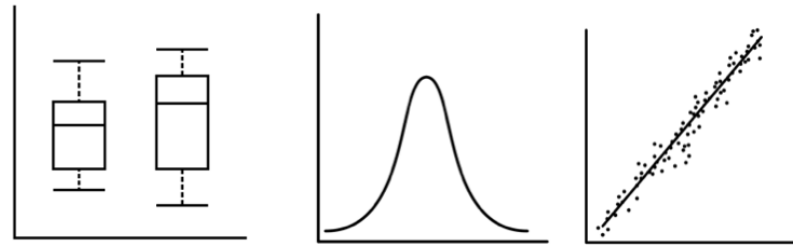


PSYC 2300

Introduction to Statistics



Lecture 10: Differences Between Two Groups (Part I)

Outline for today

- **Review**
 - Parts of last class
- **Independent-samples t -test**
 - Practice activity
- **Effect size for independent-samples t -test**
- **Independent-samples t -test in JASP**
 - Download Stats Class 12 Dataset (Independent-Samples T-Test).jasp



Review

Statistics: A set of tools and techniques that are used for describing, organizing, and interpreting information or data

Inferential Statistics: Used to make inferences (reach a conclusion) about the data

Review

Hypothesis testing involves using samples to make inferences about the population

Null Hypothesis: there is no change, no difference, or no relationship between variables

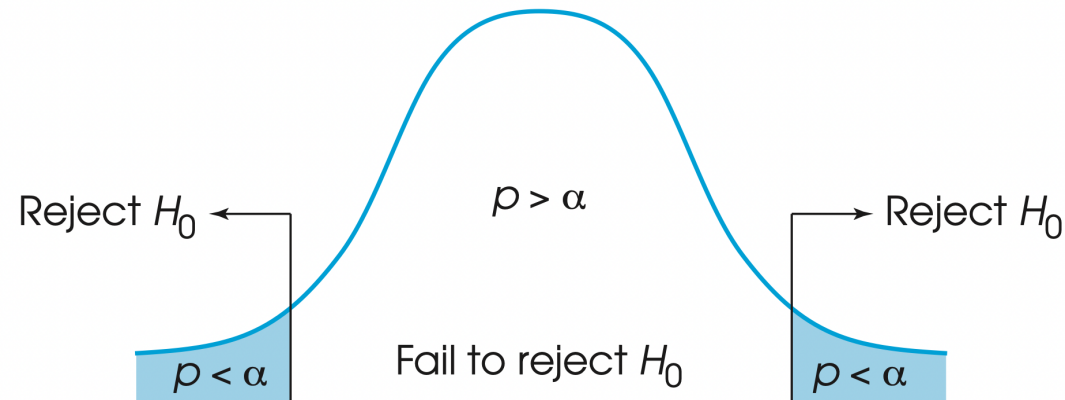
$$H_0 = \epsilon$$

Research Hypothesis: there is change, a difference, or a relationship between variables

$$H_1 = \tau + \epsilon$$

Review

Statistical Significance: A result is said to be *significant*, or *statistically significant*, if it is very unlikely to occur when the null hypothesis is true. That is, the result is sufficient to reject the null hypothesis. Thus, a treatment has a significant effect if the decision from the hypothesis test is to reject H_0



Review

Independent variable: The variable that is hypothesized to have an effect on some outcome of interest

Dependent variable: The outcome of interest that the independent variable might have an effect on

Review

Inferences about a population with one sample

z-test statistic

$$z_{\bar{x}} = \frac{\bar{x} - \mu_{\bar{x}}}{\sigma_{\bar{x}}}$$

Standard Error

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

One-sample *t*-test statistic

$$t_{\bar{x}} = \frac{\bar{x} - \mu_{\bar{x}}}{s_{\bar{x}}}$$

Estimated standard error

$$s_{\bar{x}} = \frac{s}{\sqrt{n}}$$

Independent samples t -test

t-test statistic

General form of t-test statistics

$$t = \frac{\text{sample statistic} - \text{population parameter}}{\text{estimated standard error of statistic}}$$

Three types we'll learn:

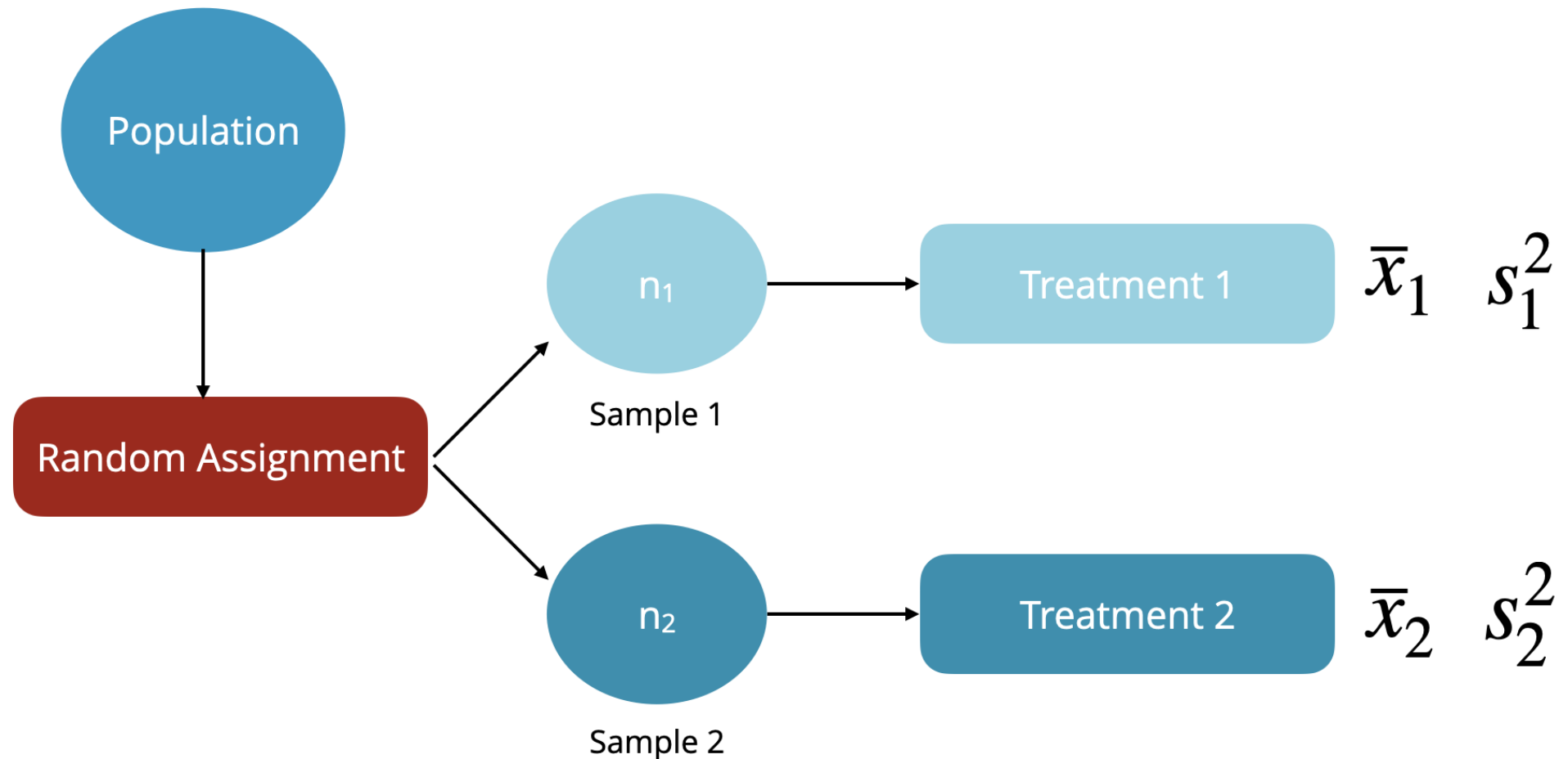
- One sample *t*-test
- **Independent samples *t*-test**
- Dependent samples *t*-test

Goal

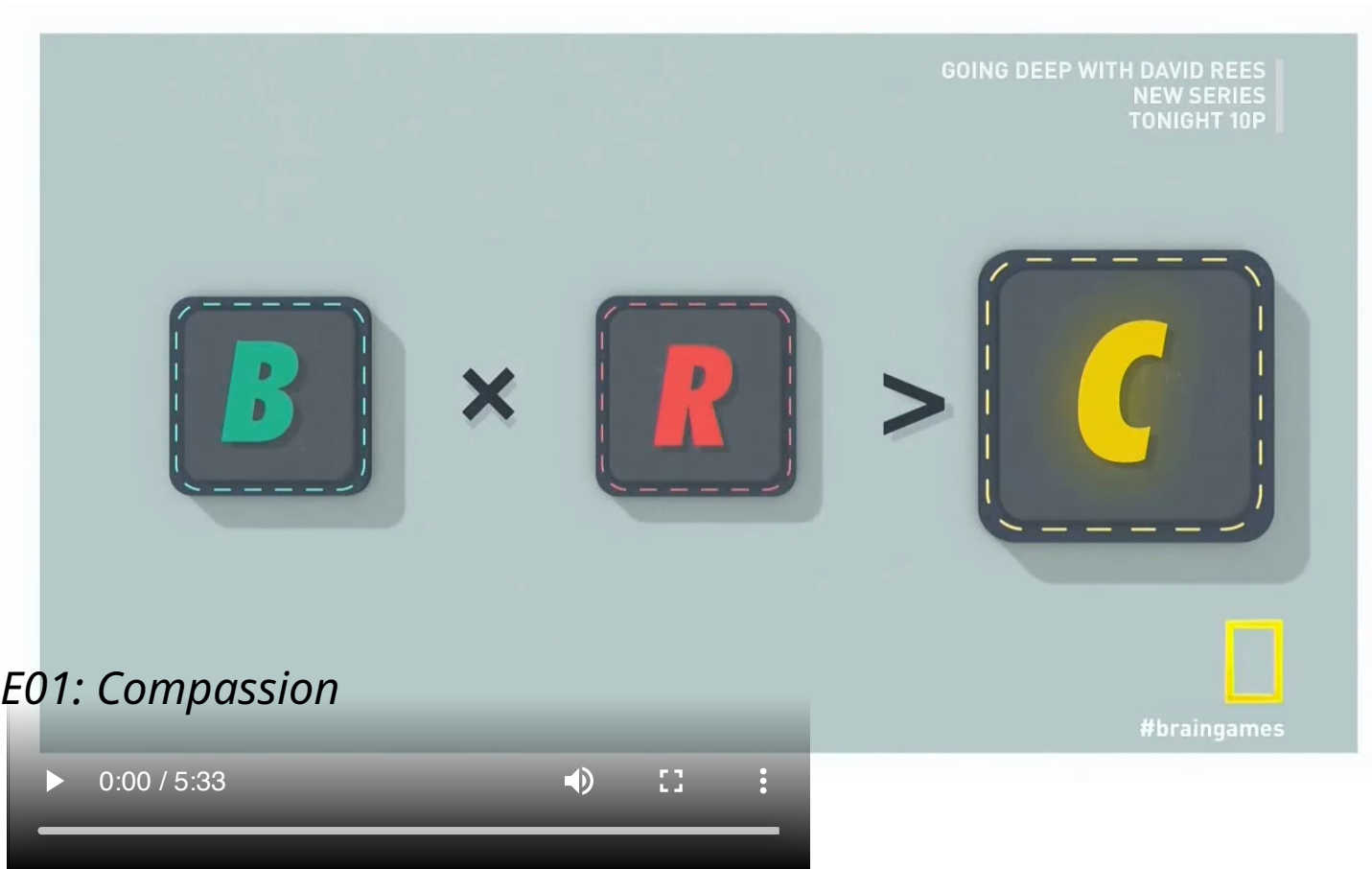
Independent samples t -test

- To investigate whether two independent groups differ significantly along a dimension of interest
- “Independent” here means unrelated (e.g., they were only tested once)
 - This is a situation where we are measuring *separate* groups of individuals, and we want to compare the means of those separate groups (also called a **between-subjects design**)

Independent Samples



Independent samples t -test



Brain Games S04E01: Compassion
[Link here](#)

Group Activity

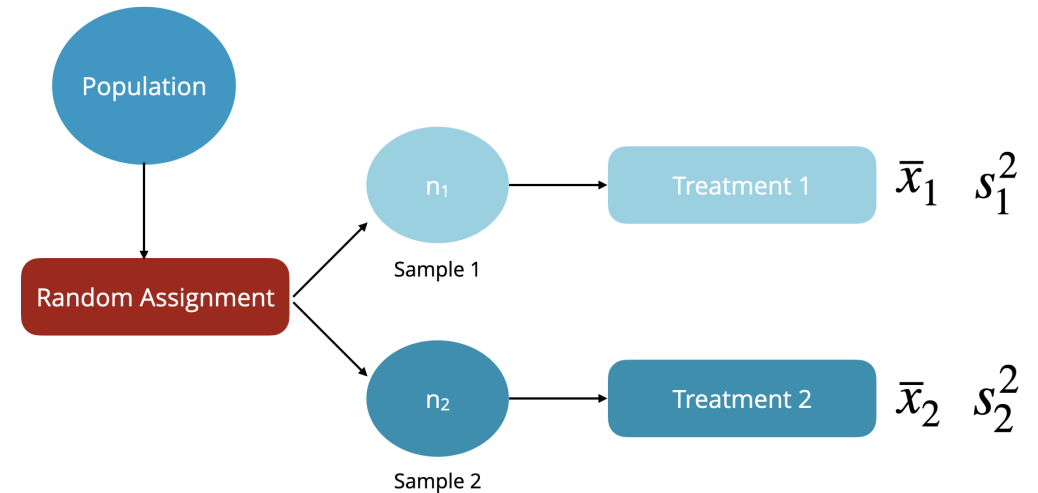
For the 1st experiment:

What was the independent variable?

What was the dependent variable?

What is the null hypothesis?

What is the alternative hypothesis?



Group Activity

Independent variable

- Hallway bump (absent, present)
 - $\bar{x}_1 = \bar{x}_{absent}$
 - $\bar{x}_2 = \bar{x}_{present}$

Dependent variable

- Compassion: Type and amount of hot sauce (Mild, Medium, Death)

Null Hypothesis H_0

$$\bar{x}_1 = \bar{x}_2$$

Compassion is not different for people who are bumped in the hallway compared to those who are not bumped in the hallway

Alternative Hypothesis H_a

$$\bar{x}_1 \neq \bar{x}_2$$

Compassion is different for people who are bumped in the hallway compared to those who are not bumped in the hallway

t-test statistic

General form of t-test statistics

$$t = \frac{\text{sample statistic} - \text{population parameter}}{\text{estimated standard error of statistic}}$$

Three types we'll learn:

- One sample *t*-test
- **Independent samples *t*-test**
- Dependent samples *t*-test

Building the t-test statistic

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - \text{population parameter}}{\text{estimated standard error of statistic}}$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\text{estimated standard error of statistic}}$$

Building the t-test statistic

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\text{estimated standard error of statistic}}$$

Null Hypothesis $H_0: \mu_1 = \mu_2$

Equivalently, if H_0 is true, $\mu_1 - \mu_2 = 0$

In other words, under the null hypothesis, the population means for these two groups will be equal to one another, meaning this new term $(\mu_1 - \mu_2)$ will cancel out

Building the t-test statistic

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\text{estimated standard error of statistic}}$$

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\text{estimated standard error of the mean difference}}$$

Independent samples t-test

Independent samples *t*-test

$$t_{(\bar{x}_1 - \bar{x}_2)} = \frac{\bar{x}_1 - \bar{x}_2}{s_{(\bar{x}_1 - \bar{x}_2)}}$$

Note that to use this test, we must assume that the variance in the population for our groups is equal (called the **homogeneity of variance** assumption).

- If we think the two treatments would differentially affect the spread of the data in the population, we would need to use a different version of this test.

Independent samples *t*-test

Estimated standard error of the mean difference

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \right] \left[\frac{n_1 + n_2}{n_1 n_2} \right]}$$

\bar{x}_1 is the mean for Sample 1

s_1^2 is the variance of Sample 1

\bar{x}_2 is the mean for Sample 2

s_2^2 is the variance of Sample 2

n_1 is the number of subjects in Sample 1

n_2 is the number of subjects in Sample 2

Independent samples t -test

Independent samples t -test

$$t_{(\bar{x}_1 - \bar{x}_2)} = \frac{\bar{x}_1 - \bar{x}_2}{s_{(\bar{x}_1 - \bar{x}_2)}}$$

Estimated standard error of the mean difference

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \right] \left[\frac{n_1 + n_2}{n_1 n_2} \right]}$$

Practice Activity

No hallway bump

$$n_1 = 10$$

$$\bar{x}_1 = 5.5$$

$$s_1^2 = 2.5$$

Hallway bump

$$n_2 = 10$$

$$\bar{x}_2 = 8.5$$

$$s_2^2 = 3$$

Independent samples t -test

$$t_{(\bar{x}_1 - \bar{x}_2)} = \frac{\bar{x}_1 - \bar{x}_2}{s_{(\bar{x}_1 - \bar{x}_2)}}$$

Estimated standard error of the mean difference

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \right] \left[\frac{n_1 + n_2}{n_1 n_2} \right]}$$

Estimated standard error of the mean difference

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \right] \left[\frac{n_1 + n_2}{n_1 n_2} \right]}$$

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{(10 - 1)2.5 + (10 - 1)3}{10 + 10 - 2} \right] \left[\frac{10 + 10}{(10)(10)} \right]}$$

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{(9)2.5 + (9)3}{18} \right] \left[\frac{20}{100} \right]}$$

Estimated standard error of the mean difference

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[\frac{22.5 + 27}{18} \right] \left[\frac{20}{100} \right]}$$

$$s_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{\left[2.75 \right] \left[0.20 \right]} = .7416$$

$$s_{(\bar{x}_1 - \bar{x}_2)} = .74$$

Independent samples t -test statistic

$$t_{(\bar{x}_1 - \bar{x}_2)} = \frac{\bar{x}_1 - \bar{x}_2}{s_{(\bar{x}_1 - \bar{x}_2)}}$$

$$t_{(\bar{x}_1 - \bar{x}_2)} = \frac{5.5 - 8.5}{0.74}$$

$$t_{(\bar{x}_1 - \bar{x}_2)} = -4.054$$

Independent samples t -test: Interpretation

Null Hypothesis $H_0: \mu_1 = \mu_2$

There is no difference in compassion for people who are bumped compared to not bumped in the hallway.

Alternative Hypothesis $H_a: \mu_1 \neq \mu_2$

There is a difference in compassion for people who are bumped compared to not bumped in the hallway.

Independent samples t -test: Interpretation

No hallway bump

$$n_1 = 10$$

$$\bar{x}_1 = 5.5$$

$$s_1^2 = 2.5$$

$$t_{\bar{x}_1 - \bar{x}_2} = -4.054$$

$$p = 0.0008$$

$$\alpha = .05$$

$$p < \alpha$$

Hallway bump

$$n_2 = 10$$

$$\bar{x}_2 = 8.5$$

$$s_2^2 = 3$$

We reject the null hypothesis. People who are bumped in the hallway are less compassionate than people who are not bumped in the hallway.

Effect Size for Independent Samples t -test

Effect size: independent samples *t*-test

**Cohen's *d* for independent samples
t-test**

$$d_{(\bar{x}_1 - \bar{x}_2)} = \frac{\bar{x}_1 - \bar{x}_2}{s_p}$$

Pooled standard deviation

$$s_p = \sqrt{\frac{s_1^2 + s_2^2}{2}}$$

Calculating Effect Size

$$d_{(\bar{x}_1 - \bar{x}_2)} = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2 + s_2^2}{2}}}$$

$$d_{(\bar{x}_1 - \bar{x}_2)} = \frac{5.5 - 8.5}{\sqrt{\frac{2.5 + 3}{2}}}$$

$$d_{(\bar{x}_1 - \bar{x}_2)} = \frac{-3}{\sqrt{2.75}} = \frac{-3}{1.658312} = -1.809068$$

Independent samples t -test in JASP

Example Experiment

Research question: Does exercising in a group (e.g., group classes) affect anxiety compared to solo exercise (i.e., working out alone)?

Null hypothesis H_0

$$\mu_1 = \mu_2$$

$$\mu_{classes} = \mu_{solo}$$

There is no difference in anxiety levels when taking a group class compared to exercising alone

Alternative hypothesis H_a

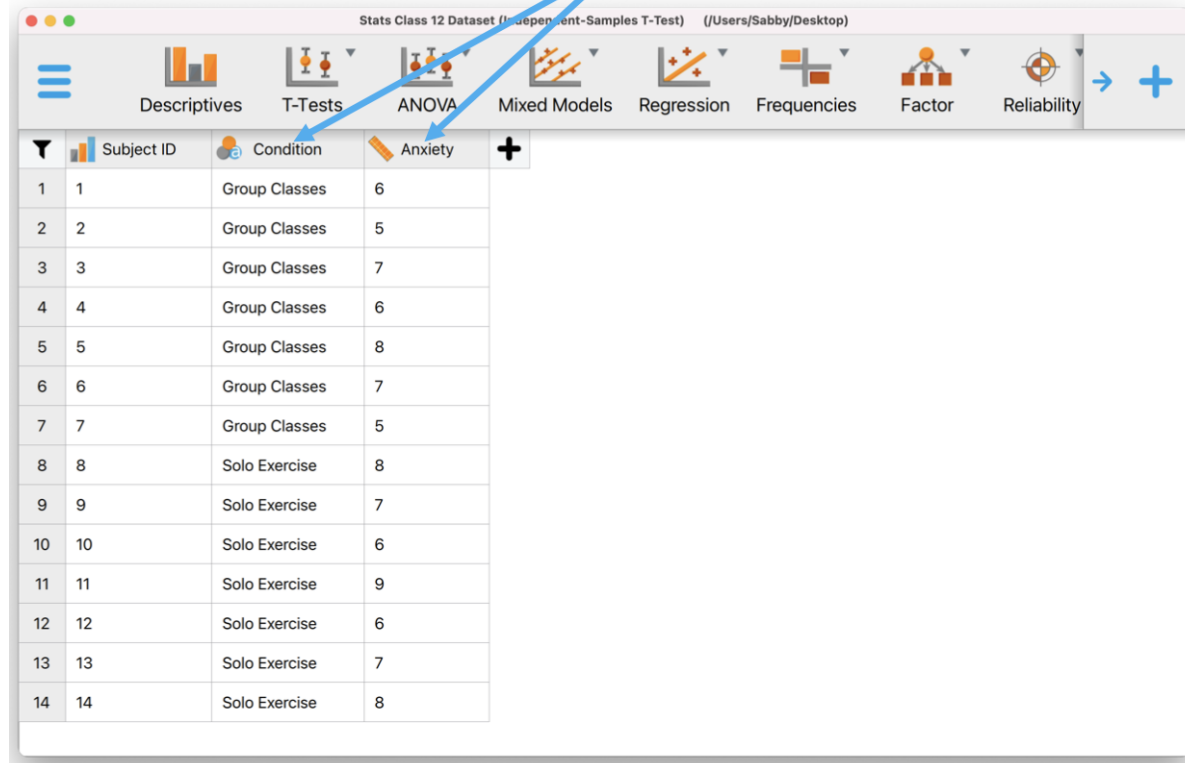
$$\mu_{classes} \neq \mu_{solo}$$

$$\mu_1 \neq \mu_2$$

There is a difference in anxiety levels when taking a group class compared to exercising alone

JASP

Notice that participants are now organized in rows, giving us one variable for Anxiety and one for Condition.



Stats Class 12 Dataset (Independent-Samples T-Test) (/Users/Sabby/Desktop)

	Subject ID	Condition	Anxiety	
1	1	Group Classes	6	
2	2	Group Classes	5	
3	3	Group Classes	7	
4	4	Group Classes	6	
5	5	Group Classes	8	
6	6	Group Classes	7	
7	7	Group Classes	5	
8	8	Solo Exercise	8	
9	9	Solo Exercise	7	
10	10	Solo Exercise	6	
11	11	Solo Exercise	9	
12	12	Solo Exercise	6	
13	13	Solo Exercise	7	
14	14	Solo Exercise	8	

Begin by clicking on “T-Tests” and selecting the “Independent Samples T-Test”

The screenshot shows the JASP software interface. The top menu bar includes 'Descriptives', 'T-Tests', 'ANOVA', 'Mixed Models', 'Regression', 'Frequencies', 'Factor', and 'Reliability'. The 'T-Tests' menu is open, showing a 'Classical' section with 'Independent Samples T-Test', 'Paired Samples T-Test', and 'One Sample T-Test'. A blue arrow points from the text box above to the 'Independent Samples T-Test' option. Below the menu, a table of data is visible, with columns for 'Subject ID', 'Group', and 'Score'.

Subject ID	Group	Score
1	1	8
2	2	7
3	3	6
4	4	9
5	5	6
6	6	7
7	7	8
8	8	8
9	9	7
10	10	6
11	11	9
12	12	6
13	13	7
14	14	8

JASP

Put Anxiety (our y variable) in the “Variables” box and Condition (our x variable) in the “Grouping Variable” box

The screenshot displays the JASP software interface for an Independent Samples T-Test. The main window is titled "Stats Class 12 Dataset (Independent-Samples T-Test)* (/Users/Sabby/Desktop)". The top toolbar includes icons for Descriptives, T-Tests, ANOVA, Mixed Models, Regression, Frequencies, Factor, and Reliability. The "Independent Samples T-Test" panel is active, showing a list of variables on the left with "Subject ID" selected. The "Variables" box contains "Anxiety", and the "Grouping Variable" box contains "Condition". The "Tests" section has "Student" checked. The "Additional Statistics" section has "Cohen's d" selected. The "Results" panel on the right shows the t-test results for Anxiety, with a t-value of -1.68.

Independent Samples T-Test	
	t
Anxiety	-1.68

Note. Student's t-test.

JASP

Finally, select “Effect Size” (set by default to Cohen’s d) to get the effect size for the independent-samples t-test

The screenshot displays the JASP software interface for an Independent Samples T-Test. The main window is titled "Stats Class 12 Dataset (Independent-Samples T-Test)*" and shows the following configuration:

- Variables:** Anxiety
- Grouping Variable:** Condition
- Tests:** Student (checked), Welch, Mann-Whitney
- Additional Statistics:** Effect Size (checked), Cohen's d (selected), Glass' delta, Hedges' g, Confidence interval (95.0 %)
- Alt. Hypothesis:** Group 1 ≠ Group 2

The **Results** panel on the right shows the output for the Independent Samples T-Test:

Independent Samples T-Test		
	t	df
Anxiety	-1.68	

Note. Student's t-test.

JASP now gives you the independent-samples t-test statistic, the p -value for this test, and the effect size. That's it! 😊

The screenshot displays the JASP software interface for an Independent Samples T-Test. The main window is titled "Stats W6C2 Anxiety Dataset*". The top toolbar includes icons for Descriptives, T-Tests, ANOVA, Regression, Frequencies, and Factor. The "Independent Samples T-Test" panel is active, showing the following settings:

- Variables:** Anxiety
- Grouping Variable:** Condition
- Tests:** Student (checked), Welch, Mann-Whitney
- Alt. Hypothesis:** Group 1 = Group 2 (selected), Group 1 > Group 2, Group 1 < Group 2
- Additional Statistics:** Location parameter, Confidence interval (95%), Effect Size (checked), Cohen's d (selected), Class' delta, Hedges' g, Descriptives, Descriptives plots, Confidence interval (95%), Vovk-Sellke maximum p-ratio
- Assumption Checks:** Normality, Equality of variances
- Missing Values:** Exclude cases analysis by analysis (selected), Exclude cases listwise

The "Results" panel on the right displays the "Independent Samples T-Test" results in a table:

	t	df	p	Cohen's d
Anxiety	-1.681	12.000	0.119	-0.899

Below the table, a note states: "Note: Student's t-test." A blue arrow points from the text box above to the "Independent Samples T-Test" section of the results panel.

Next time

Lecture

- Differences between two groups II

Reading

- Ch.11

Quiz 3

- Due tonight 2/9/22 11:59pm MT
(Ch.9, 10)

