

MSc Applied Psychology

Applied Research Design and Analysis (ARDA)

Analysis of Variance (ANOVA): Interactions and Post-hoc analyses

Dr Kate Williams

Planned/Post-hoc Comparisons

- Exploring significant main effects when there are more than 2 levels associated with an IV.
- Are you expecting differences at the start of your study?
 - Planned comparisons (*a Prior*)
- Are you wanting to explore non-hypothesised differences?
 - Post-hoc comparisons for between-subject factors (e.g., Tukey, Scheffe, Bonferroni)
 - Comparing main effects for within-subject factors (e.g., Bonferroni Pair-wise comparisons)

Let's look at our Intervention study in further detail to examine **distress** levels...

- Research Question:
 - Is a coping intervention programme more effective than a control condition in reducing distress across **three time** points?
 - 1. Referral, 2. Waiting period, and 3. After diagnosis
- How would you set this study up?
- What would you be comparing? And why?

Intervention Study

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



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

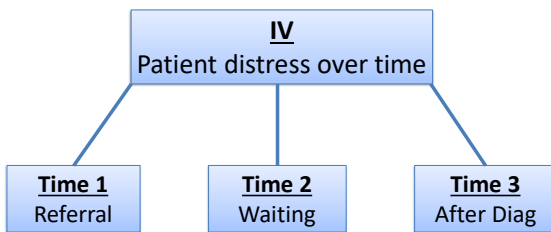
	CONTROL	INTERVENTION
Time 1		
Time 2		
Time 3		

- A 2 x 3 Mixed design ANOVA

Study Design

	CONTROL	INTERVENTION	Total Mean
Time 1	8.21	7.46	15.67
Time 2	6.21	6.30	12.51
Time 3	5.56	6.46	12.02
Total Mean	19.98	20.22	40.2

Time IV has more than 2 levels



Even if the main effect for time is sig, ANOVA **does not** tell us which means are different from which other means.
 E.g., could be a significant difference between T1 & T2 but not between T2 & T3.

SPSS ANOVA 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

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

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

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

Assumption being tested is that correlation between all variables is roughly the same. Sig value here should be bigger than 0.05 (i.e., **NOT** significant). If it is significant then 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). Need to ensure 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

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	1.884	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	1.884	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

Final column 'Partial Eta Squared' shows estimate of effect size

SPSS Output: Main effects

Tests of Within-Subjects Effects

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	1.884	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	1.884	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			

Significant main effect of Time

SPSS Output: Main effects

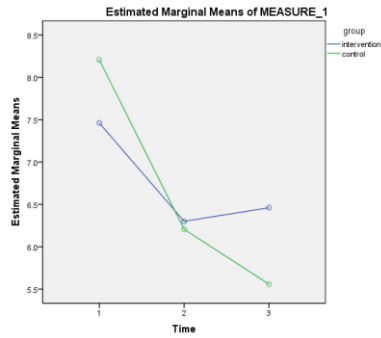
Tests of Between-Subjects Effects

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	278.893	.000	.518
group	1.369	1	1.369	.011	.917	.000
Error	32571.759	259	125.760			

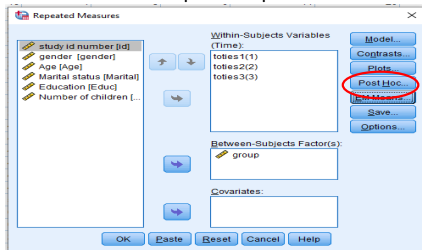
No significant main effect of Group

Plot



Post-hoc comparisons – Between groups

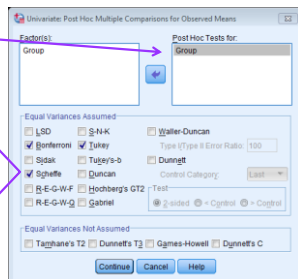
- If you have a significant main effect of a between-subjects factor with more than 2 levels:
 - E.g., 3 groups (Caffeine, Placebo, No caffeine)
 - You can ask SPSS to perform post-hoc tests



Post-hoc comparisons – Between groups

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.



SPSS Output: Post-hoc comparisons – Between groups

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.

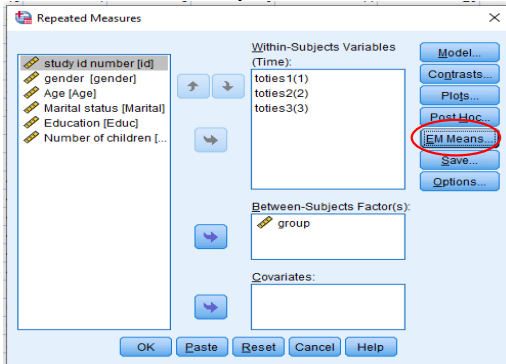
Reporting Between groups post-hoc analyses

- 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.
- E.g., “Employing the Bonferroni post-hoc test, statistically significant differences were found in error rates between the Caffeine ($M=4.7$; $SD=0.2$) and No Caffeine ($M=1.3$; $SD=0.1$) groups ($p < 0.005$), and between the Caffeine ($M=4.7$; $SD=0.2$) and Placebo ($M=2.7$; $SD=1.7$) groups ($p < 0.001$). However, there was no statistically significant difference found between the Placebo ($M=2.7$; $SD=1.7$) and No caffeine ($M=1.3$; $SD=0.1$) groups ($p = 0.1$).”

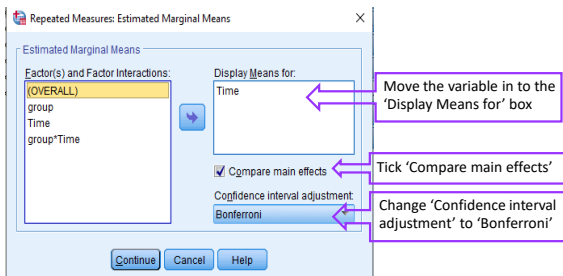
Comparing significant main effects for within-subject factors

- 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 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?

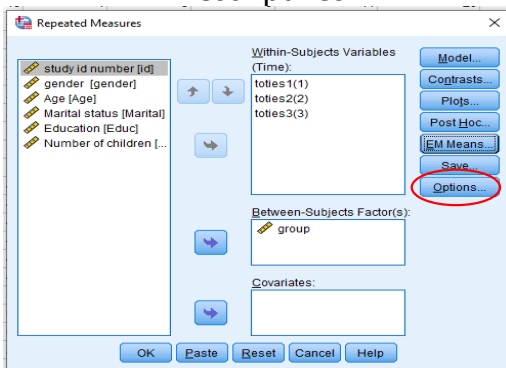
Pairwise Comparisons - Within



Pairwise Comparisons - Within

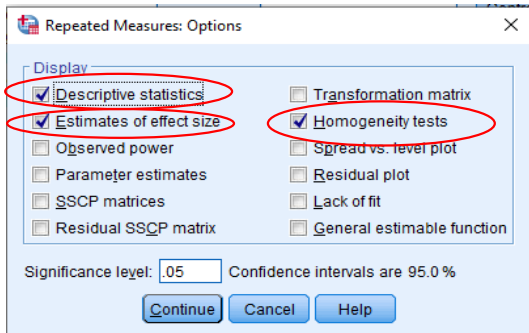


Descriptives



Descriptives

Ensure these boxes are ticked



SPSS Output: Pairwise Comparisons

Measure: MEASURE_1

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

Based on estimated marginal means

^a. The mean difference is significant at the .05 level.

^b. Adjustment for multiple comparisons: Bonferroni.



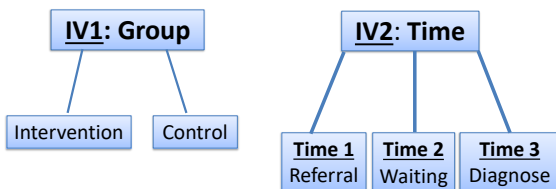
Reporting Within groups post-hoc analyses

- The information you present should include:
 - The type of post-hoc test
 - The mean and SD values for each group
 - The Sig value for each comparison.

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 intervention study example there were 2 IVs: Group (Intervention vs. Control) that could interact with the other IV of Time point (1,2,3).

Interaction: Intervention Study



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 smaller constituent elements.

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.

Interaction effects in ANOVA

- Say we obtained a significant interaction between Group and Time in the intervention study....
- We might split the SPSS file by Group and look at the effect of Time on distress scores separately for the intervention group only and then run a separate analysis for the effect of Time on distress scores for the Control group only.
- Use your SPSS books to see how splitting a file is done – remember to turn off the split file option when you are finished otherwise all subsequent analysis will be split.

Interaction effects in ANOVA

- Relatively straight forward to interpret an interaction when each of your factors only has 2 levels.
- **BUT:** What if you had a study where one (or more) of the factors (IVs) has more than 2 levels?
- This gets quite tricky and you need to think carefully about what further analyses to do and how to interpret the results.

Interaction effects in ANOVA

- If you are comparing means across levels using t-tests, you **MUST ALWAYS KEEP ONE FACTOR CONSTANT!**
- Say there was a significant interaction between:
 - IV1: Group (2 levels: Intervention or Control)
 - IV2: Time (3 levels: 1, 2, 3).

Interaction effects in ANOVA

- You could compare the means for:
 - Intervention group Time 1 and Time 2;
 - Intervention group Time 2 and Time 3;
 - Intervention group Time 1 and Time 3
 - Control group Time 1 and Time 2;
 - Control group Time 2 and Time 3;
 - Control group Time 1 and Time 3
- **BUT NEVER:** Intervention group Time 1 with Control group Time 3, for example.

Note on follow-up tests

- Think about whether the comparisons are within-subjects or between-subjects
 - This will dictate whether you run Independent samples or Repeated-measures analyses.
- Think about whether you have any interaction effects, as this will dictate on what data you run any follow up analyses.
