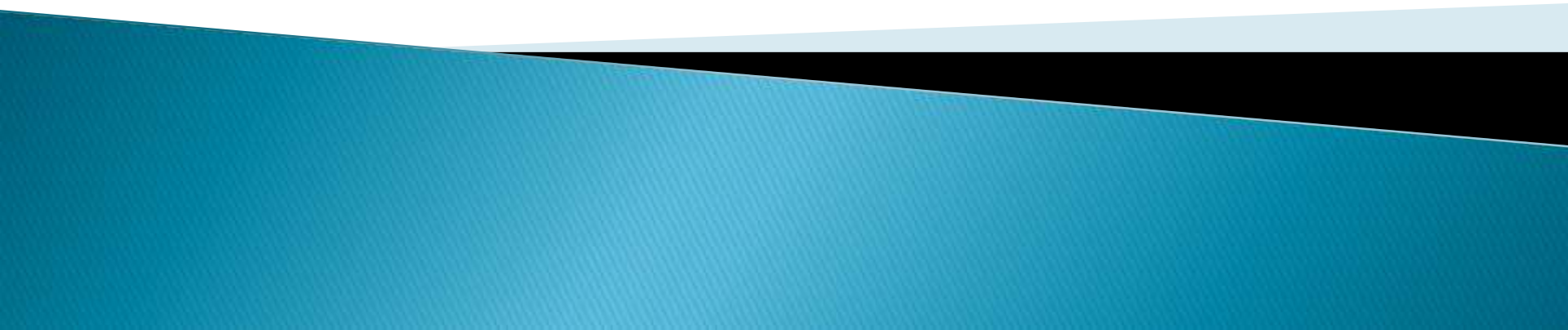


ANOVA II

Mixed Design and Post-hoc Comparisons

Dr. Paul Hutchings
Miss Katie Sullivan



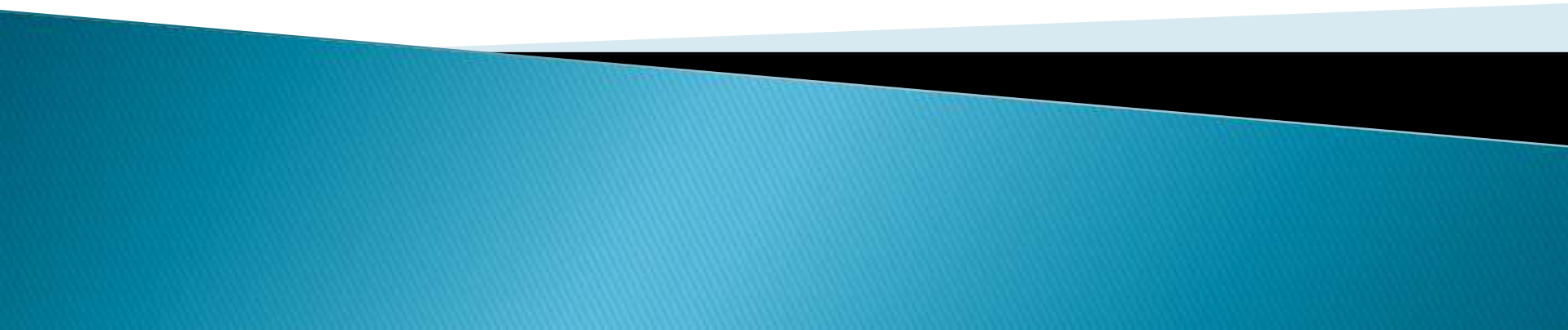
ESSENTIAL READING

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

Research Design and Analysis

Lecture 3: ANOVA II Mixed Design and Post-hoc Comparisons

Dr. Kate Williams



ESSENTIAL READING

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

Lecture Outline

- ▶ Mixed ANOVA design (within and between IVs).
- ▶ Unplanned (*Post-hoc*) tests.

Mixed ANOVA

- ▶ Combines within-subjects variables and between-subjects variables in one analysis.
 - ▶ Requires (at the minimum):
 - One categorical between-subjects IV (2 or more levels)
 - One categorical within-subjects IV (2 or more levels)
 - One continuous DV
 - ▶ But can involve more than 2 IVs
 - ▶ IVs can include more than 2 levels/conditions.
- 

Let's look at an example in detail...

- ▶ Research Question:
 - Is a coping intervention programme more effective than a control condition in reducing distress across three time periods?
 - ▶ How would you set this study up?
 - ▶ What would you be comparing? And why?
- 

Coping Intervention Study

- ▶ One categorical between-subjects IV
(number of levels ?)
- ▶ One categorical within-subjects IV
(number of levels ?)
- ▶ One continuous DV



Coping Intervention Study

- ▶ One categorical between-subjects IV (2 or more levels)
 - INTERVENTION GROUP v CONTROL GROUP
- ▶ One categorical within-subjects IV (2 or more levels)
 - TIME 1 (referral) v TIME 2 (waiting period) v TIME 3 (after diagnosis)
- ▶ One continuous DV
 - Distress scores (measured on validated scale)

Study Design

	CONTROL	INTERVENTION
Time 1		
Time 2		
Time 3		

- ▶ A 2 x 3 Mixed design ANOVA

Study Design

	CONTROL	INTERVENTION	Total Mean
Time 1	8.21	7.46	7.85
Time 2	6.21	6.30	6.25
Time 3	5.56	6.46	5.99
Total Mean	6.66	6.74	

SPSS Output



Descriptive Statistics

	group	Mean	Std. Deviation	N
tot_int1	intervention	7.46	8.681	124
	control	8.21	8.077	137
	Total	7.85	8.361	261
tot_int2	intervention	6.30	7.338	124
	control	6.21	7.049	137
	Total	6.25	7.174	261
tot_int3	intervention	6.46	7.807	124
	control	5.56	6.266	137
	Total	5.99	7.041	261

SPSS Output: Assumptions

Box's Test of Equality of Covariance Matrices^a

Box's M	8.555
F	1.408
df1	6
df2	473190.960
Sig.	.207

Check that the Sig. value here is bigger than .001 (i.e., NOT significant) to ensure that this assumption has not been violated.

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design:
Intercept + group
Within Subjects
Design: Time

SPSS Output: Assumptions

Mauchly's Test of Sphericity^b

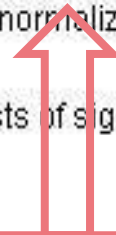
Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon ^a		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Time	.927	19.536	2	.000	.932	.942	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + group
Within Subjects Design: Time



The assumption being tested is that the correlation between all the variables is roughly the same. The sig value here should ideally be bigger than 0.05 (i.e., **NOT** significant). If it is significant then the assumption of sphericity is violated and you will need to report values from either the 'Multivariate Tests' box or other rows in the 'Tests of within-subjects effects' box in the output.

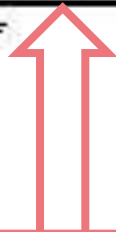
SPSS Output: Assumptions

Levene's Test of Equality of Error Variances^a

	F	df1	df2	Sig.
tot_int1	.013	1	259	.910
tot_int2	.264	1	259	.608
tot_int3	3.297	1	259	.071

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + group
Within Subjects Design: Time



Check that the Sig. value for each condition in this box is bigger than 0.05 (i.e., **NOT** significant). We need to make sure that all are not significant because this tells us that the assumption of homogeneity of variances has not been violated and so we are safe to proceed with our interpretation of the ANOVA.

SPSS Output: Interaction

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	510.938	2	255.469	11.226	.000	.042
	Greenhouse-Geisser	510.938	1.864	274.099	11.226	.000	.042
	Huynh-Feldt	510.938	1.884	271.155	11.226	.000	.042
	Lower-bound	510.938	1.000	510.938	11.226	.001	.042
Time * group	Sphericity Assumed	88.442	2	44.221	1.943	.144	.007
	Greenhouse-Geisser	88.442	1.864	47.446	1.943	.148	.007
	Huynh-Feldt	88.442	1.884	46.937	1.943	.147	.007
	Lower-bound	88.442	1.000	88.442	1.943	.165	.007
Error(Time)	Sphericity Assumed	11788.265	518	22.757			
	Greenhouse-Geisser	11788.265	482.793	24.417			
	Huynh-Feldt	11788.265	488.034	24.155			
	Lower-bound	11788.265	259.000	45.515			

No significant interaction

Be careful when reading the columns

The last column 'Partial Eta Squared' shows the estimate of the effect size

SPSS Output: Main effects

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Time	Sphericity Assumed	510.938	2	255.469	11.226	.000	.042
	Greenhouse-Geisser	510.938	1.864	274.099	11.226	.000	.042
	Huynh-Feldt	510.938	1.884	271.155	11.226	.000	.042
	Lower-bound	510.938	1.000	510.938	11.226	.001	.042
Time * group	Sphericity Assumed	88.442	2	44.221	1.943	.144	.007
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Error(Time)	Sphericity Assumed	11788.265	518	22.757			
	Greenhouse-Geisser	11788.265	482.793	24.417			
	Huynh-Feldt	11788.265	488.034	24.155			
	Lower-bound	11788.265	259.000	45.515			

Significant main effect of Time

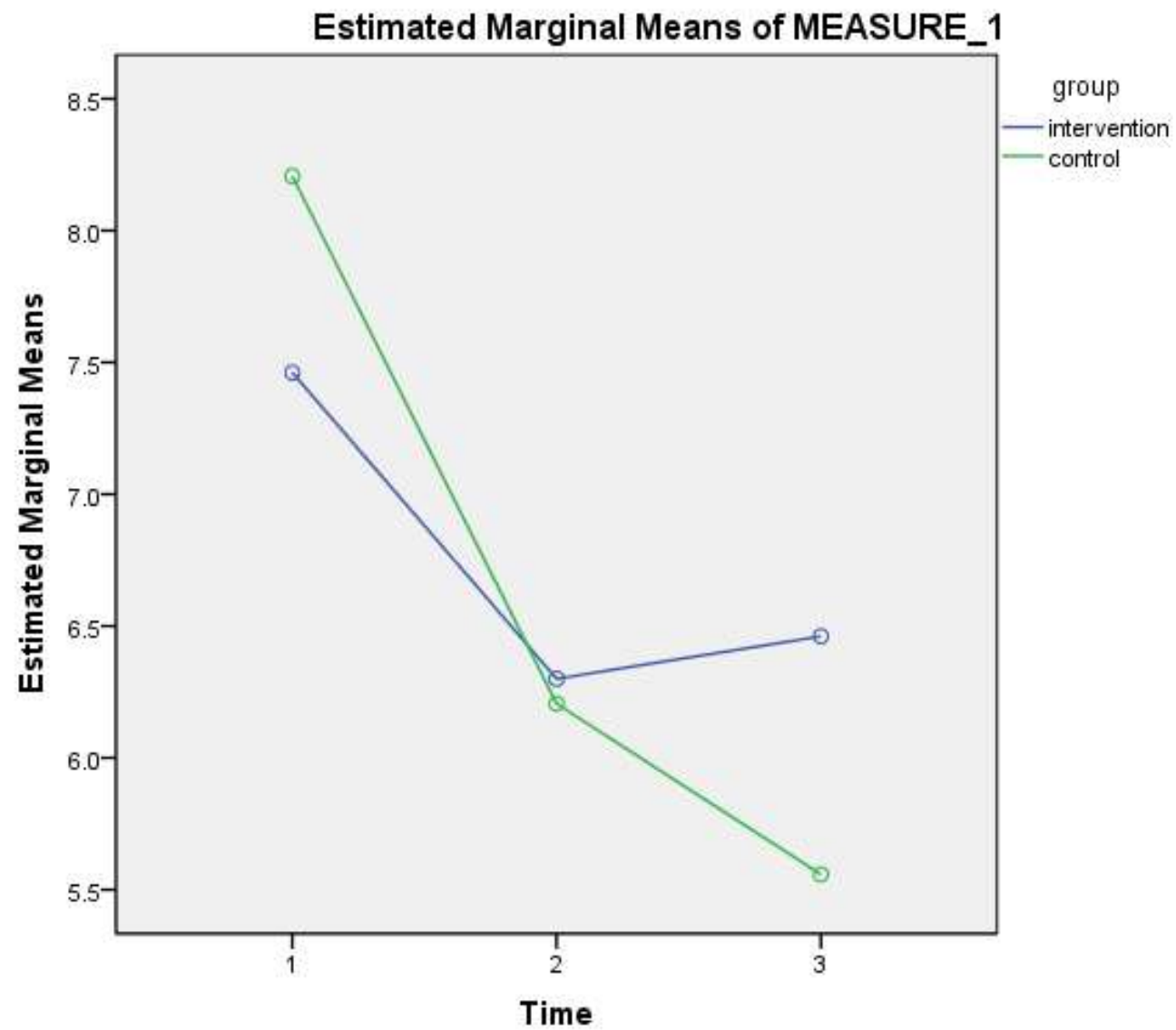
SPSS Output: Main effects

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	35048.299	1	35048.299	278.693	.000	.518
group	1.369	1	1.369	.011	.917	.000
Error	32571.759	259	125.760			

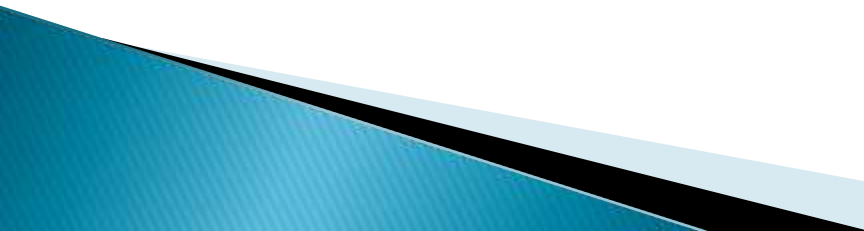
No significant main effect of Group



Reporting multifactorial ANOVA statistics

- ▶ ANOVA will analyse:
 - Main effects (effects of one IV in isolation)
 - Interactions (combined effects of more than one IV)
 - Main statistics for each analysis:
 - F-value, degrees of freedom (df), & p-value (sig. value)
 - F-value equating to the t-value in the t-test
 - Need 2 values for the df: the value from the row of your IV and the value from the 'error' row of output.
 - Sig. Value $p < 0.05$ is significant
 - All show whether (or not) there are **significant differences** (and to what degree) between the means in each grouping of data.

Interpretation of ANOVA Output

- ▶ Report descriptives
 - ▶ Check Levene's test of equality of error variances
 - Needs to be **greater** than .05
 - ▶ Report main effects (For each IV)
 - ▶ Report interaction effects
 - ▶ Report effect size (Partial Eta Squared)
 - ▶ Report planned &/or post-hoc tests (if needed)
- 

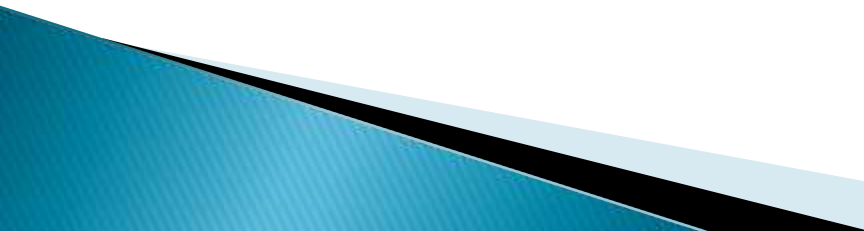
Interpretation of ANOVA Output

- ▶ Use your SPSS stats book
 - This is the only way you will understand it for yourself!
 - ▶ Tells you exactly what to interpret and how to report it
 - ▶ Just make sure you have selected the correct ANOVA based on your experimental design!
- 

Reporting a Mixed ANOVA

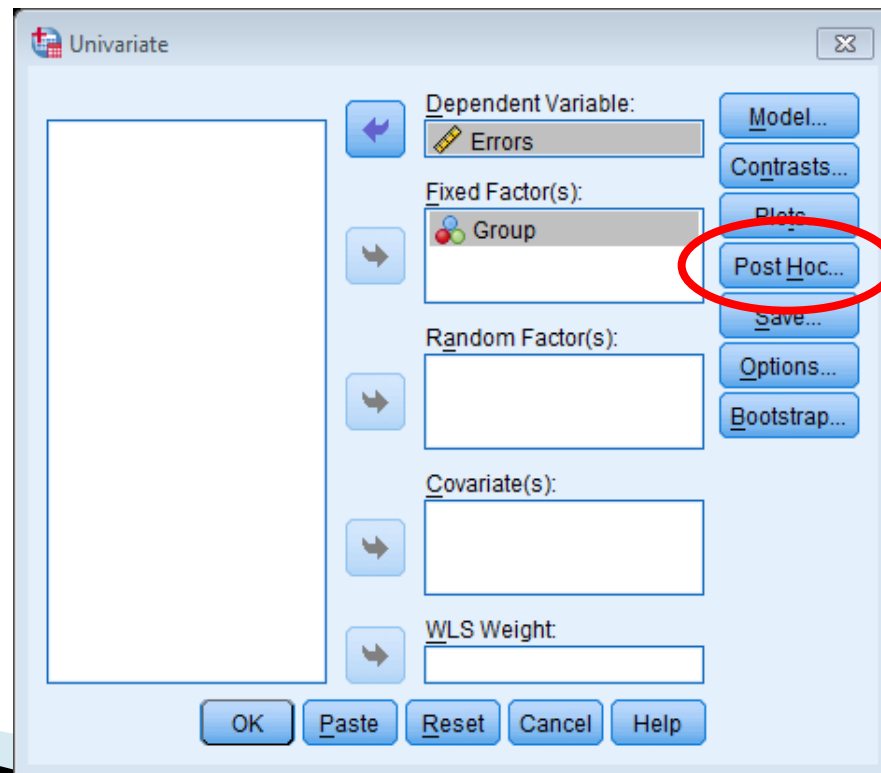
- ▶ Start with some general text and a table of descriptives or a graph if appropriate.
- ▶ A mixed-model ANOVA was carried out to explore the impact of a coping intervention on participants' distress scores across three time periods (referral, waiting period, and after test results). There was no significant interaction between group (intervention or control) and time $F(2,518) = 1.9, p > .05$). There was a significant main effect for time $F(2,518) = 11.3, p < .01$. The main effect comparing the intervention with control was not significant $F(2, 259) = .01, p > .05$, suggesting that the intervention was not more effective than the control condition in reducing distress.

Exploring significant main effects when there are more than 2 levels

- ▶ Are you expecting differences at the start of your study?
 - Planned comparisons (more on this next week)
 - ▶ Are you wanting to explore non-hypothesised differences?
 - Post-hoc comparisons for between-subject factors (e.g., Tukey, Scheffe)
 - Comparing main effects for within-subject factors (e.g., Bonferroni)
- 

Post-hoc comparisons

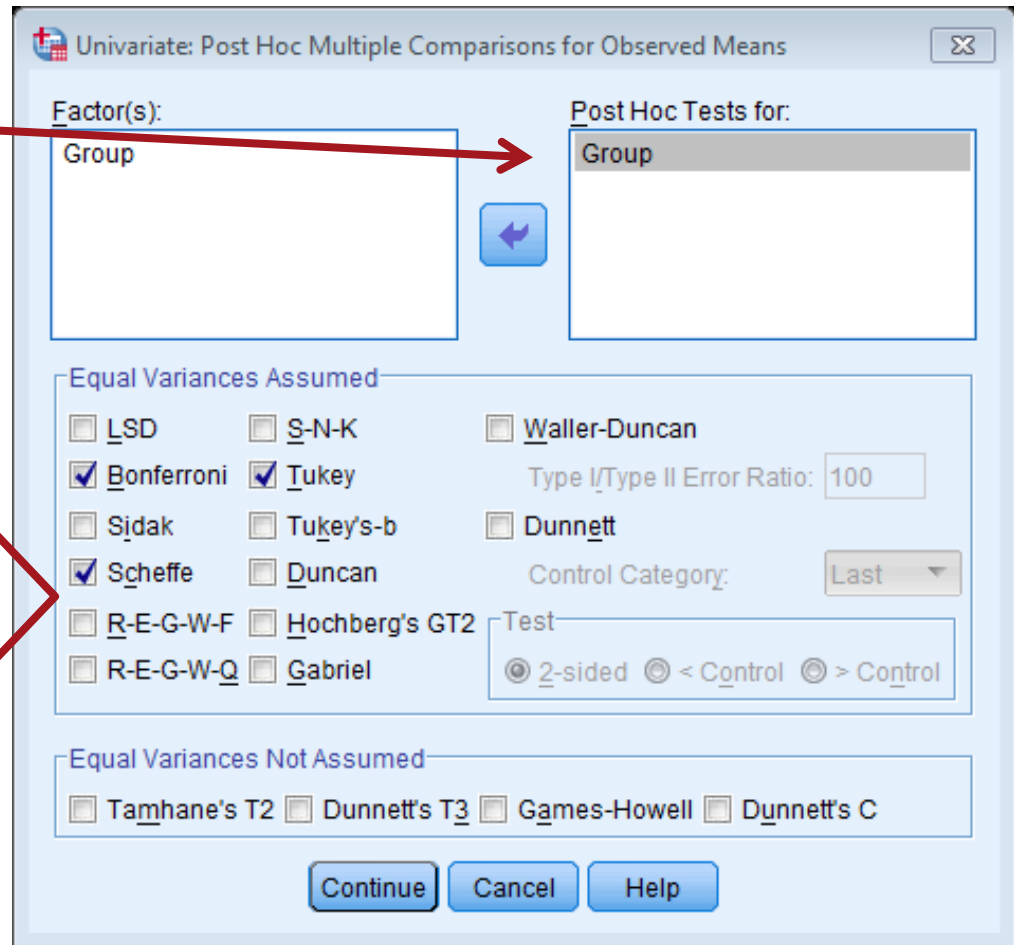
- ▶ If you have a significant main effect of a between-subjects factor with more than 2 levels:
 - E.g., 3 groups (Caffeine, Placebo, No caffeine)
 - You can ask SPSS to perform post-hoc tests



Post-hoc comparisons

Move the variable in to the 'Post Hoc Tests for:' box

Some post-hoc tests are more conservative than others. Depending on the statistics book you read some would recommend using Tukey, while others would recommend Scheffe, and others Bonferroni. I have ticked all of these so you can see the difference in the values they produce.



The image shows the 'Univariate: Post Hoc Multiple Comparisons for Observed Means' dialog box in SPSS. The 'Factor(s):' box contains 'Group'. The 'Post Hoc Tests for:' box also contains 'Group'. A red arrow points from the 'Factor(s):' box to the 'Post Hoc Tests for:' box. The 'Equal Variances Assumed' section has checkboxes for LSD, Bonferroni (checked), Sidak, Scheffe (checked), R-E-G-W-F, R-E-G-W-Q, S-N-K, Tukey (checked), Tukey's-b, Duncan, Hochberg's GT2, and Gabriel. The 'Waller-Duncan' checkbox is also present. The 'Type I/Type II Error Ratio' is set to 100. The 'Control Category' is set to 'Last'. The 'Test' section has radio buttons for 2-sided (selected), < Control, and > Control. The 'Equal Variances Not Assumed' section has checkboxes for Tamhane's T2, Dunnett's T3, Games-Howell, and Dunnett's C. At the bottom are 'Continue', 'Cancel', and 'Help' buttons.

Univariate: Post Hoc Multiple Comparisons for Observed Means

Factor(s):
Group

Post Hoc Tests for:
Group

Equal Variances Assumed

☐ LSD ☐ S-N-K ☐ Waller-Duncan
☒ Bonferroni ☒ Tukey Type I/Type II Error Ratio: 100
☐ Sidak ☐ Tukey's-b ☐ Dunnett
☒ Scheffe ☐ Duncan Control Category: Last
☐ R-E-G-W-F ☐ Hochberg's GT2 Test:
☐ R-E-G-W-Q ☐ Gabriel ☒ 2-sided ☐ < Control ☐ > Control

Equal Variances Not Assumed

☐ Tamhane's T2 ☐ Dunnett's T3 ☐ Games-Howell ☐ Dunnett's C

Continue Cancel Help

SPSS Output: Post-hoc comparisons

Group

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
		Placebo	1.80	.757	.083	-.22	3.82
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
		Placebo	1.80	.757	.099	-.31	3.91
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
		Placebo	1.80	.757	.105	-.30	3.90

Based on observed means.

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

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

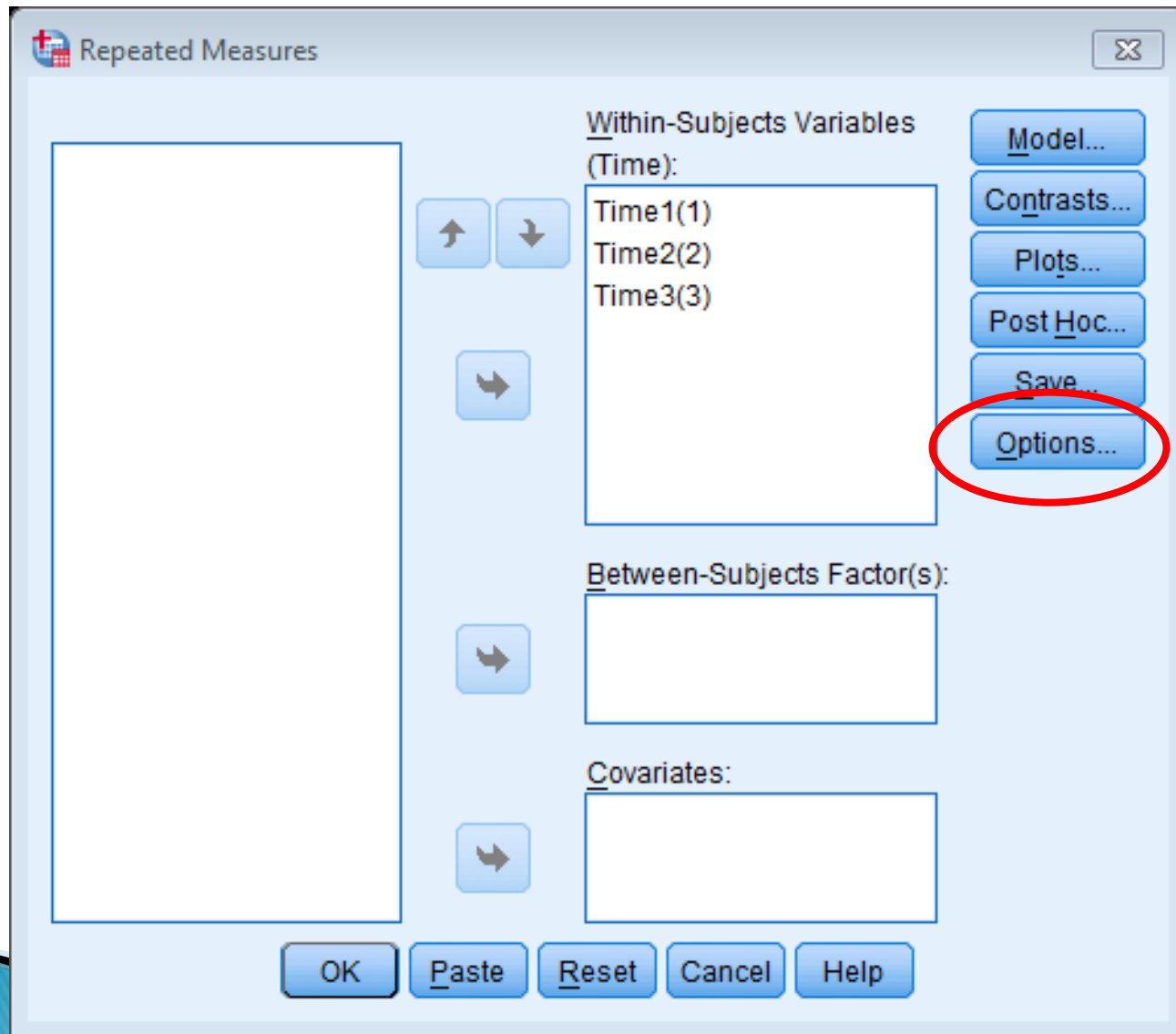
Reporting post-hoc analyses

- ▶ 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.
- 

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:
 - SPSS can perform Pairwise comparisons
- ▶ E.g., In our coping intervention example there was a significant main effect of time (3 levels)
- ▶ Where does the difference lie?
 - Time1 & Time 3? Time2 & Time3? Time1 & Time2? All?

Pairwise Comparisons



Pairwise Comparisons

Repeated Measures: Options

Estimated Marginal Means

Factor(s) and Factor Interactions:

(OVERALL)
Time

Display Means for:

Time

☒ Compare main effects

Confidence interval adjustment:
Bonferroni

Display

☐ Descriptive statistics	☐ Transformation matrix
☐ Estimates of effect size	☐ Homogeneity tests
☐ Observed power	☐ Spread vs. level plot
☐ Parameter estimates	☐ Residual plot
☐ SSCP matrices	☐ Lack of fit
☐ Residual SSCP matrix	☐ General estimable function

Significance level: .05 Confidence intervals are 95.0 %

Continue Cancel Help

Move the variable in to the 'Display Means for' box

Tick the 'Compare main effects' box.

Change 'Confidence interval adjustment' to 'Bonferroni'

Pairwise Comparisons

Pairwise Comparisons

Measure: MEASURE_1

		Mean Difference (I- J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
(I) Time	(J) Time				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.

Note 1 ...

- ▶ Although the main values you need for your ANOVA 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.

Good Practice

- ▶ If you don't need decimal places then best change this in variable view to 0.
 - ▶ In the 'Options' dialogue box always ask for:
 - Descriptive statistics (Means & Standard Deviation)
 - 'Estimates of effect size' which tells you the proportion of total variance accounted for by the factor (ANOVA).
 - 'Homogeneity tests' – you can proceed and assume homogeneity if Levene's test is **not** significant.
- 

Final reminder.....

**READ YOUR
RESEARCH
METHODS BOOKS**

