

Learning Centre



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CONTENT



- 1. What is an ANOVA?
- 2. Types of ANOVA
- ^{3.} Worked example on SPSS
- 4. Reporting

So...What is an ANOVA?



A statistical analysis used to find out if there are significant differences between 3 (or more) groups

Common Types of ANOVAs



One-way ANOVA

Used when you have 1 independent variable

Two-way ANOVA

Used when you have 2 independent variables

You can have a study with both between and within factors, making it a mixed design!

Note that it doesn't

have to stop at 2!

Between Subjects ANOVA Used when evaluating differences in independent groups

Within Subjects ANOVA

Used when evaluating differences in related groups



Types of ANOVAs

You can also mix and match the different types of ANOVA, such as a one-way between subjects design, or even a fourway mixed subjects design. Endless possibilities!



"I believe that drinking coffee affects anxiety levels. Is this true?"

I tested my hypothesis by conducting an experiment and assigning my statistics class of 30 people into 3 groups: those who drank 1 cup of coffee, those who drank 3 cups of coffee, and those who drank 5 cups of coffee.

I also asked them to rate their anxiety level (from 1-10) after drinking their respective beverages. I wonder what my results would be..."

-ENTHUSIASTIC RESEARCHER

Location of SPSS Data Files



Example SPSS data for practice are available on LearnJCU:

Log in to LearnJCU -> Organisations -> Learning Centre JCU Singapore -> Statistics Support -> Statistics Resources -> SPSS Data for Practice

Assumptions Testing



Prior to conducting the ANOVA, there is a need to conduct assumptions testing...



02 Normality 03

Independence of Observations Homogeneity of Variance

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tistics Data Editor

A

To check if there are extreme scores in our dataset, we can examine <u>boxplots</u> to determine outliers

Analyze -> Descriptive Statistics -> Explore

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Move the DV 'Anxiety' to the Dependent List

OK!

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()4

Assumptions Testing

01 Outliers



03

Independence of Homogeneity of Observations Variance



itistics Data Editor

To check normality, we use the Shapiro Wilk statistic

> Analyze -> Descriptive Statistics -> Explore

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Move 'Anxiety' to the Dependent List, and 'Condition' to the Factor List

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✓ SerialNumber Dependent List: ✓ Anxiety ✓ Eactor List: ✓ Condition ✓ Label Cases by:	Statistics Plo <u>t</u> s Options Bootstrap
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Click on *plots* and select *Normality plots with tests*

Continue and OK

*The steps in checking for normality is similar to checking for outliers, so you can do both at the same time!





rests of Normanty							
		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Condition	Statistic	df	Sig.	Statistic	df	Sig.
Anxiety	1 Cup Coffee	.180	10	.200	.966	10	.854
	3 Cups Coffee	.223	10	.172	.923	10	.384
	5 Cups Coffee	.182	10	.200	.930	10	.445

Tests of Normality

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

To satisfy the assumption of normality, we are looking for the Shapiro-Wilk test to be **non-significant** at $\alpha = .05$

As seen above, all Shapiro-Wilk tests are non-significant, therefore normality can be assumed

Assumptions Testing



01 Outliers

02

Normality

03 Independence of Observations

04

Homogeneity of Variance



This assumption can be assured in a study-design stage before data collection.

Independence of observations means that NO participant is randomly assigned into more than one condition.

Assumptions Testing





- Dat-



We can check this assumption by using *Levene's Test*

Analyze -> Compare Means -> One-Way ANOVA

Statistics D							
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Select 'Anxiety' as the Dependent List, 'Condition' as the Factor

Click on **Options**





Select Homogeneity of variance test

Continue, and OK

🕼 One-Way ANOVA: Options 🛛 🗙 🗙
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Homogeneity of variance test
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Continue Cancel Help



Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Anxiety	Based on Mean	.367	2	27	.696
	Based on Median	.362	2	27	.699
	Based on Median and with adjusted df	.362	2	20.561	.700
	Based on trimmed mean	.366	2	27	.697

To satisfy the assumption of homogeneity of variance, we are looking for Levene's test to be *non-significant* at $\alpha = .05$

As seen above, the Levene tests are non-significant (i.e. p > .05), therefore homogeneity of variance can be assumed

Violations of Assumptions?



Here are some potential steps to take if assumptions are violated:

Outliers – remove Normality – transform data Homogeneity of variance – increase sample size

*The above is a non exhaustive list, other steps can be taken, but you may need to provide justification on why such steps are taken



Onto SPSS!

One-Way ANOVA		×
SerialNumber	D <u>ependent List:</u>	Contrasts Post <u>H</u> oc Options Bootstrap
ОК	Eactor:	Help

- Click on Analyze -> Compare Means -> One-Way ANOVA
- Move Condition from the left column to the right column, under Factor (IV), and Anxiety to Dependent List (DV)
- Click OK!

Output





Since this value is .000, we reject the null hypothesis, and conclude that yes, the number of cups of coffee that a person drinks will affect he anxiety level.

But wait!



Remember that we tested 3 different groups: either 1, 3, or 5 cups of coffee.

We know from our results that there is an overall difference in anxiety levels between the 3 conditions, but where exactly does the difference lie?

To find out, we can run a *post-hoc test*





We can conduct the post-hoc test at the same time we run the ANOVA, just click on the *post-hoc option*

In this example, we use the Tukey post-hoc test

🔄 One-Way ANOVA			×	🝓 One-Way ANOVA	A: Post Hoc Multiple Co	omparisons	×
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ОК	• Paste	Eactor: Condition Reset Cancel Help]	Equal Variances N	Iot Assumed Dunnett's T <u>3</u> 0.05 Continue	Cancel Help	

Post-Hoc Tests



Post Hoc T	ests					
		Multiple	Compariso	ons		
Dependent Vari: Tukey HSD	able: Anxiety					
		Mean Difference (I-			95% Confid	ence Interval
(I) Condition	(J) Condition	J)	Std. Error	Sig.	Lower Bound	Upper Bound
1 Cup Coffee	3 Cups Coffee	-3.100	.735	.001	-4.92	-1.28
	5 Cups Coffee	-4.300	.735	.000	-6.12	-2.48
3 Cups Coffee	1 Cup Coffee	3.100 [*]	.735	.001	1.28	4.92
	5 Cups Coffee	-1.200	.735	.249	-3.02	.62
5 Cups Coffee	1 Cup Coffee	4.300 [*]	.735	.000	2.48	6.12
	3 Cups Coffee	1.200	.735	.249	62	3.02

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

The multiple comparisons table shows us the breakdown between each level of our IV

Looking at **Sig.** values, we can tell if there is a significant difference in anxiety between: 1 vs. 3 cups of coffee 1 vs. 5 cups of coffee 3 vs. 5 cups of coffee

Note: No difference in anxiety between 3 vs. 5 cups of coffee!

Reporting



An example write-up can be found on:

JCUS Learning Centre website -> Statistics and Mathematics Support



A doctor was interested in finding out if a new headache relief drug can reduce a patient's pain, and if this effect can sustain.

To test this, he recruited 30 patients with chronic headaches, and recorded their ratings of how painful their headaches were (rated 1-10). The researcher recorded this information 3 times: before participants took the drug, 30 minutes after participants took the drug, and 12 hours after participants took the drug..



Is the drug effective?

Assumptions Testing



03

Sphericity





To check if there are extreme high/low scores in our dataset, we can examine <u>boxplots</u> to determine outliers

Analyze -> Descriptive Statistics -> Explore

atistics Data Editor

<u>A</u> nalyze	<u>G</u> raphs	<u>U</u> tilities	E <u>x</u> tensions	<u>W</u> indow	<u>H</u> elp	
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<u>B</u> ayes	sian Statist	cs	•	🗄 <u>D</u> escripti	ives	
Ta <u>b</u> le	s		•	A Explore		
Co <u>m</u> p	bare Means	3	•	Crosstat	DS	
<u>G</u> ene	ral Linear N	lodel	•			
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Move the 3 different times (Before, ThirtyMin, and TwelveHours) as the Dependent List

Then OK!

🕼 Explore X							
SerialNumber							
■ Display ■ Dis							
OK Paste Reset Cancel Help							



The boxplots indicate that there are no outlier in the dataset





TwelveHours

Assumptions Testing



01 Outliers

02 Normality

03 Sphericity



atistics Data Editor

To check normality, we use the <u>Shapiro Wilk statistic</u>

Analyze -> Descriptive Statistics -> Explore

<u>A</u> nalyze	<u>G</u> raphs	<u>U</u> tilities	E <u>x</u> tensions	<u>W</u> indow	<u>H</u> elp	
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Move the 3 different times (Before, ThirtyMin, and TwelveHours) as the Dependent List





Click on *plots* and select *Normality plots* with tests

Continue and OK

*The steps in checking for normality is similar to checking for outliers, so you can do both at the same time!





rests of Normanty								
	Kolm	ogorov-Smir	nov ^a	5	Shapiro-Wilk			
	Statistic	df	Sig.	Statistic	df	Sig.		
Before	.195	30	.005	.939	30	.086		
ThirtyMin	.163	30	.041	.931	30	.053		
TwelveHours	.148	30	.094	.942	30	.101		

Tests of Normality

a. Lilliefors Significance Correction

To satisfy the assumption of normality, we are looking for the Shapiro-Wilk test to be **non-significant** at α = .05

As seen above, all three Shapiro-Wilk tests are non-significant, therefore normality can be assumed

Assumptions Testing



01 Outliers



Normality





itistics Data Editor

To check for sphericity, **go to** Analyze -> General Linear Model -> Repeated Measures

<u>A</u> nalyze	<u>G</u> raphs	<u>U</u> tilities	E <u>x</u> tensions	<u>W</u> indov	w <u>H</u>	<u>l</u> elp	
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Since we are measuring pain across 3 different timings, we can name the within-subject factor as 'Time', with '3' levels

Click Add, and Define

🕼 Repeated Measures Define Factor(s) 🛛 🗙							
Within-Subject Factor Name:							
time							
Number of Levels: 3							
Add							
Change							
Remove							
Measure <u>N</u> ame:							
Add							
Change							
Remove							
Define Reset Cancel Help							





Move all 3 times (Before, ThirtyMin, TwelveHours) to Within-Subjects Variables

Click OK



Mauchly's Test of Sphericity ^a									
Measure: MEASURE_1									
Epsilon ^b									
Within Subjects Effect	Mauchly's W	Approx. Chi- Square	df	Sig.	Greenhouse- Geisser	Huynh-Feldt	Lower-bound		
time	.902	2.881	2	.237	.911	.969	.500		

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

a. Design: Intercept

Within Subjects Design: time

b. 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.

If the Mauchly's Test of Sphericity is non-significant, the assumption for sphericity is not violated

If assumption is violated, we will use an Epsilon adjusted test (Greenhouse-Geisser or Huynh-Feldt) instead

Onto ANOVA!



Analyze -> General Linear Model -> Repeated Measures

*Conducing the ANOVA is similar to testing the assumption for sphericity, so we can do that concurrently

itistics Data Editor

Analyze	<u>G</u> raphs	<u>U</u> tilities	E <u>x</u> tensions	<u>W</u> indo	w	<u>H</u> elp	
Re <u>p</u> o	rts		•		4 4 4 4	A	
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Since we are measuring pain across 3 different timings, we can name the withinsubject factor as 'Time', with '3' levels.

Click Add, and Define

*This step can be skipped if already completed for assumption of sphericity.

🔚 Repeated Measures Define Factor(s) 🛛 🗙								
Within-Subject Factor Name:								
time								
Number of Levels: 3								
Add Change Remove								
Measure <u>N</u> ame:								
Add								
Change								
Remove								
Define <u>R</u> eset Cancel Help								





Move all 3 times (Before, ThirtyMin, and TwelveHours) to Within-Subjects Variables

*This step can be skipped if already completed for assumption of sphericity



Click on *EM Means* (this is for pairwise comparison)

Select 'Time' and move it to the right side column

Select compare main effects

Choose the confidence interval adjustment as LSD

Continue

tail Repeated Measures: Estimated Marg	🖣 Repeated Measures: Estimated Marginal Means 🛛 🛛 🗙							
Estimated Marginal Means <u>F</u> actor(s) and Factor Interactions: (OVERALL) Time	*	Display <u>M</u> eans for: Time						
		Compare main effects Confidence interval adjustmen LSD(none)	it:					

Cancel

Help

Continue



Additionally, you can go to **options** and select variables that are useful to report in the result write-up

Once done, click continue, and OK

Repeated Measures: Options ×						
Display Descriptive statistics Estimates of effect size Observed power Parameter estimates	 Tr<u>a</u>nsformation matrix <u>H</u>omogeneity tests Spread vs. level plot <u>R</u>esidual plot 					
SCP matrices Residual SSCP matrix	Lack of fit General estimable function					
Significance level: .05 Confidence intervals are 95.0 % Continue Cancel Help						

Measure: MEASURE 1



modedio. n						
Source		Type III Sum of Squares	df	Mean Square	F	Sig.
time	Sphericity Assumed	174.867	2	87.433	17.661	.000
	Greenhouse-Geisser	174.867	1.822	95.982	17.661	.000
	Huynh-Feldt	174.867	1.937	90.256	17.661	.000
	Lower-bound	174.867	1.000	174.867	17.661	.000
Error(time)	Sphericity Assumed	287.133	58	4.951		
	Greenhouse-Geisser	287.133	52.834	5.435		
	Huynh-Feldt	287.133	56.186	5.110		
	Lower-bound	287.133	29.000	9.901		

Tests of Within-Subjects Effects

Since the assumption for sphericity was not violated, the 'Sphericity Assumed' row is used.

For overall ANOVA, F(2, 58) = 17.66, p < .001. There was a significant difference between patients' pain at different times after taking the new drug

*If assumption for sphericity was violated, look at either the Greenhouse-Geisser or Huynh-Feldt row.



Now we know that, patients' pain decreased after taking the drug (check **Descriptives** to confirm)

To follow up, we can do a pairwise comparison (where exactly did the difference lie?)

In **the pairwise comparison table**, there are comparisons for Time 1 vs 2, 2 vs 3, and 1 vs 3

		Mean			95% Confiden Differ	ce Interval for ence ^b
(I) time	(J) time	J)	Std. Error	Sig. ^b	Lower Bound	Upper Bound
1	2	3.067*	.491	.000	1.819	4.315
	3	2.833	.574	.000	1.376	4.291
2	1	-3.067*	.491	.000	-4.315	-1.819
	3	233	.648	1.000	-1.880	1.413
3	1	-2.833	.574	.000	-4.291	-1.376
	2	.233	.648	1.000	-1.413	1.880

Pairwise Comparisons

Based on estimated marginal means

Measure: MEASURE 1

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

*You can manually consider conduct pairwise comparisons with Bonferroni adjustment as well.



A significantly higher pain was reported before taking the drug than at 30 minutes after taking the drug (time 1 vs 2; p < .001)

A significantly higher pain was reported before taking the drug than at 12 hours after taking the drug (time 1 vs 3; p < .001)

No significant difference in pain of patients was reported between after 30 minutes and 12 hours of taking the drug (time 2 vs 3; p = 1.0)

	(I) time	(J) time	Mean Difference (I- J)	Std. Error	Sig. ^b	95% Confiden Diffen Lower Bound	ce Interval for ence ^b Upper Bound
	1	2	3.067	.491	.000	1.819	4.315
		3	2.833	.574	.000	1.376	4.291
	2	1	-3.067	.491	.000	-4.315	-1.819
		3	233	.648	1.000	-1.880	1.413
	3	1	-2.833	.574	.000	-4.291	-1.376
		2	.233	.648	1.000	-1.413	1.880

Pairwise Comparisons

Based on estimated marginal means

Measure: MEASURE 1

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

b. Adjustment for multiple comparisons: Bonferroni.

Reporting



An example write-up can be found on:

JCUS Learning Centre website -> Statistics and Mathematics Support





The examples listed here are for one-way ANOVAS; conducting two-way ANOVAS (or more) are slightly different.

For example, two-way ANOVAS will use: Analyze -> General Linear Model -> Univariate

However, assumptions testing will remain the same throughout.



Questions?

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www.jcu.edu.sg