CH. 11 Analysis of Variance using JAMOVI

PY 221 Statistics & Research Methods I

Dr. Valenti

Outline for Ch. 11 - ANOVA

- Analysis of Variance (ANOVA)
  - **Example, and null & alternative hypotheses**
  - How to run this using JAMOVI
  - How to interpret JAMOVI output
    - If our groups *are* significantly different, consider running follow-up tests
      - How to run and interpret "post-hoc tests"
  - How to write up results using APA style

ANOVA: Example study

Research Question 1:

Does note-taking behavior influence understanding of course material?

- 15 Ps
- Independent variable (manipulated) **– note-taking behavior during class**
  - 5 took notes by hand / 5 did not take notes / 5 took notes with a laptop
- Dependent variable – **after-class understanding of material**
    - measured understanding using a 7-item quiz after class

ANOVA: What hypotheses are we testing?

null hypothesis (multiple ways to write it)

- the **difference between the group means** for quiz score **equals zero**, *or*
- the **mean quiz scores do *not* differ** across the three groups, *or*
- note-taking behavior **has *no* effect** on understanding of material.

alternative hypothesis

- the **difference between the group means** for quiz score **doesn't equal zero**, *or*
- the **mean quiz scores *do* differ** across the three groups, or
- note-taking behavior **has an effect** on understanding of material.

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ANOVA: How to run in JAMOVI

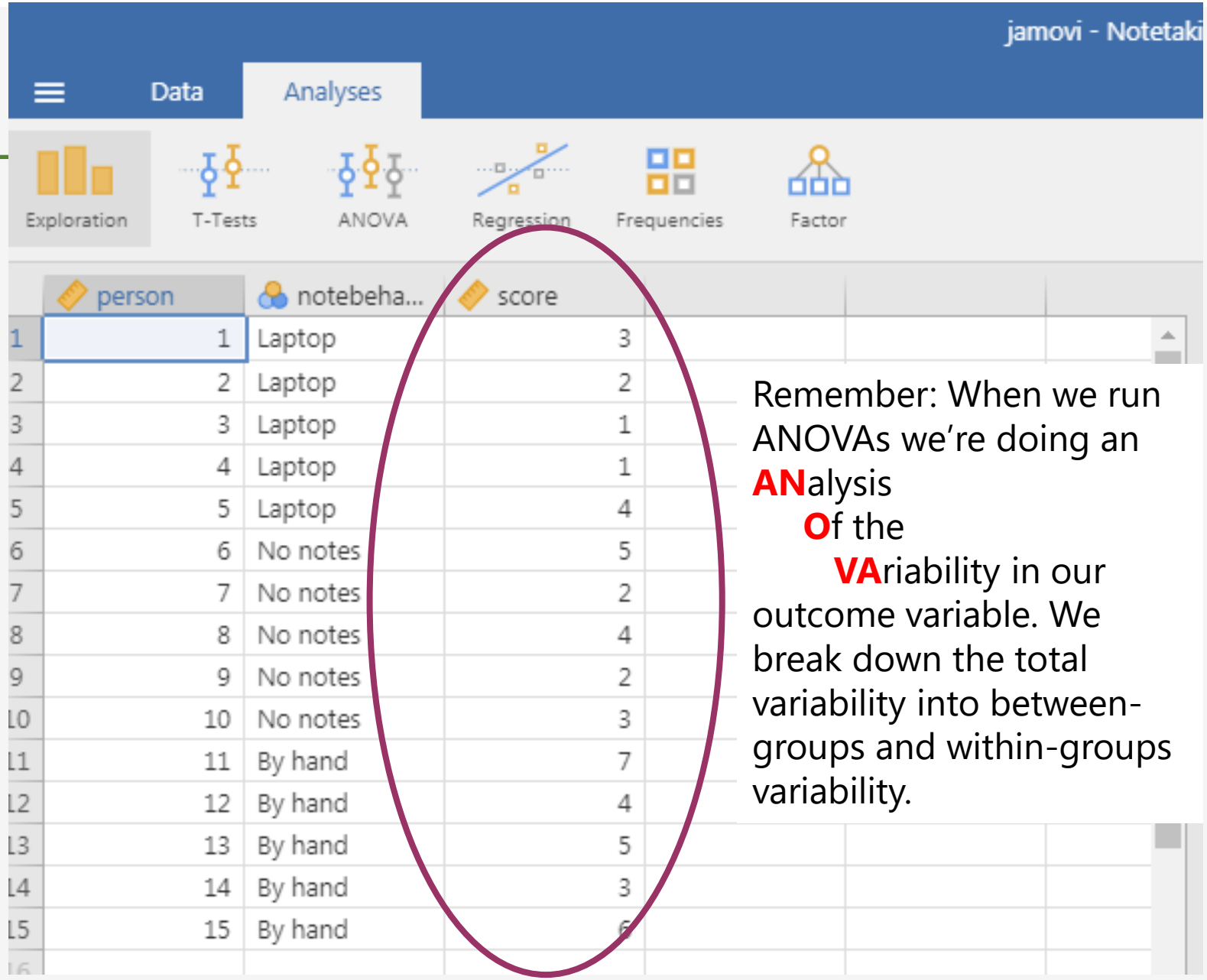
Layout of your data file

only one IV/predictor

For a one-way ANOVA, each participant will have data for two variables:

- 1 variable for **IV - note-taking behavior** (*notebehavior)*
  - Each participant is categorized according to which condition/group they were in: *took notes w/laptop*, *no notes*, or *took notes by hand*
- 1 variable for **DV - understanding of material** (*score*)
  - Captures the score on the quiz, from 0 to 7, for each participant

ANOVA: data file set up

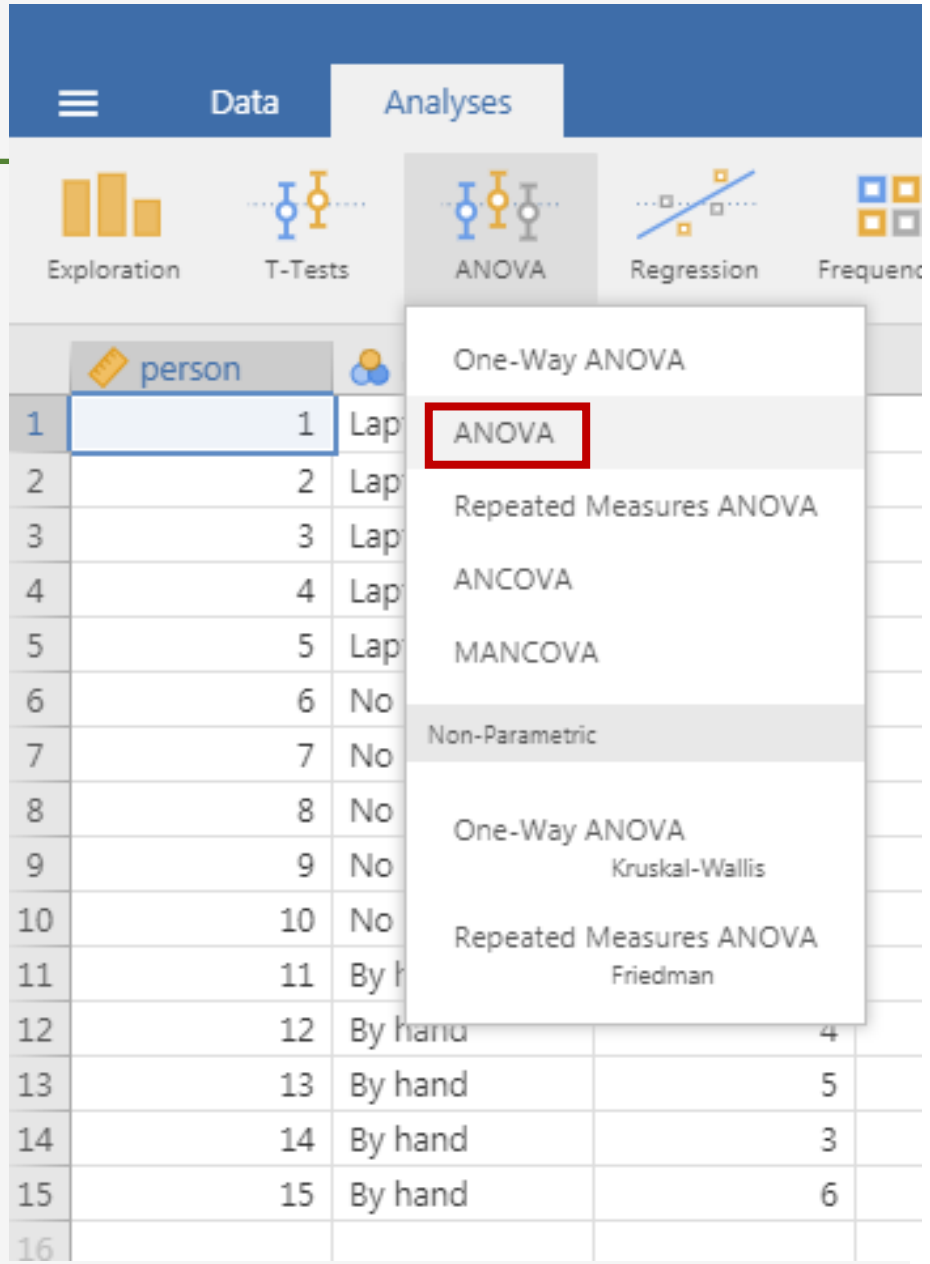


	person	notebeha...	score
1	1	Laptop	3
2	2	Laptop	2
3	3	Laptop	1
4	4	Laptop	1
5	5	Laptop	4
6	6	No notes	5
7	7	No notes	2
8	8	No notes	4
9	9	No notes	2
10	10	No notes	3
11	11	By hand	7
12	12	By hand	4
13	13	By hand	5
14	14	By hand	3
15	15	By hand	6

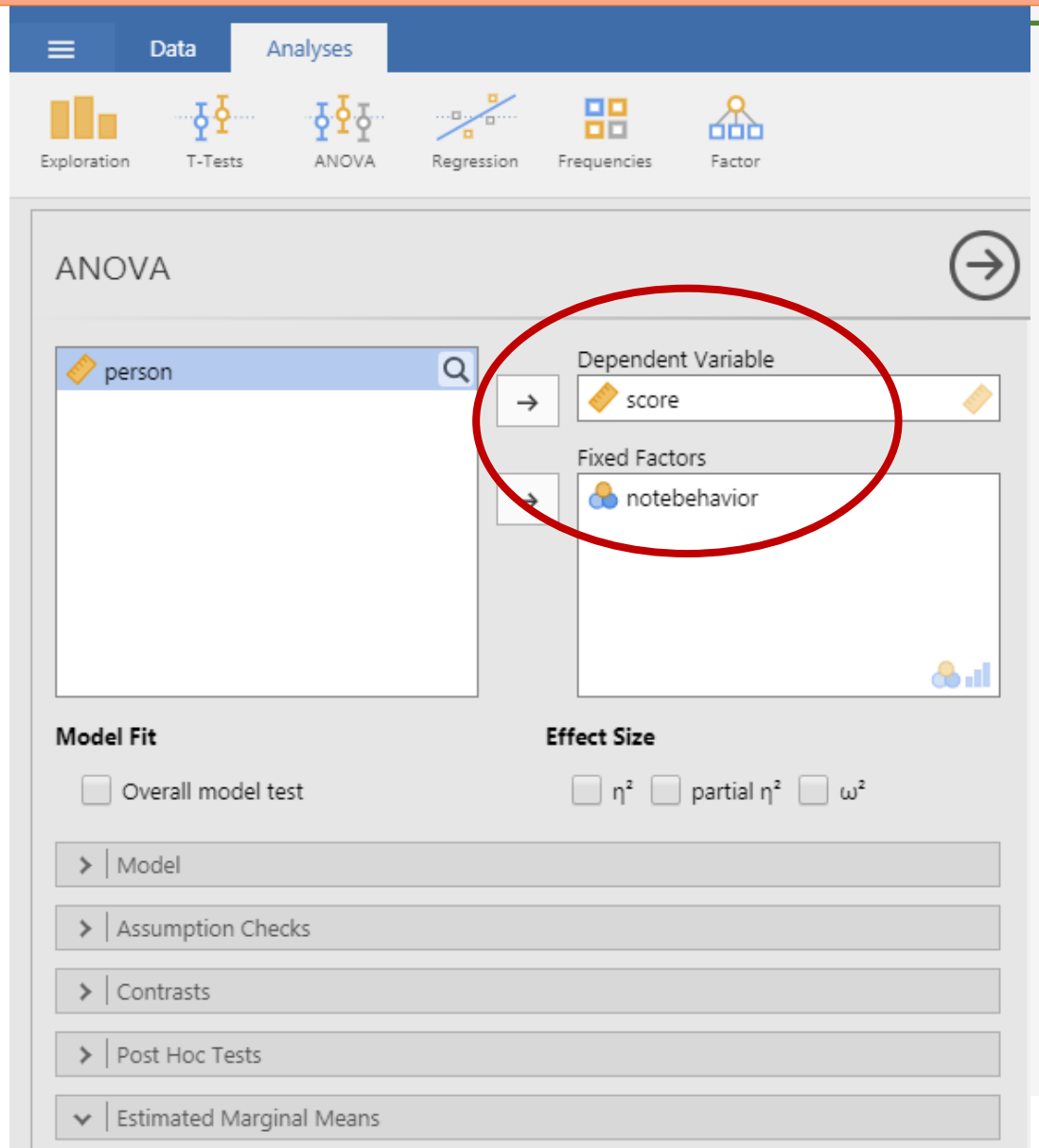
Remember: When we run ANOVAs we're doing an **AN**alysis **O**f the **VA**riability in our outcome variable. We break down the total variability into between-groups and within-groups variability.

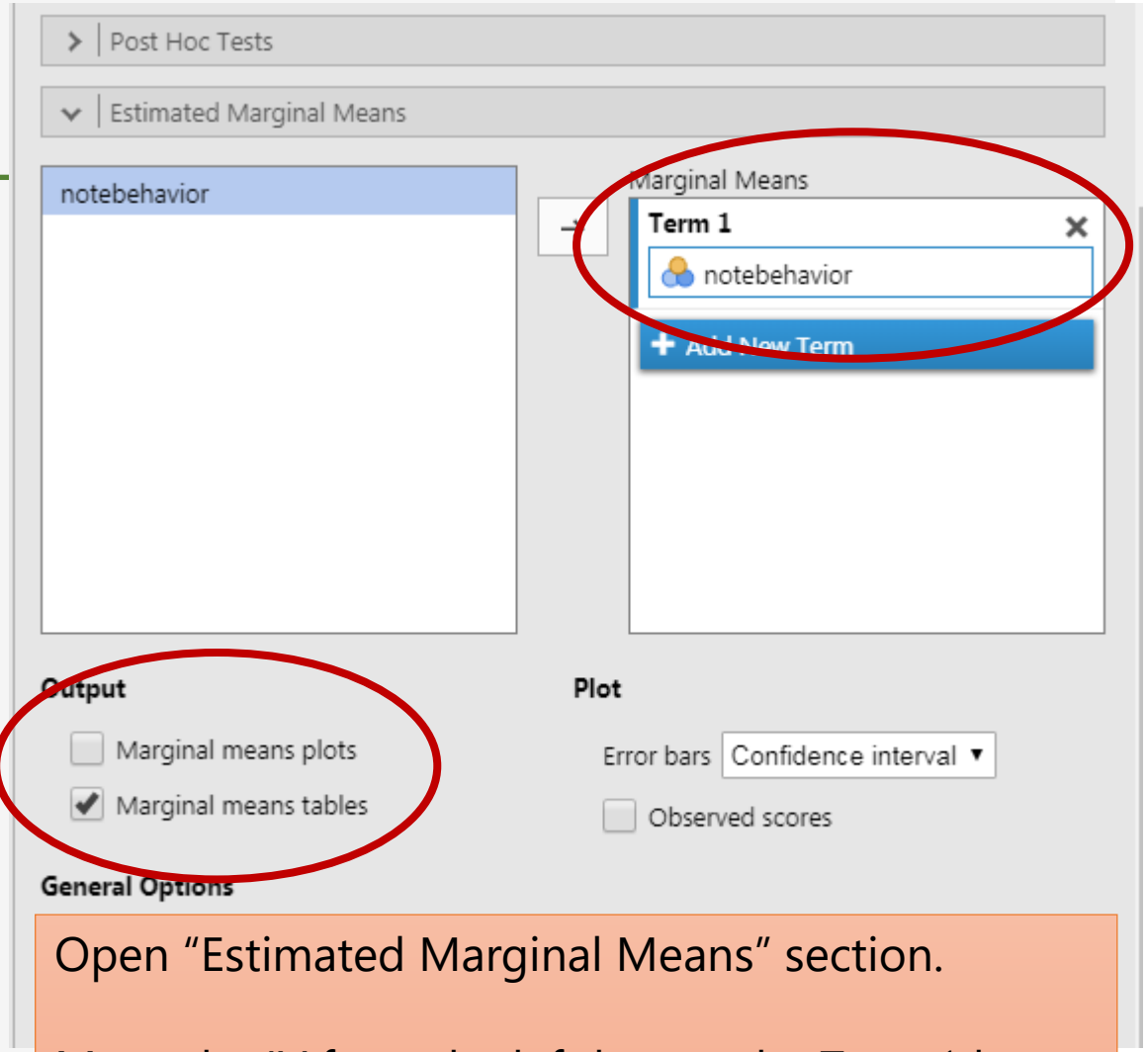
ANOVA: How to run in JAMOVI

Analyses → ANOVA → ANOVA



Put outcome variable/DV into “Dependent Variable” box.
Put predictor variable/IV into “Fixed Factors” box.





Open “Estimated Marginal Means” section.

Move the IV from the left box to the Term 1 box.

Un-check (un-select) the “Marginal means plots”.
Check/select the “Marginal means *tables*”

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ANOVA: What hypotheses are we testing? (*review*)

<u>null hypothesis</u>

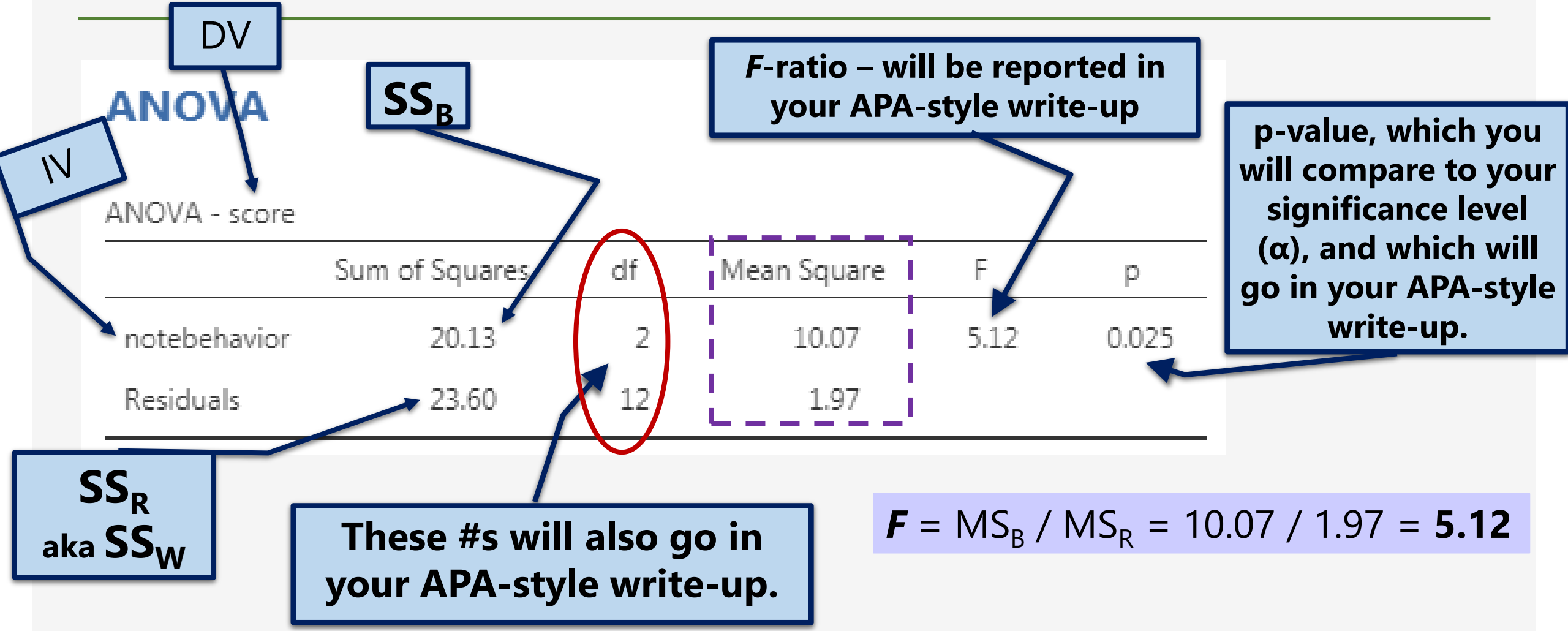
- the mean quiz scores do *not* differ across the three groups

<u>alternative hypothesis</u>

- the mean quiz scores *do* differ across the three groups

- Our *F*-ratio & associated *p*-value tell us whether or not null is credible.
  - small *F*, ***p* >= .05** → Retain the null (assuming α = .05). No sig. difference.
  - large *F*, ***p* < .05** → Reject the null (assuming α = .05). A statistically significant difference.

ANOVA: How to interpret output from ANOVA table



$F = MS_B / MS_R = 10.07 / 1.97 = \mathbf{5.12}$

Step 4 – Make the decision

- null hypothesis: the difference between our group means for quiz score = 0. Note-taking behavior has no effect on after-class understanding of material.

- alternative hypothesis: the **difference** between our group means for quiz score **doesn't equal zero**. Note-taking behavior **has an effect** on understanding of material.

- **In this example, *p* = .025, which is < .05, meaning we will *reject* the null hypothesis, and include that note-taking behavior does have a significant effect on understanding of the material.**

ANOVA: How to interpret output from "Estimated Marginal Means" table

Estimated Marginal Means

notebehavior

Estimated Marginal Means - notebehavior

notebehavior	Mean	SE	95% Confidence Interval	
			Lower	Upper
Laptop	2.20	0.63	0.83	
No notes	3.20	0.63	1.83	
By hand	5.00	0.63	3.63	

These *SE*s may be reported in your APA-style Results section.

groups/ conditions /levels of your IV (predictor)

Mean quiz score of students in each of the 3 conditions of the IV (*aka*, the group means)

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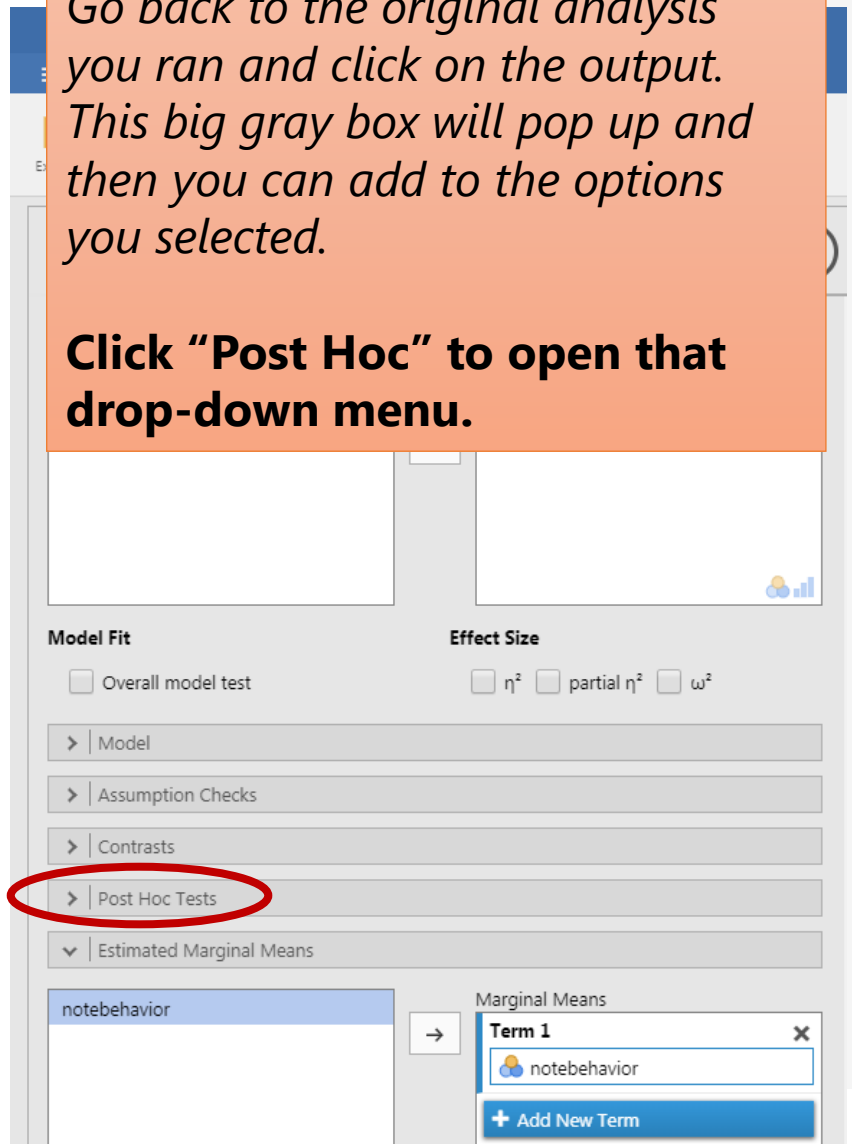
Reminder: Purpose of post-hoc tests is to examine **all pairs** of conditions/groups to see if their means differ significantly. No a priori hypotheses.

Laptop vs. no notes
Laptop vs. by hand
No notes vs. by hand

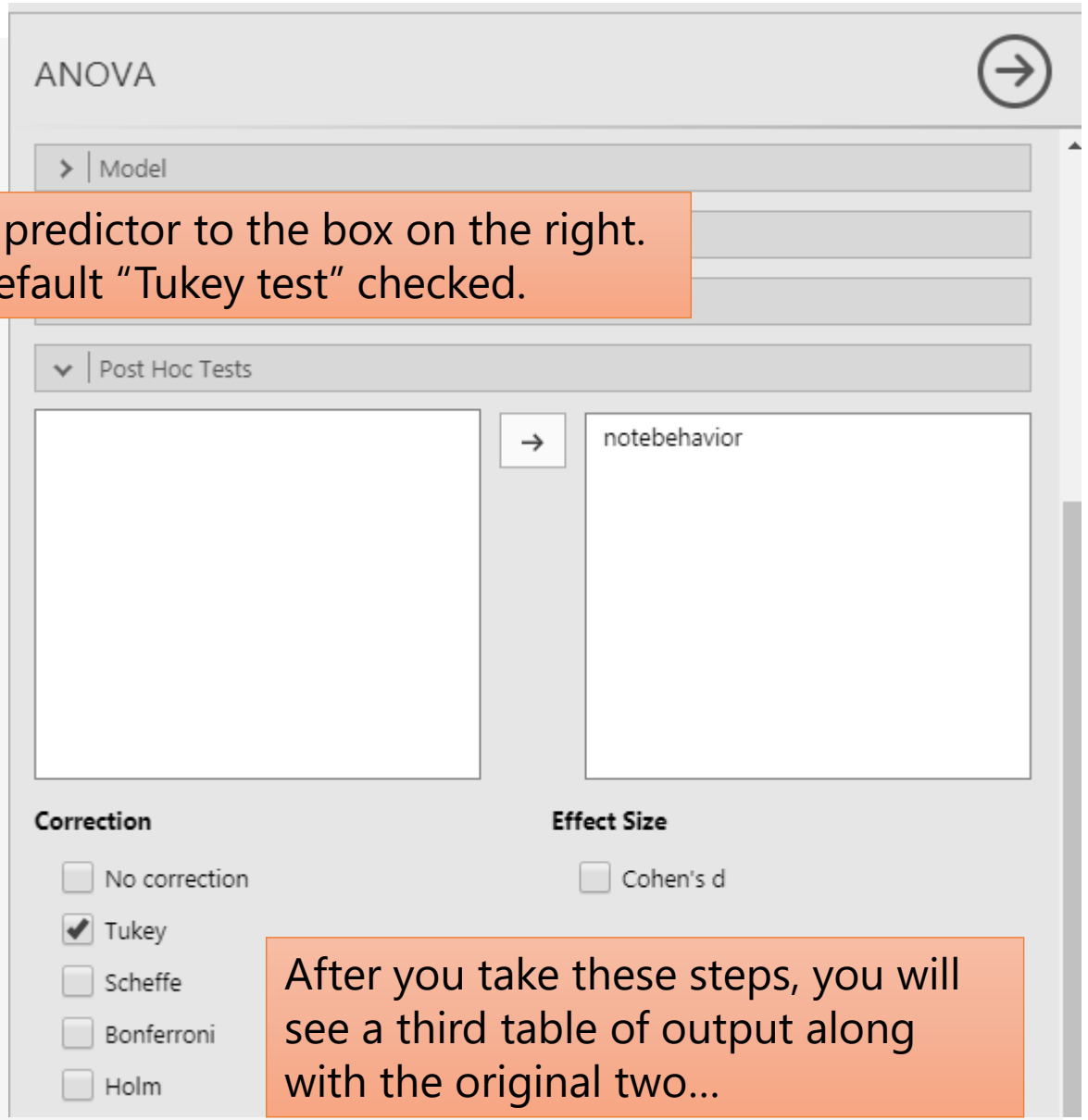
ANOVA – POST-HOC TESTS: How to run in JAMOVI

Go back to the original analysis you ran and click on the output. This big gray box will pop up and then you can add to the options you selected.

Click "Post Hoc" to open that drop-down menu.



Move your predictor to the box on the right. Keep the default "Tukey test" checked.



After you take these steps, you will see a third table of output along with the original two…

ANOVA POST-HOC tests: How to interpret output

For this study, three comparisons are being made.

This column tells you the *size of the difference* between the two group means in that row.
(remember: Null: difference = 0 / Alt: difference ≠ 0)

Post Hoc Comparisons - notebehavior

Comparison						
notebehavior	notebehavior	Mean Difference	SE	df	t	p_{tukey}
Laptop	No notes	−1.00	0.89	12.00	−1.13	0.516
Laptop	By hand	−2.80	0.89	12.00	−3.16	0.021
No notes	By hand	−1.80	0.89	12.00	−2.03	0.147

1
2
3

Each of these 3 rows has a different pair of 2 conditions/groups being compared.

Each *p* tells you if there is a significant difference in quiz score between the 2 compared groups in that row.
Compare *p* to your α.

ANOVA POST-HOC tests: How to interpret output

Interpretation *(not in APA style yet)*: We learn that there is a significant difference in quiz scores between students who take notes with a **laptop** and students who take notes **by hand**. No other pairs of conditions have quiz scores that are significantly different from one another.

Another way to say it: Taking notes by hand causes significantly better understanding of the material (2.80 quiz points better) than taking notes with a laptop.

Post Hoc Tests

Which 2 groups have quiz scores that are significantly different from each other? *(Assume an α of .05, and assume null hypothesis means "no difference".)*

Post Hoc Comparisons - notebehavior

Comparison							
notebehavior		notebehavior	Mean Difference	SE	df	t	p_{tukey}
Laptop	-	No notes	−1.00	0.89	12.00	−1.13	0.516
	-	By hand	−2.80	0.89	12.00	−3.16	0.021
No notes	-	By hand	−1.80	0.89	12.00	−2.03	0.147

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Reporting ANOVA results in APA Style – the gist

1. State the statistical test you ran, including info about the predictor and outcome variables
2. Describe whether the analysis suggests that there are vs. aren't differences in the group means, by reporting the results of the omnibus *F*-test (i.e., report *F* statistic, dfs, and *p*-value).
3. If the omnibus *F*-test is significant, report the results of each post-hoc comparison (i.e., report whether each pair is significantly different or not).
   - Include means & standard errors for all groups/conditions, at some point.
   - Don't forget to provide evidence for your statements (e.g., p-values for each comparison).

Writing up results of ANOVA and post-hoc tests, using APA style (part 1 of 3)

Results

We used ANOVA to predict quiz scores from note-taking behavior. There was a significant effect of note-taking behavior on quiz score, $F(2, 12) = 5.12$, $p = .025$. …

Remember that we always say that we "**predict** [DV/outcome] **from** [IV/predictor]"

And we always refer to the "**effect of** [IV/predictor] **on** [DV/outcome]"

ANOVA - score

	Sum of Squares	df	Mean Square	F	p
notebehavior	20.13	2	10.07	5.12	0.025
Residuals	23.60	12	1.97		

Writing up results using APA style (part 2 of 3)

Tukey's HSD post-hoc tests revealed that taking notes by hand causes significantly higher quiz scores (M = 5.00, SE = 0.63) than taking notes on a laptop (M = 2.20, SE = 0.63), p = .021.

Quiz scores for the "no notes" group (M = 3.20, SE = 0.63) fell between the scores for the other two groups, but did not differ significantly from either of them (both *ps* > .14). (See *Figure 1*.)

Take the lowest p-value that *isn't* statistically significant, and put it here.

Estimated Marginal Means

notebehavior

Estimated Marginal Means - notebehavior

notebehavior	Mean	SE	95% Confidence Interval Lower	95% Confidence Interval Upper
Laptop	2.20	0.63	0.83	3.57
No notes	3.20	0.63	1.83	4.57
By hand	5.00	0.63	3.63	6.37

Post Hoc Comparisons - notebehavior

Comparison			Mean Difference	SE	df	t	p_{tukey}
notebehavior		notebehavior					
Laptop	-	No notes	−1.00	0.89	12.00	−1.13	0.516
	-	By hand	−2.80	0.89	12.00	−3.16	0.021
No notes	-	By hand	−1.80	0.89	12.00	−2.03	0.147

Writing up results using APA style (part 3 of 3)

Estimated Marginal Means

notebehavior

Estimated Marginal Means - notebehavior

notebehavior	Mean	SE	95% Confidence Interval	
			Lower	Upper
Laptop	2.20	0.63	0.83	3.57
No notes	3.20	0.63	1.83	4.57
By hand	5.00	0.63	3.63	6.37

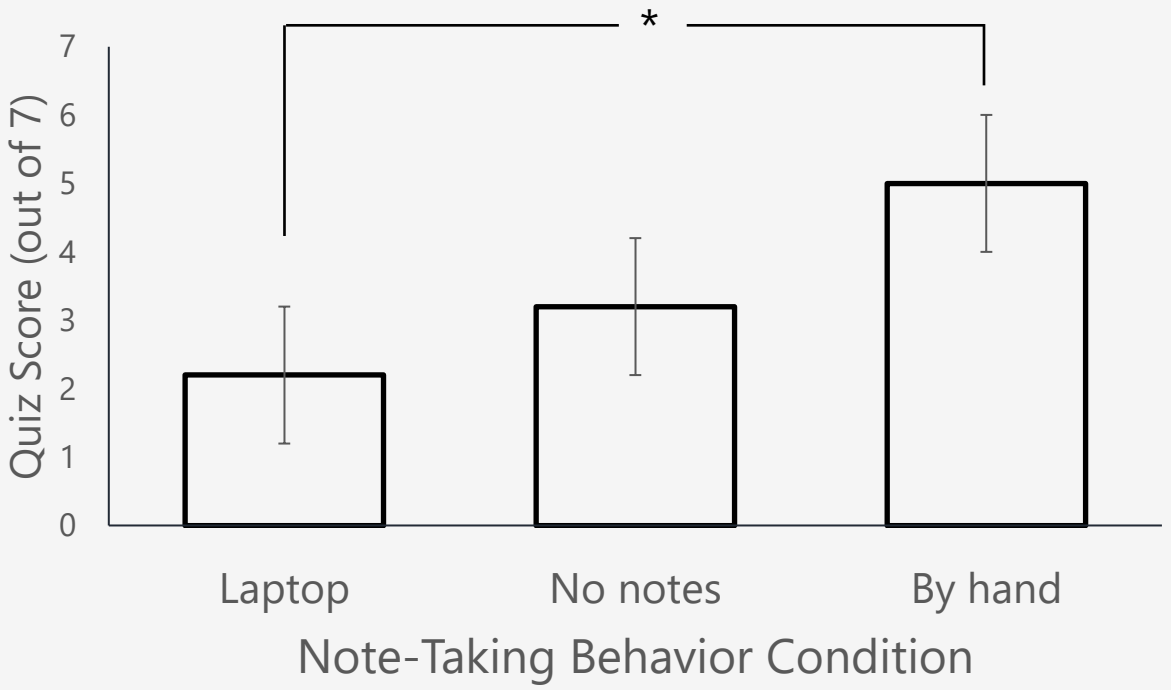

Figure 1. Quiz scores (out of 7) among students with different note-taking behaviors. Note: Error bars indicate standard errors. *indicates significance at the $p < .05$ level.

Research Question #2: Does a student's political ideology relate to the number of nights per week that they drink alcohol?

- Which of these best describes your political ideology? (*ideology*)
  - liberal, moderate, conservative
- On average, how many nights per week do you drink alcoholic beverages? (*niteyoudrink_1*)

Key provided in class.

Also posted on Moodle in Misc Res section

Political ideology and weekly drinking frequency – ANOVA output

- Predictor: ideology
  - 3 levels: liberal, moderate, conservative
- Outcome: # nights per week person drinks
  - quantitative variable

ANOVA

ANOVA - niteyoudrink_1

	Sum of Squares	df	Mean Square	F	p
ideology	12.58	2	6.29	2.85	0.089
Residuals	33.04	15	2.20		

[3]

Estimated Marginal Means

ideology

Estimated Marginal Means - ideology

			95% Confidence Interval	
ideology	Mean	SE	Lower	Upper
liberal	2.14	0.56	0.95	3.34
moderate	0.71	0.56	−0.48	1.91
conservative	2.75	0.74	1.17	4.33

APA Style Results Section – political ideology & weekly drinking

Results

We used ANOVA to predict weekly drinking frequency from political ideology. There was not a significant relationship between political ideology and weekly drinking frequency, $F(2,15) = 2.85$, $p = .089$.

Results

(another way to write it)

We used ANOVA to predict weekly drinking frequency from political ideology. There were no significant differences in how many nights per week people drink when comparing liberals, moderates, and conservatives, $F(2,15) = 2.85$, $p = .089$.

Results

(yet another way to write the same thing)

We used ANOVA to predict weekly drinking frequency from political ideology. Liberals, moderates, and conservatives drink the same number of nights per week, on average, $F(2,15) = 2.85$, $p = .089$.

Research Question: Does a student's political ideology relate to the number of Harry Potter movies they have seen?

- Which of these best describes your political ideology? (*ideology*)
  - liberal, moderate, conservative
- How many of the 8 Harry Potter movies have you seen? (*pottermovie_1*)
  - Indicated a number from 0 to 8

Ideology & HP Movies - output

Reminder

null hypothesis (no diffs)

- the **mean # of HP movies seen** across the three groups **does *not* differ**
- $\mu_{liberals} = \mu_{moderates} = \mu_{conservatives}$

If we assume an alpha of .05, then the mean # of HP movies seen differs significantly when comparing:

- liberals and conservatives
- moderates and conservatives

ANOVA

reject null

ANOVA - pottermovie_1

	Sum of Squares	df	Mean Square	F	p
ideology	71.01	2	35.51	10.37	0.002
Residuals	47.93	14	3.42		

[3]

Post Hoc Tests

Post Hoc Comparisons - ideology

Comparison			Mean Difference	SE	df	t	p_{tukey}
ideology		ideology					
liberal	-	moderate	−1.21	1.03	14.00	−1.18	0.484
	-	conservative	4.00	1.19	14.00	3.35	0.012
moderate	-	conservative	5.21	1.16	14.00	4.50	0.001

Estimated Marginal Means

ideology

Estimated Marginal Means - ideology

			95% Confidence Interval	
ideology	Mean	SE	Lower	Upper
liberal	6.50	0.76	4.88	8.12
moderate	7.71	0.70	6.21	9.21
conservative	2.50	0.93	0.52	4.48

APA Style Results Section – political ideology & HP movies

Results

We used ANOVA to predict **the number of Harry Potter movies seen** from **political ideology**. There was a **significant** relationship between **political ideology** and number of Harry Potter movies seen, ***F*(2,14) = 10.37, *p* = .002**. Tukey HSD post-hoc tests revealed that conservatives (*M* = 2.50, *SE* = 0.93) have seen significantly fewer Harry Potter movies than liberals have **(*M* = 6.50, *SE* = 0.76), *p* = .012**. Conservatives have also seen **significantly fewer** Harry Potter movies than moderates have (*M* = **7.71, *SE* = 0.70**), ***p* = .001**. There were no significant differences in the number of Harry Potter movies seen by **liberals** and moderates, ***p* = .48.**

APA Style Results Section – political ideology & HP movies

State the statistical test you ran.

Describe results of omnibus *F*-test

If significant, report results of post-hoc tests, with means.

Results

We used ANOVA to predict **the number of Harry Potter movies seen** from **political ideology**. There was a **significant** relationship between **political ideology** number of Harry Potter movies seen, ***F*(2,14) = 10.37, *p* = .002**. Tukey HSD post-hoc tests revealed that conservatives (*M* = 2.50, *SE* = 0.93) have seen significantly fewer Harry Potter movies than liberals have **(*M* = 6.50, *SE* = 0.76), *p* = .012**. Conservatives have also seen **significantly fewer** Harry Potter movies than moderates have (*M* = **7.71, *SE* = 0.70**), ***p* = .001**. There were no significant differences in the number of Harry Potter movies seen by **liberals** and moderates, ***p* = .48.**