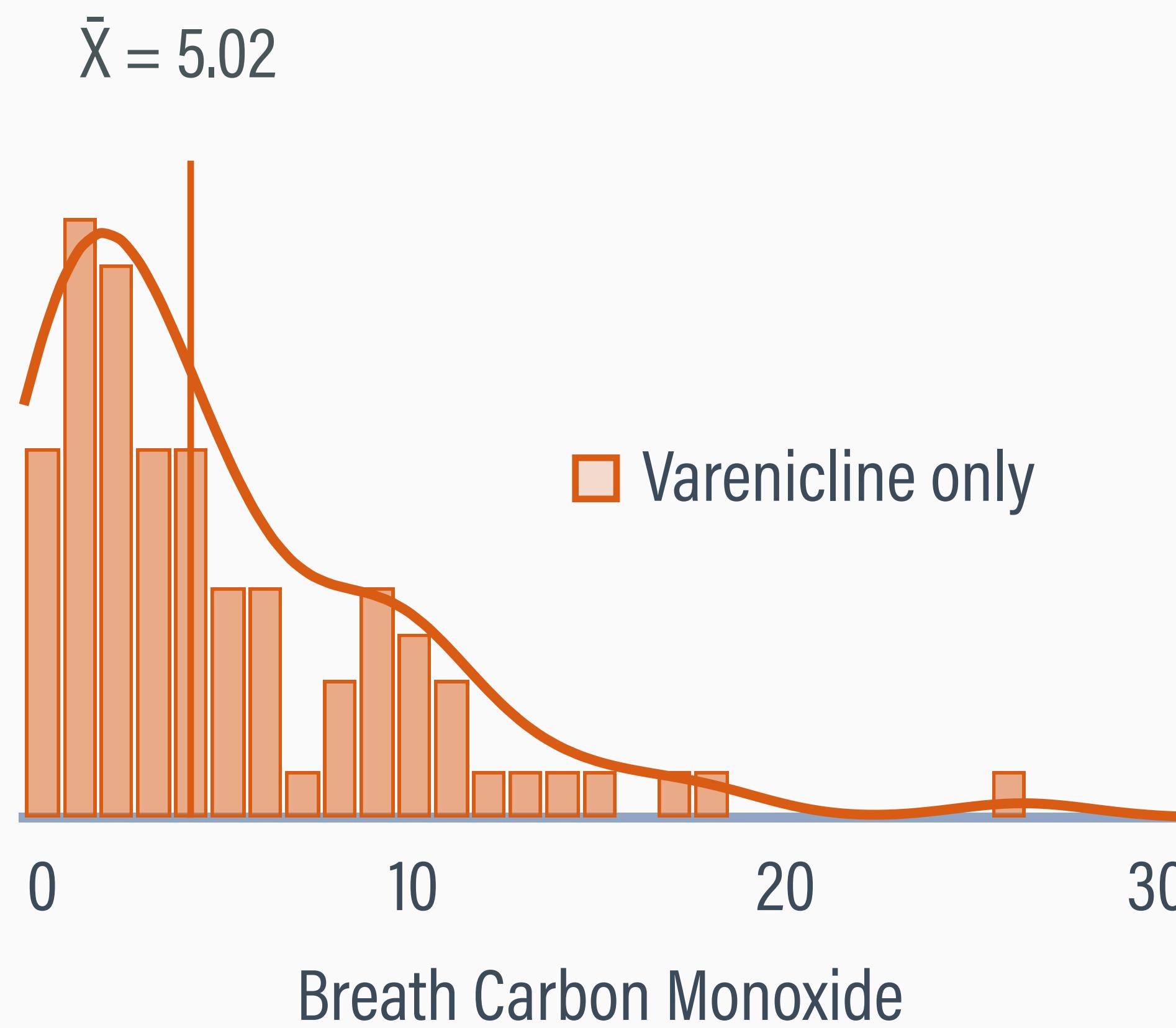
R OUTPUT

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
Participant	1	165	83.00	47.78	83	83.00	60.79	1	165	164	0.00	-1.22	3.72
Condition*	2	165	1.50	0.50	2	1.50	0.00	1	2	1	-0.01	-2.01	0.04
Gender*	3	165	1.61	0.49	2	1.63	0.00	1	2	1	-0.43	-1.83	0.04
COWeek0	4	165	10.55	6.86	9	9.82	5.93	0	46	46	1.41	3.60	0.53
COWeek4	5	165	5.46	5.10	4	4.69	4.45	0	24	24	1.24	0.96	0.40
COWeek8	6	165	5.53	5.96	3	4.55	2.97	0	29	29	1.75	3.35	0.46
QuitCigsWeek4*	7	165	1.62	0.49	2	1.65	0.00	1	2	1	-0.48	-1.78	0.04
QuitCigsWeek8*	8	165	1.64	0.48	2	1.68	0.00	1	2	1	-0.59	-1.66	0.04
DrinksWeek0	9	165	6.40	4.42	6	5.77	2.97	1	35	34	2.44	10.46	0.34
DrinksWeek4	10	165	3.59	2.98	3	3.30	2.97	0	13	13	0.80	0.30	0.23
DrinksWeek8	11	165	3.23	2.68	3	2.97	2.97	0	13	13	0.89	0.67	0.21
CigsWeek0	12	165	14.22	8.22	12	13.05	5.93	3	51	48	1.59	3.20	0.64
CigsWeek4	13	165	4.18	5.70	2	3.08	2.97	0	41	41	3.01	13.13	0.44
CigsWeek8	14	165	3.16	4.75	2	2.25	2.97	0	35	35	3.44	16.81	0.37

COMPARATIVE RESEARCH QUESTIONS

- Comparative research questions ask whether two or more groups (or occasions) differ from one another
- Question: Do participants in the two treatment groups differ in their smoking levels?
- We can answer this question by comparing the group means

GROUP MEANS



R OUTPUT

Descriptive statistics by group

Condition: **Varenicline**

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
COWeek8	1	82	5.02	4.88	3.5	4.33	3.71	0	26	26	1.57	3.09	0.54

Condition: **Varenicline + Naltrexone**

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
COWeek8	1	83	6.02	6.86	3	4.81	4.45	0	29	29	1.62	2.31	0.75



One of the main goals of the research study is to determine whether the treatment groups differ. In small groups of two or three, discuss the size of the mean difference. How would you gauge the magnitude of the medication difference? Do the groups exhibit a meaningful difference? This is a subjective evaluation, so provide a rationale.

OUTLINE

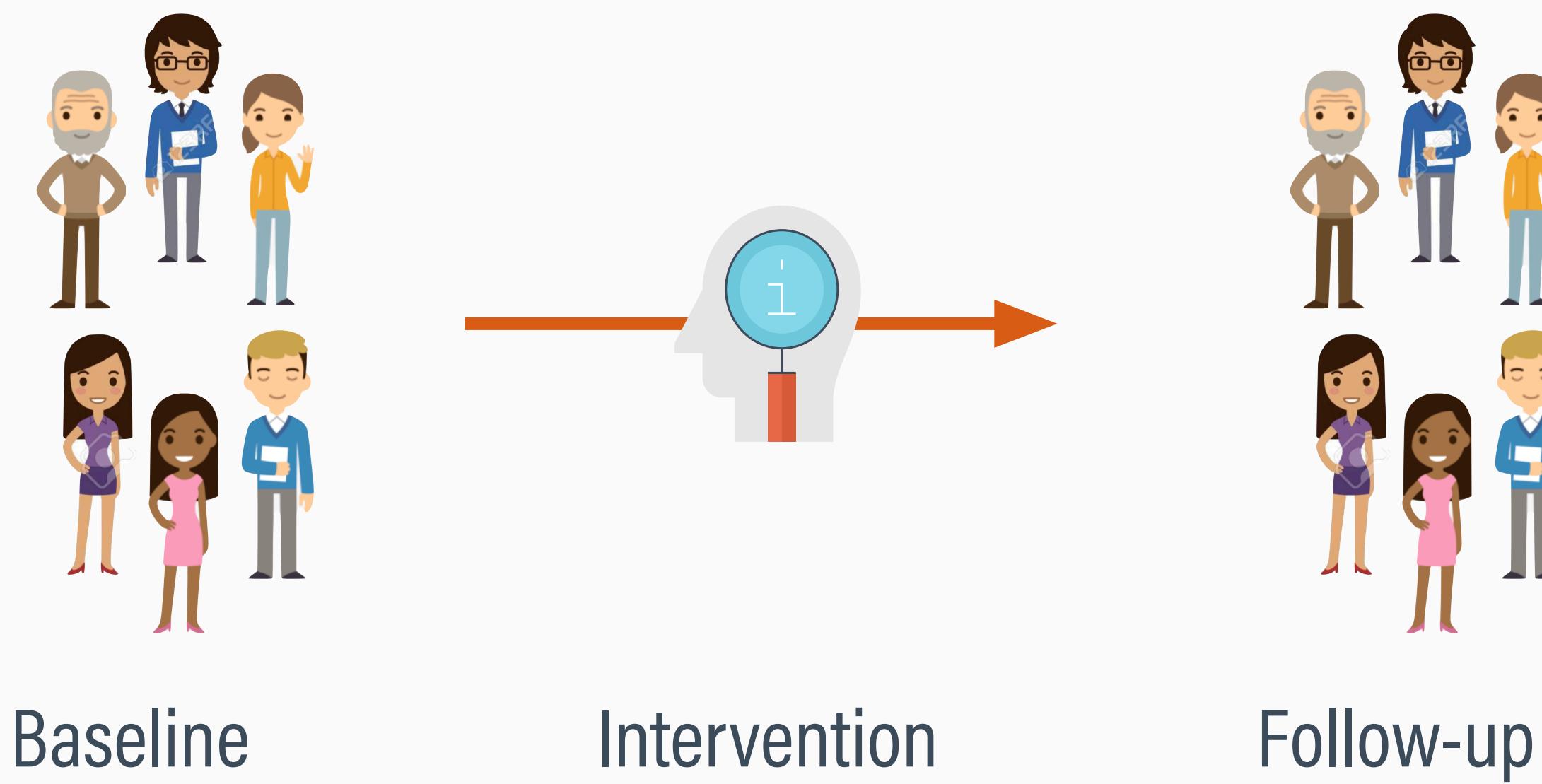
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WITHIN-SUBJECTS RESEARCH DESIGNS

- A **within-subjects research design** produces two or more scores from the same participant
- A classic within-group design collects two or more repeated measurements from the same group of individuals (e.g., a pretest measure followed by a posttest)
- The scores can also come from matched pairs of scores

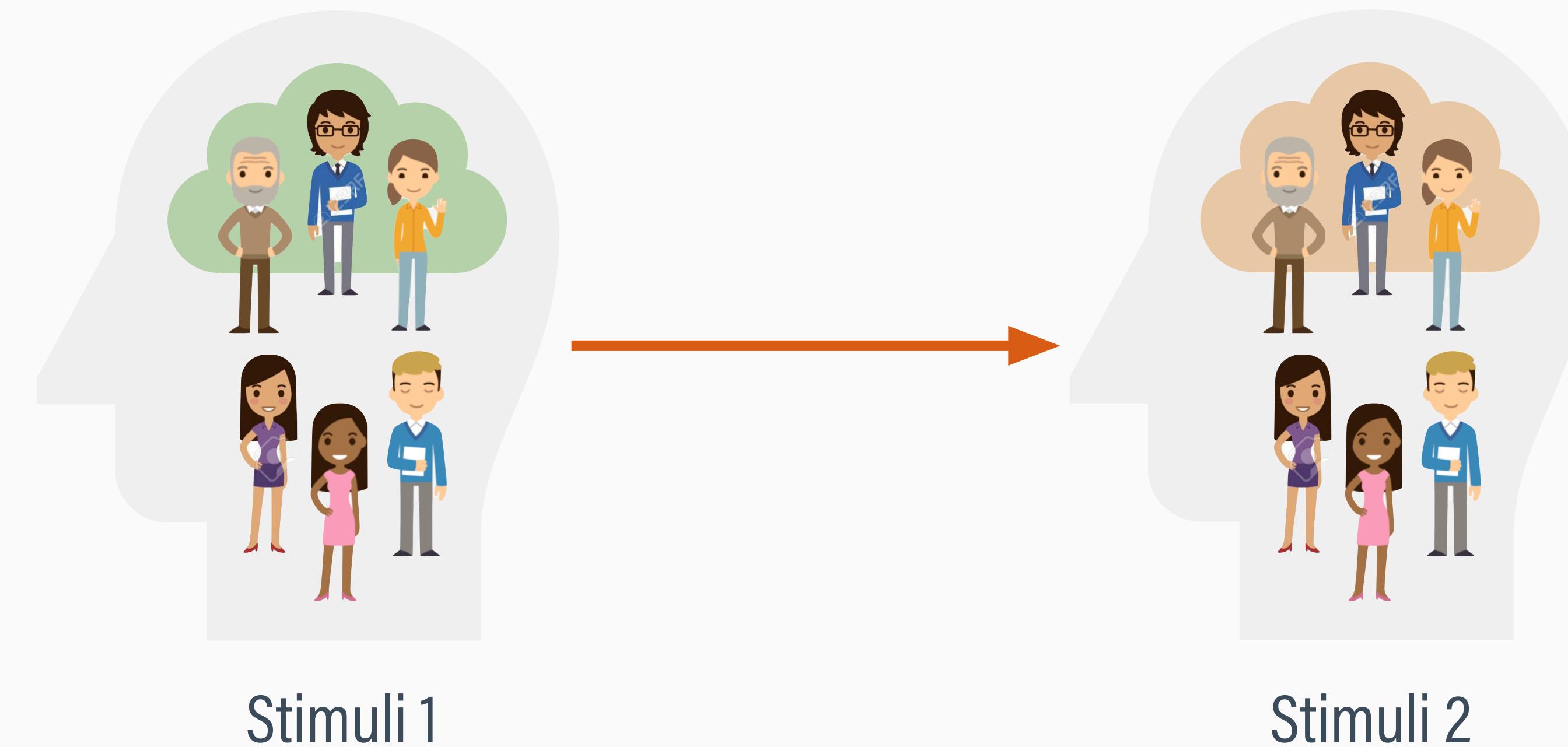
INTERVENTION APPLICATION

- Two scores are obtained from the same group of people before and after an intervention



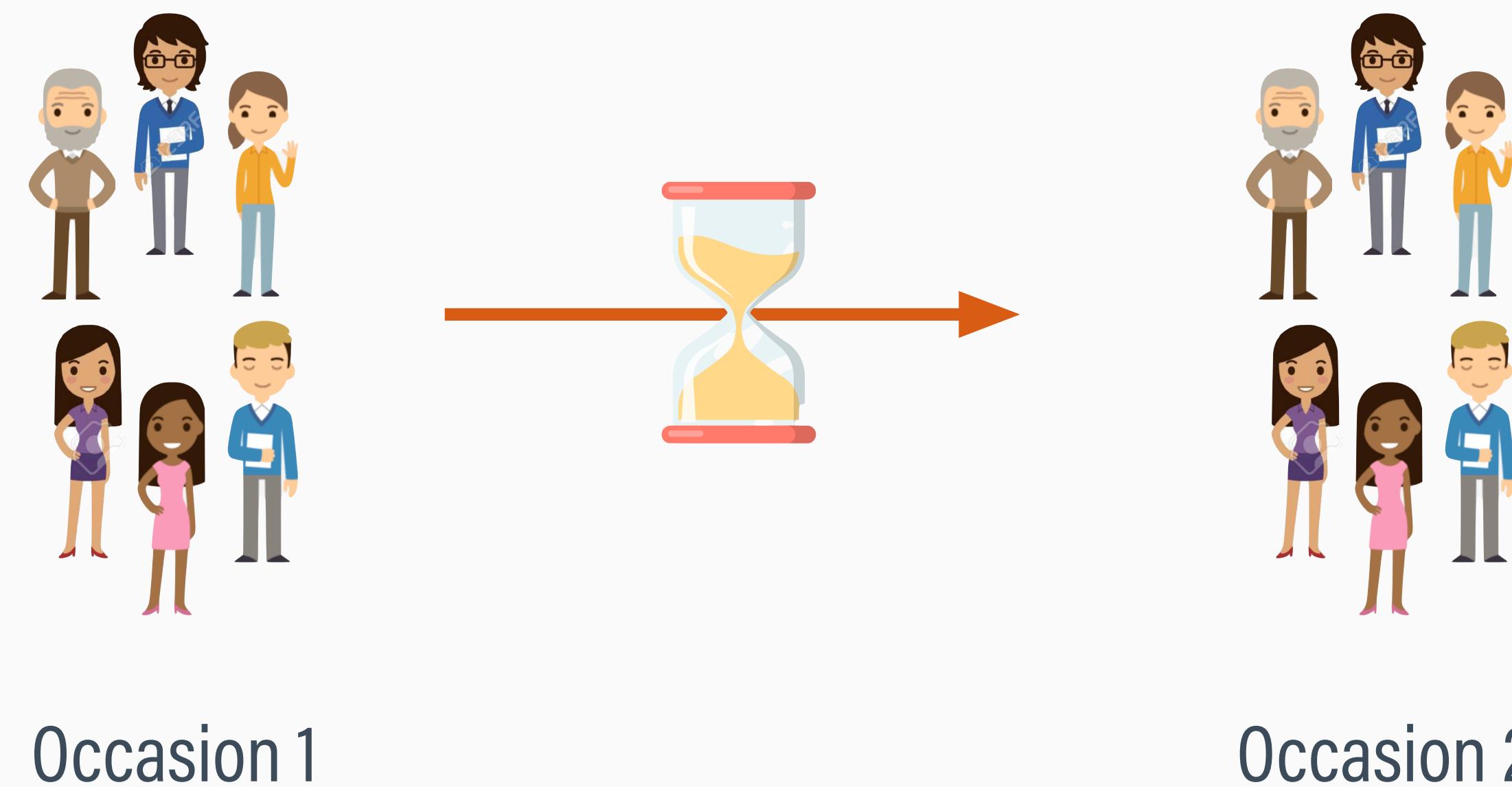
EXPERIMENTAL APPLICATION

- The same group of people are exposed to two different experimental conditions



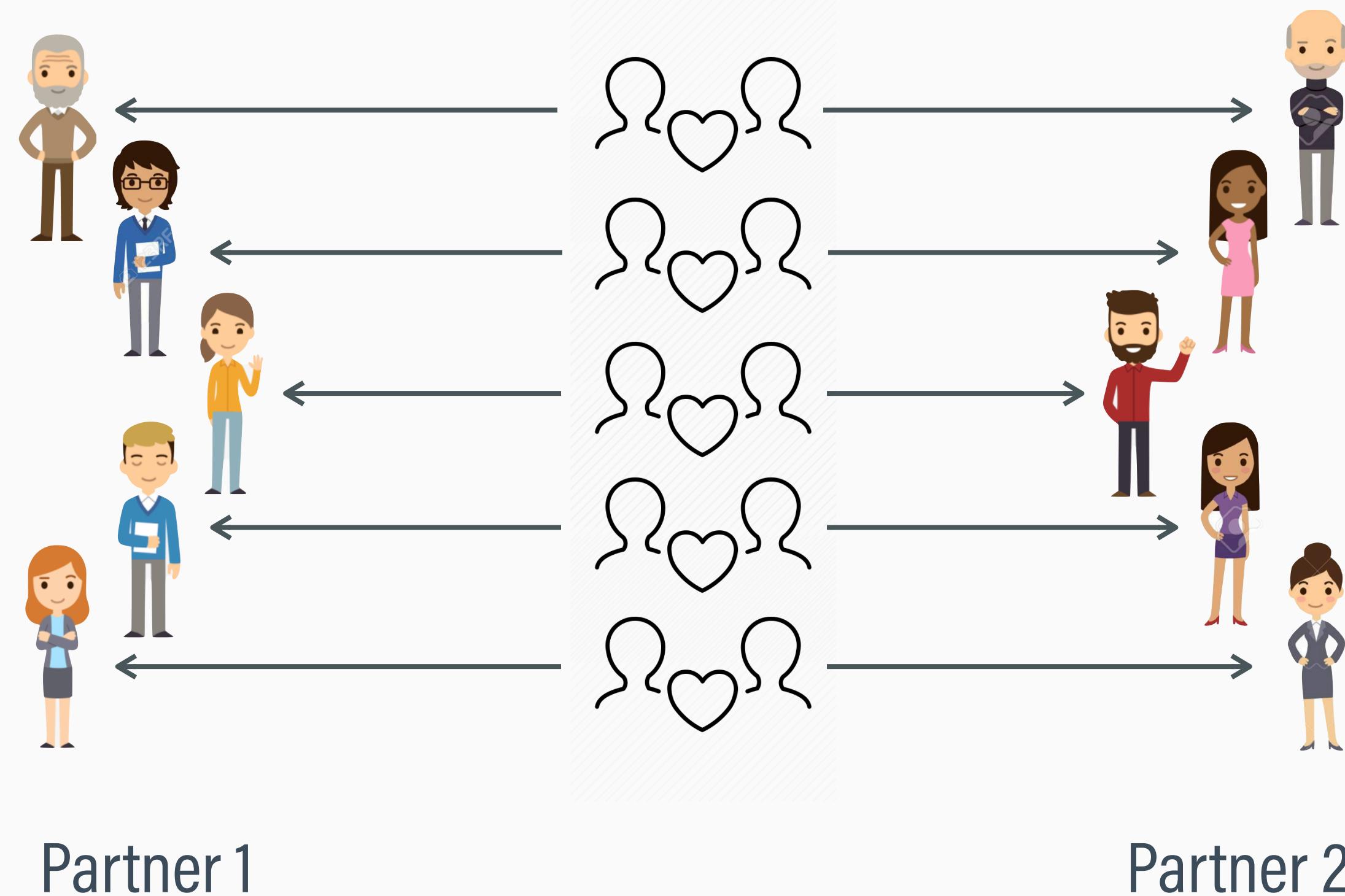
DEVELOPMENTAL APPLICATION

- The same group of people are followed over time, with the goal of examining change or development



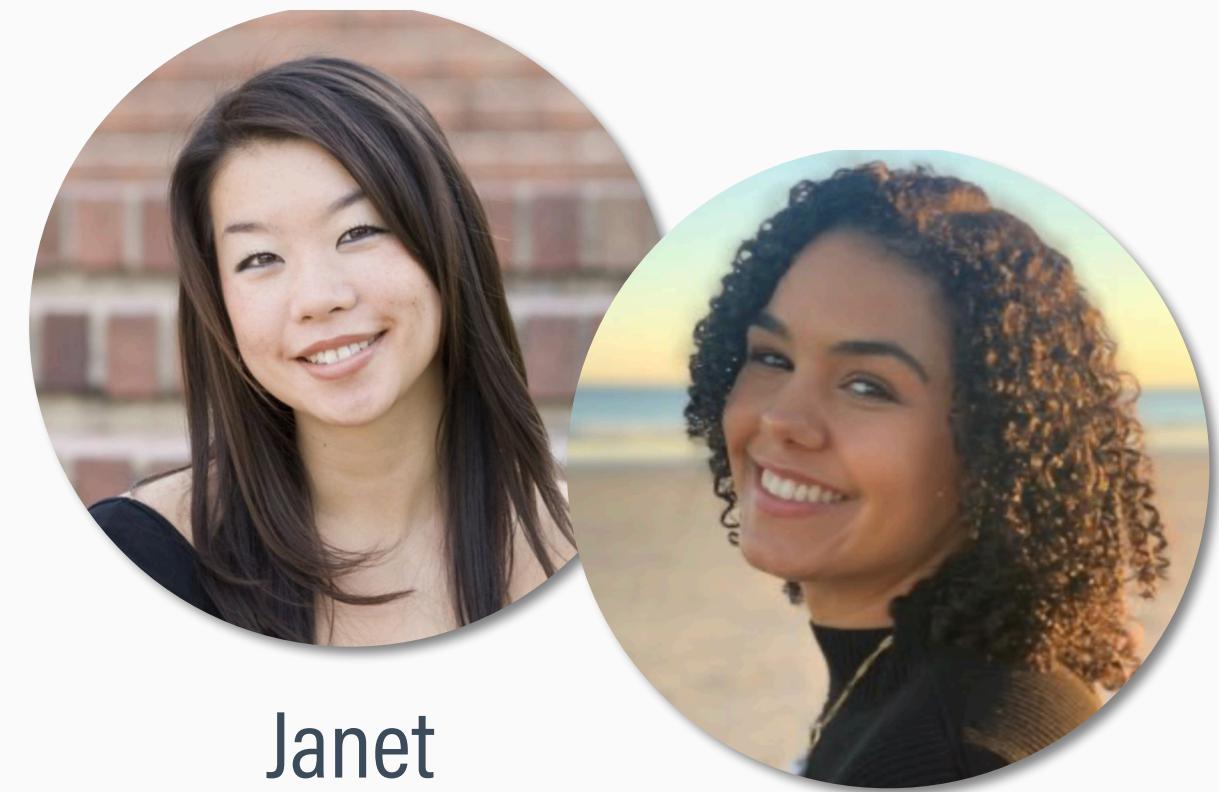
DYADIC APPLICATION

- Pairs of individuals forming naturally-occurring dyads (e.g., romantic partners, siblings) with linked scores



SKIN COLOR SATISFACTION AND BINGE EATING

Although it has been demonstrated that (a) body dissatisfaction and internalization of societal appearance standards contribute to disordered eating and (b) that internalization of societal appearance standards leads to decreased skin color satisfaction among Black women, it has not been established whether skin color dissatisfaction contributes to disordered eating among Black women or girls. The objective of the present study is to determine the influence of skin color satisfaction as a potential predictor for binge eating, and its effect through body image in Black girls during the vulnerable developmental period of adolescence.

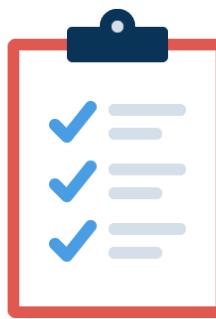


Janet
Tomiyama

Jordan
Parker

Parker, J.E., Enders, C.K., Mujahid, M.S., Laraia, B.A., Epel, E.S., Tomiyama, A.J. (2022). Prospective relationships between skin color satisfaction, body satisfaction, and binge eating in Black girls. *Body Image*, 41, 342-353.

KEY VARIABLES



Age

The grouping variable was age. Participants were followed longitudinally, with dependent variable measured at ages 10 and 18.



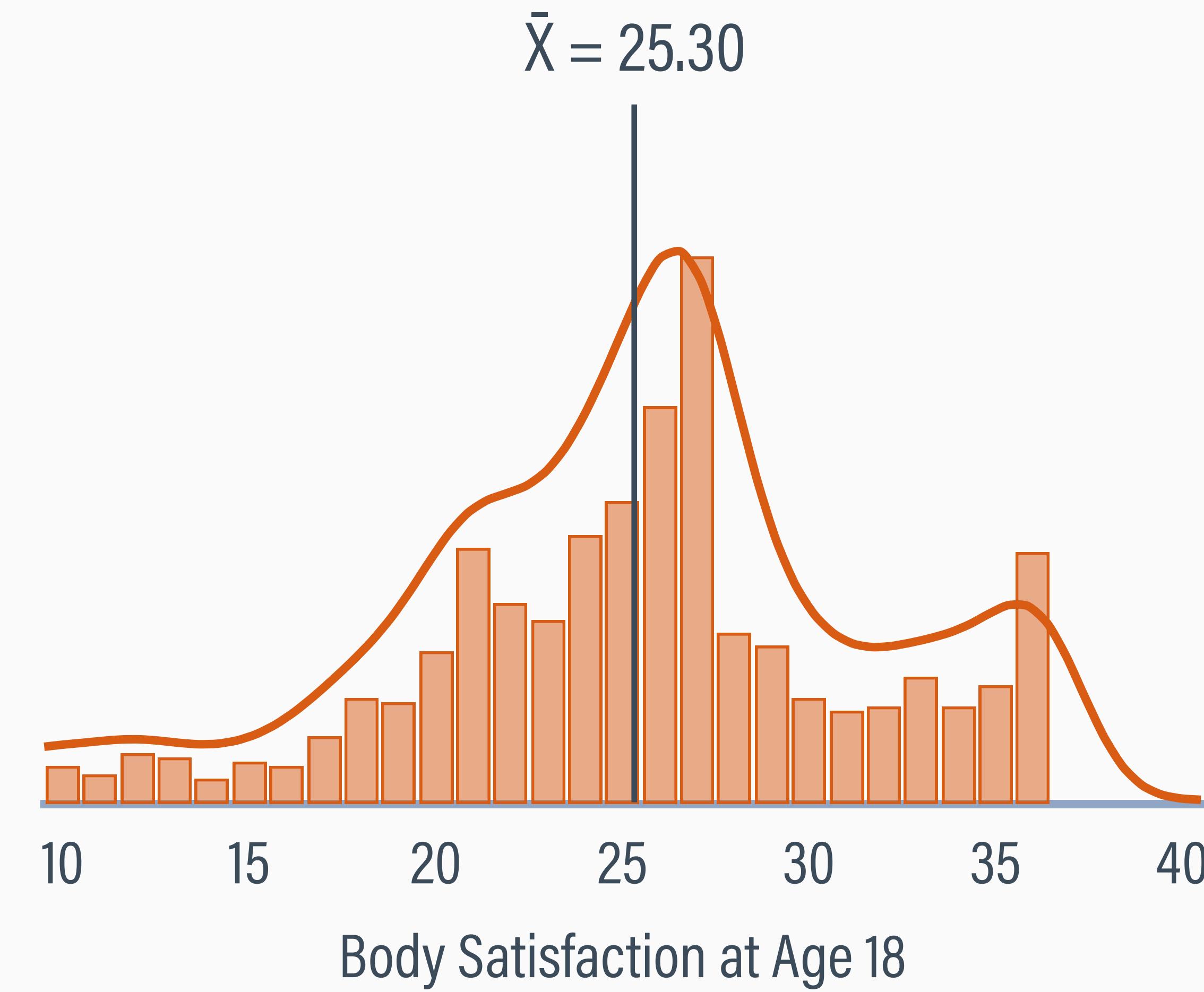
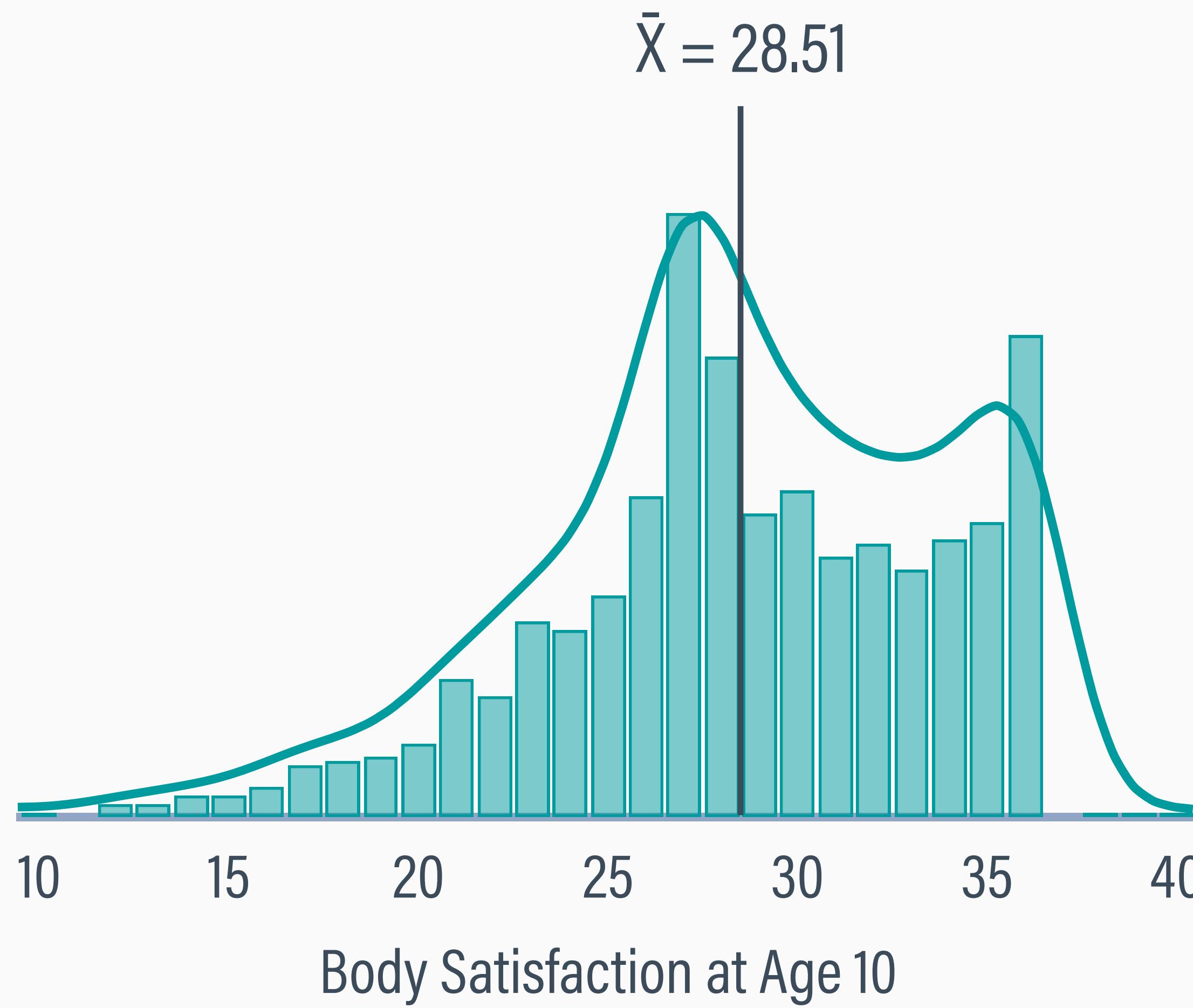
Body Satisfaction

Body satisfaction is the facet of self-concept associated that includes attitudes, evaluations, and feelings about one's own body. Measured by summing responses to nine 4-point questionnaire items.

COMPARATIVE RESEARCH QUESTIONS

- Comparative research questions ask whether two or more groups (or occasions) differ from one another
- Question: Does female body satisfaction change between the ages of 10 and 18?
- We can answer this question by comparing the means

BODY SATISFACTION BY AGE



R OUTPUT

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
Participant	1	882	441.50	254.76	441.50	441.50	326.91	1.00	882.00	881.00	0.00	-1.20	8.58
ParentEduc*	2	882	2.27	0.80	2.00	2.34	1.48	1.00	3.00	2.00	-0.52	-1.26	0.03
ParentIncome*	3	882	2.38	1.11	2.00	2.35	1.48	1.00	4.00	3.00	0.12	-1.33	0.04
BMI10	4	882	19.60	4.22	18.48	19.11	3.57	12.37	35.16	22.79	1.10	0.94	0.14
SkinColorSat10	5	882	3.59	0.64	4.00	3.70	0.00	1.00	4.00	3.00	-1.58	2.41	0.02
SkinColorSat18	6	882	3.50	0.65	4.00	3.58	0.00	1.00	4.00	3.00	-1.36	2.36	0.02
BodySat10	7	882	28.49	5.14	28.00	28.83	5.93	9.00	36.00	27.00	-0.61	0.36	0.17
BodySat18	8	882	25.44	6.06	26.00	25.64	5.93	9.00	36.00	27.00	-0.33	0.10	0.20
BingeEatDisorder10	9	882	2.59	1.82	2.00	2.49	1.48	0.00	8.00	8.00	0.45	-0.35	0.06
BingeEatDisorder18	10	882	1.68	1.45	1.00	1.52	1.48	0.00	8.00	8.00	0.88	0.84	0.05



One of the main goals of the research study is to determine whether body satisfaction changes. In small groups of two or three, discuss the size of the mean difference. How would you gauge the magnitude of the medication difference? Do the age-specific means exhibit a meaningful difference? This is a subjective evaluation, so provide a rationale.

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STUDY QUESTIONS (1)

A researcher collecting data on the number of selfies posted to a social media site has the following sample of data: 25, 0, 1, 0, 2, 14, 0, 2, 1, 5, 3. The mean is 4.8 and the median is 2.

1. Suppose that the score of 25 is changed to 50. What will happen to the mean (get larger, get smaller, stay the same)? What will happen to the median?

STUDY QUESTIONS (2)

- 2) A researcher wants to report the central tendency for gender.
Which measure(s) of central tendency could be used to summary this variable?

- 3) A researcher wants to report the central tendency for an education variable with five categories: less than high school, high school, some college, college degree, graduate degree.
Which measure(s) of central tendency could be used to summary this variable? For each that you list, explain why it is or is not appropriate for this variable.

STUDY QUESTIONS (3)

The mean salary of an NFL player is about \$3.2 million, and the median salary is approximately \$860,000.

4. Based on the two measures of central tendency, sketch a bar plot (or kernel density plot) that depicts the NFL salary distribution?

5. Why is the mean salary more than three times larger than the median salary?

STUDY QUESTIONS (4)

A researcher is interested in studying postpartum depression in new mothers. She recruits a sample of 100 new mothers, and study participants to rate their depression using the Beck depression inventory. They use the mean to summarize depression levels.

6. Describe or define the sample, population, parameter, and estimate in this research scenario.