

ANOVA III

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ESSENTIAL READING

- ▶ Coolican, H. (2014). *Research methods and statistics in psychology*. London: Taylor & Francis. **Chapters 20, 21, & 22.**

Lecture Outline

- ▶ Planned (*a Priori*) Comparisons
 - ▶ Unplanned (*Post-hoc*) tests
 - ▶ Interactions
 - ▶ Nonparametric equivalents to one-way ANOVA
 - ▶ Wrap-up & Summary of ANOVA
 - ▶ Quiz
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Planned and Unplanned Comparisons

- ▶ So if the F-ratio in an ANOVA is significant then it tells us that the DV varies with the levels of the factor.
 - ▶ If the Factor only has 2 levels – Great!
 - The mean for one level must be significantly different from the mean of the other level.
 - We can look back at the means (displayed in the descriptive statistics box in the SPSS output), to show us which mean is higher.
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Planned and Unplanned Comparisons

- ▶ HOWEVER: if there are more than 2 levels, the ANOVA doesn't tell us which means are different from which other means.
 - ▶ So the DV varies with the levels of the factor but we need to do some further analyses to examine the data in more detail.
 - ▶ We need to compare the means or groups of means in a way that will allow us to appropriately interpret the results.
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What can we do...?

- ▶ **Planned (*a Priori*) Comparisons:** These are decided upon before the data is collected. The researcher predicts/suggests which means will differ significantly from each other.
 - ▶ **Unplanned (*a Posteriori/Post-hoc*) Comparisons:** Here the differences among means are explored after the data has been collected.
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Why does this matter?

- ▶ Depending on the type of comparison we do, we need to use a different type of test.
 - ▶ Why?: Because the probability of making a Type 1 error is smaller when the comparisons are planned in advance.
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Type 1 Error

- ▶ Remember Type 1 error is **incorrectly** rejecting a null hypothesis.
 - ▶ So concluding that there is a significant effect when actually the means differ due to chance.
 - ▶ When we make multiple comparisons we run the chance of making Type 1 errors.
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For example...

- ▶ We give a group of males and a group of females 50 words and ask them to give us as many associations to the words in 1 minute.
 - ▶ For each word we test whether there's a significant difference in the number of associations given by the males & females
 - ▶ We could run 50 independent samples t-tests
 - ▶ **BUT**: there's a risk that 2.5 of these tests ($50 \times .05$) will be detected as significant by chance.
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Type 1 error with unplanned comparisons

- ▶ So why is there a greater risk of making a Type 1 error with unplanned comparisons?
 - ▶ E.g., An experiment uses a one-way ANOVA to examine the effect of 5 different noise levels on memory.
 - ▶ This type of experiment would produce 5 different means: one for each condition.
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Type 1 error with unplanned comparisons

- ▶ So you could do 10 comparisons: to compare all the means.
 - ▶ Say the null hypothesis is true – noise does **not** affect memory.
 - ▶ But by chance 2 of the means are far enough apart they lead us to incorrectly reject the null hypothesis.
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Type 1 error with unplanned comparisons

- ▶ The data would now contain a Type 1 error.
- ▶ BUT: If you had planned your single comparisons in advance you would have a probability of 0.1 hitting on the one comparison out of 10 that involves the Type 1 error.

Planned Comparisons

- ▶ So by planning comparisons before hand (based on justified theoretical assumptions) you could test differences between specific groups or conditions, rather than just comparing all and running the risk of making a Type 1 error.

Planned comparisons

- ▶ So Planned Comparisons (*a Priori*) are comparisons with a specific prediction that we make **before** conducting the ANOVA, based on theoretical grounds.
 - ▶ Making selected and predetermined comparisons incurs a far lower probability of making a Type 1 error than if we make all possible comparisons.
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Planned Comparisons

- ▶ A method of dealing with the increased error rate created by multiple comparisons is to just lower the alpha (α) by dividing it with the number of comparisons being made.
 - ▶ E.g., if you were to do 2 t-tests then you would divide $0.05/2 = .025$.
 - ▶ So you would only accept a difference as significant if p falls under .025.
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Planned Comparisons

- ▶ If you intend to make a few comparisons, then instead of lower the Alpha, you could conduct Bonferroni t-tests.
 - Use a formula by Howell (1992) using the MS error term from the ANOVA.
 - Use tables by Dunn (1961), which raise the critical value of t depending on the number of comparisons performed.

*See the Coolican book for details on this method

Planned Comparisons

▶ Linear contrasts.

- Tests for significance between *combinations* of means.
- Allows us to compare one level (or sets of levels) with another level (or sets of levels).
- Weights are assigned to each level
 - Known as coefficients
- This technique is available on SPSS, which uses the t-statistic to test specific contrasts.

Linear Contrasts

- ▶ By assigning weights we can make 3 sorts of comparison:
 1. Compare one condition with another
 2. Compare one condition with the mean of two or more of the other condition
 3. Compare the mean of one set of conditions with the mean of another set of conditions.
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Linear Contrasts

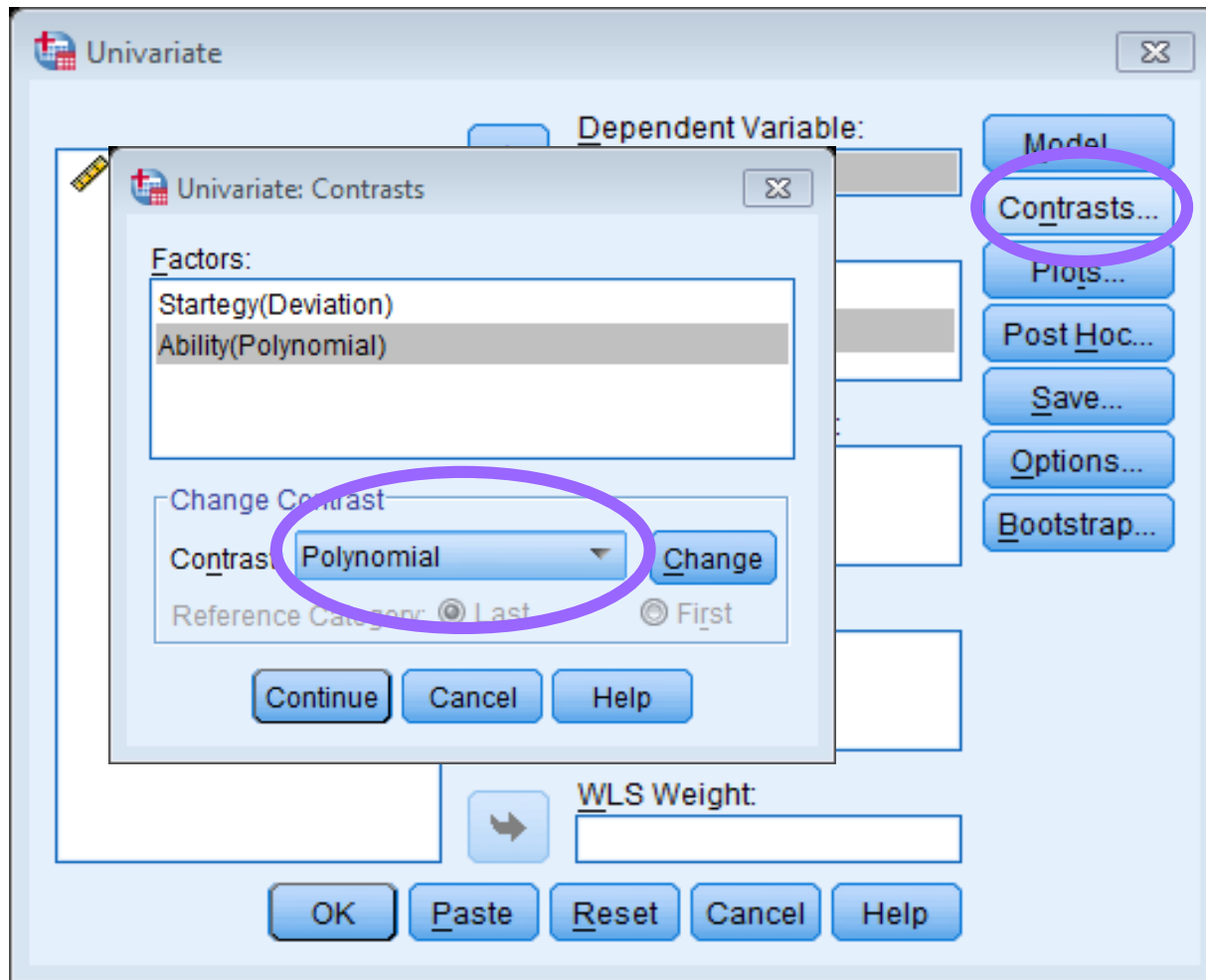
- ▶ In all 3 cases you can assign a weight of zero to a condition that you do not want to be included.
 - ▶ Conditions that are to be compared with each other are assigned opposite signs (positive or negative).
 - ▶ In all cases the sum of the weights must be zero.
 - ▶ E.g., if you had 4 conditions but you only wanted to compare conditions 1 and 3, you would assign the weights: 1, 0, -1, 0.
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Linear Contrasts

- ▶ If you wanted to compare the average of the first 2 conditions with the third condition, you would assign: 1, 1, -2, 0.
- ▶ If you wanted to compare the mean of the first 2 groups with the mean of the last 2 groups, you would assign: 1, 1, -1, -1.
- ▶ Using the General Linear Model command in SPSS, you can choose between a range of pre-set contrasts
 - or you can input your own as described above using the one-way ANOVA command.

Linear Contrasts

To select pre-set contrasts using the General Linear Model Command. Click contrasts, then click the arrow for a drop-down menu of contrasts.



Planned Comparisons

- ▶ Use your SPSS books to see how you write up the results of your planned comparisons.
 - ▶ Remember contrasts can only tell you whether the conditions you compared are significantly different or not, you will need to look at the descriptives to work out the direction of the difference.
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Post-hoc Comparisons

- ▶ Looked at these last week.
 - ▶ SPSS will only perform post-hoc tests with a factor that has **more** than 2 levels.
 - ▶ It will only compare between-subjects factors.
 - ▶ Should only be used if the main effect is significant.
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SPSS Output: Post-hoc comparisons

Multiple Comparisons

Dependent Variable: Errors

	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Caffeine	Placebo	-3.40 [*]	.757	.002	-5.42	-1.38
		No Caffeine	-5.20 [*]	.757	.000	-7.22	-3.18
	Placebo	Caffeine	3.40 [*]	.757	.002	1.38	5.42
		No Caffeine	-1.80	.757	.083	-3.82	.22
	No Caffeine	Caffeine	5.20 [*]	.757	.000	3.18	7.22
Scheffe	Caffeine	Placebo	-3.40 [*]	.757	.003	-5.51	-1.29
		No Caffeine	-5.20 [*]	.757	.000	-7.31	-3.09
	Placebo	Caffeine	3.40 [*]	.757	.003	1.29	5.51
		No Caffeine	-1.80	.757	.099	-3.91	.31
	No Caffeine	Caffeine	5.20 [*]	.757	.000	3.09	7.31
Bonferroni	Caffeine	Placebo	-3.40 [*]	.757	.002	-5.50	-1.30
		No Caffeine	-5.20 [*]	.757	.000	-7.30	-3.10
	Placebo	Caffeine	3.40 [*]	.757	.002	1.30	5.50
		No Caffeine	-1.80	.757	.105	-3.90	.30
	No Caffeine	Caffeine	5.20 [*]	.757	.000	3.10	7.30

Based on observed means.

The error term is Mean Square(Error) = 1.433.

*. The mean difference is significant at the 0.05 level.

Reporting post-hoc analyses

- ▶ Use your SPSS stats book to see how you report post-hoc analyses.
 - ▶ The information you present should include:
 - The type of post-hoc test
 - The mean and Standard Deviation values for each group
 - The Sig value for each comparison.
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Comparing significant main effects for within-subject factors

- ▶ If you have a significant main effect of a within-subjects factor with more than 2 levels:

Pairwise Comparisons

Measure: MEASURE_1

(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
1	2	3.900 [*]	.407	.000	2.706	5.094
	3	4.000 [*]	.537	.000	2.423	5.577
2	1	-3.900 [*]	.407	.000	-5.094	-2.706
	3	.100	.379	1.000	-1.011	1.211
3	1	-4.000 [*]	.537	.000	-5.577	-2.423
	2	-.100	.379	1.000	-1.211	1.011

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Interaction effects in ANOVA

- ▶ Experiments involving more than one factor (IV) gives us the main effect of each of the factors but also the possibility of an interaction between the factors.
 - ▶ Manipulating more than 1 factor means we can see the ways in which a factor *interacts* with another.
 - ▶ E.g., In the teaching example from last week there were 2 IVs: Teaching Style & Original Ability, with an interaction effect: of strategy (higher scores for B) only emerging for the low ability group.
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Interaction effects in ANOVA

- ▶ In order to investigate an interaction effect you would need to look at **Simple Effects**.
 - ▶ A simple effect occurs when there is a significant effect of one level of a factor across the levels of the other factor.
 - ▶ It can be thought of like separating the whole design of your study in to its smaller constituent elements.
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Interaction effects in ANOVA

- ▶ Simple effects can be investigated with:
 - T-tests
 - Planned Contrasts
 - One-way ANOVA
- ▶ **BUT:** Remember the investigation of simple effects must avoid 'capitalising on chance'.
- ▶ Think back to how you deal with multiple comparisons...

Interaction effects in ANOVA

- ▶ You may need to split the sample into groups according to one of your IVs.
 - ▶ You could do this by using the 'Split File' option in SPSS – this allows you to split your sample according to one categorical variable and repeat analyses separately for each group.
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Interaction effects in ANOVA

- ▶ Say we obtained a significant interaction between age and sex on levels of optimism, we might split the SPSS file by sex and look at the effect of age on optimism separately for males only and then for females only.
 - ▶ Use your SPSS books to see how this is done
 - remember to turn off the split file option when you are finished otherwise all subsequent analysis will be split.
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Interaction effects in ANOVA

- ▶ It is relatively straight forward to interpret an interaction when each of your factors only has 2 levels.
 - ▶ **BUT:** What if you had an experiment where one (or more) of the factors has more than 2 levels? This gets quite tricky and you will need to think carefully about what further analyses to do & how to interpret the results.
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Interaction effects in ANOVA

- ▶ If you are comparing means across levels using t-tests, you **MUST ALWAYS KEEP ONE FACTOR CONSTANT**
 - ▶ Say for example you had a significant interaction between:
 - IV1: Object Attribute (3 levels: Colour, Shape, Pattern)
 - IV2: Time (3 levels: 5, 10, 15 seconds).
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Interaction effects in ANOVA

- You could compare the means for:
 - Colour 5 seconds with Colour 10 seconds;
 - Colour 5 seconds with Colour 15 seconds;
 - Colour 10 seconds with Colour 15 seconds.
- BUT NEVER: Colour 5 seconds with Shape 10 seconds for example.

Note on follow-up tests

- ▶ Remember to think about whether the comparisons you are making are within-subjects or between-subjects as this will dictate whether you run Independent samples or Repeated-measures analyses.

Three-way ANOVA

- ▶ Possible three-way ANOVA Designs
 - Three-way between ANOVA
 - All 3 IVs are between-subjects
 - Three-way within ANOVA
 - All 3 IVs are within-subjects
 - Three-way Mixed ANOVA
 - E.G., 2 IVs are between-subjects while the other IV is within-subjects

Table of three-way ANOVA

		Year 1	Year 2	Year 3	Row Mean
Male	Psychology	40	28	10	26
	Art	30	22	20	24
	Mean	35	25	15	25
Female	Psychology	36	48	60	48
	Art	40	88	80	69.3
	Mean	38	68	70	58.6
	Column mean	36.5	46.5	42.5	41.83

Three-way ANOVA Designs

- ▶ Interpretation of Exp. with 3 IVs:
 - Main effect of IV 1
 - Main effect of IV 2
 - Main effect of IV 3
 - Interaction between IV1 & IV2
 - Interaction between IV1 & IV3
 - Interaction between IV2 & IV3
 - 3 way interaction between IV1 & IV2 & IV3

Graphing three-way ANOVAs

- ▶ Best to use two graphs side by side
 - ▶ You will need to decide which factor is to be placed along the horizontal axis and which factor is to be displayed by separate lines.
 - The remaining third factor will be represented by the different graphs.
 - ▶ The decision could result in 1 of 6 different ways to present the means
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Three-way ANOVA Interaction

- ▶ Each of your graphs basically depicts whether there is a two-way interaction or not.
 - ▶ With the three-way interaction being defined as the difference between the two-simple interaction effects.
 - ▶ If there is a significant three-way interaction then it doesn't matter which of the 3 variables is chosen to represent the different graphs, as there will be significant differences in the simple interaction effects in each case.
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Three-way ANOVA Interaction

- ▶ A three-way interaction can be defined in terms of simple effects in a similar way to the definition of a two-way interaction.
 - Remember a two-way interaction is the difference in the simple main effects of one of the variables as you change levels of the other variable.
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Three-way ANOVA

- ▶ First check whether the three-way interaction is significant
 - If so then focus follow-up tests on the various simple effects or interaction contrasts, followed by appropriate mean comparisons.
- ▶ If the three-way interaction is not significant then check whether any of the two-way interactions are significant.
 - Follow-up with relevant simple effects

Two-way Interactions in Three-way ANOVAs

- ▶ If your three-way interaction is not significant but one or more of your two-way interactions are significant then you must remember to ‘collapse’ (i.e., average) your scores across the variable that is not involved in the two-way interaction.

Three-way ANOVA

- ▶ If none of the interactions are significant, you can then focus on the main effects.
- ▶ Regardless of whether you are looking at interaction effects or main effects then you always need to keep in mind whether any of the factors (IVs) have more than 2 levels.

Complex ANOVA Designs

- ▶ Interpreting interactions needs a great deal of thought: especially when there's more than 2 IVs, or your IVs have more than 2 levels.
 - ▶ Consider whether you need to:
 - Split the file to examine variables separately
 - Run separate ANOVAs (either one-way or two-way)
 - Consider how many levels there are for each IV
 - Work out which means need to be compared with each other.
 - Think about whether you are comparing within- or between-subjects variables/conditions.
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Non-Parametric Equivalents

- ▶ If your data does not meet all the assumptions required for carrying out an ANOVA and you cannot transform your data, then you can use non-parametric alternatives:
 - ▶ The Kruskal-Wallis test: The nonparametric equivalent of the one-way between ANOVA.
 - Data are ranked and the result tells us how likely the differences between ranks for each condition were to occur if the null hypothesis is true.
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Non-Parametric Equivalents

- ▶ The Friedman Test: Nonparametric equivalent of the one-way within ANOVA.
 - ▶ Ranks the scores for each participant.
 - ▶ Provides a sum of ranks for each condition.
 - ▶ Gives the calculation of χ^2 , the df, the p , and a histogram for each condition showing the rank frequencies and means of ranks in each condition.
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ANOVA Summary

- ▶ Research designs often assess differences in scores (DV)
 - Differences based on variable (IV) effects
 - ▶ Simple comparison between 2 conditions of any variable (e.g. t-test)
 - ▶ ANOVA allows more complex designs in this type of analysis:
 - More conditions of IV
 - More IVs
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ANOVA Summary

- ▶ ANOVA allows us to study designs which combine variables or increase conditions
 - ▶ Reflecting greater potential states of a variable: Multiple levels/conditions present
 - ▶ Reflecting potential for effects of:
 - Multiple factors
 - Variables of a different nature (ecological/controlled)
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ANOVA Summary:

- ▶ With ANOVA outputs, although the main values you will need for your write-up are the F, df, & sig values you need to check other tables from the output (depending on the type of ANOVA) in order to ensure there have been no violations and to ensure you read the values you need from the correct rows.
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Final reminder.....

**READ YOUR
RESEARCH
METHODS BOOKS**

