ANOVA

Learning Centre

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

JAMES COOK UNIVERSITY SINGAPORE

One-way ANOVA

Used when you have 1 independent variable

Two-way ANOVA

Used when you have 2 independent variables

Note that it doesn't have to stop at 2!

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

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 four-way mixed subjects design. Endless possibilities!

Between Subjects ANOVA: Example

"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

JAMES COOK UNIVERSITY SINGAPORE

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…

01
Outliers

02
Normality

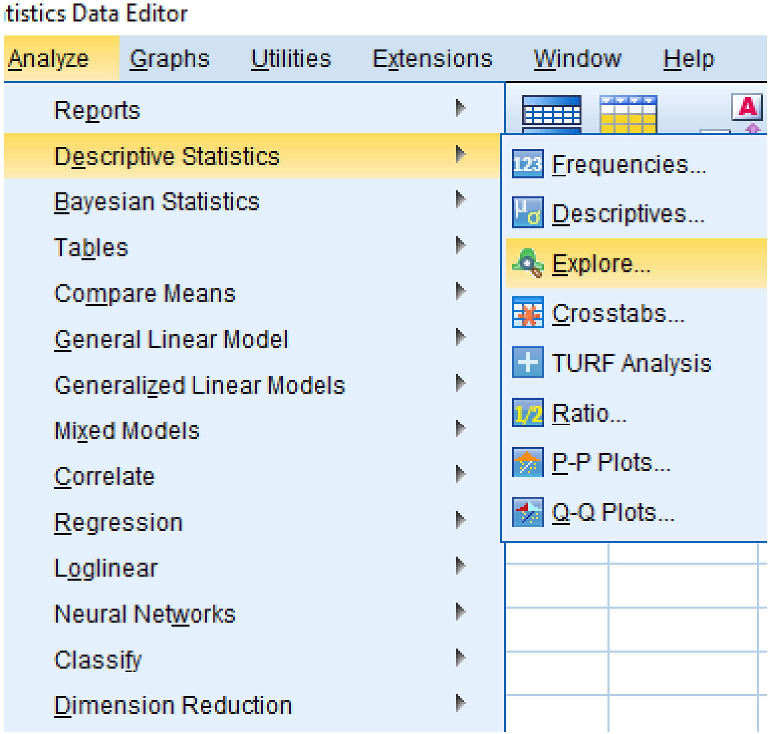
03
Independence of Observations

04
Homogeneity of Variance

1. Outliers

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

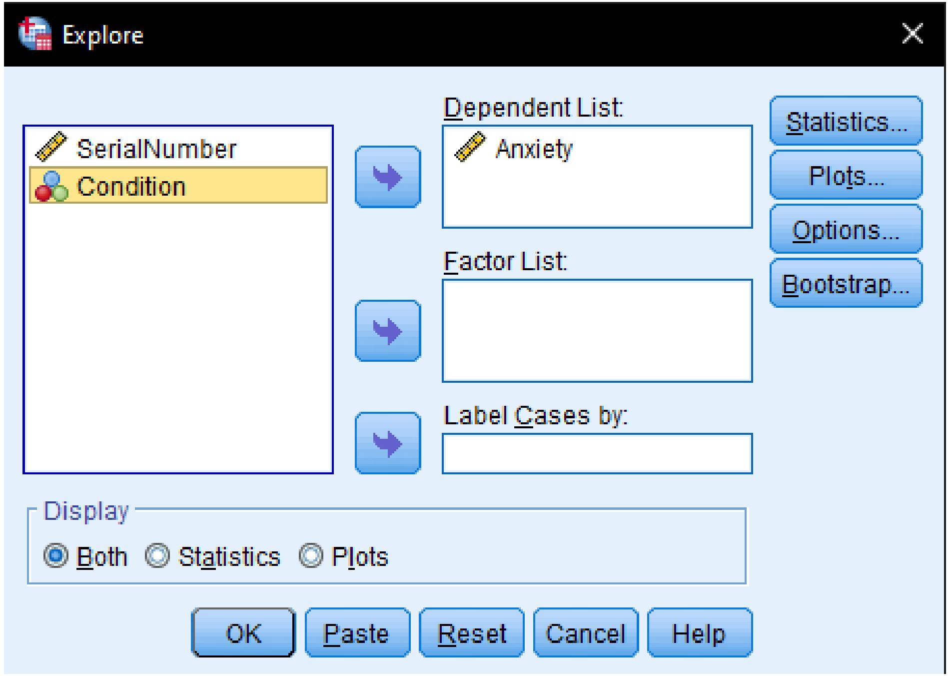
Analyze -> Descriptive Statistics -> Explore



1. Outliers

Move the DV ‘Anxiety’ to the Dependent List

OK!

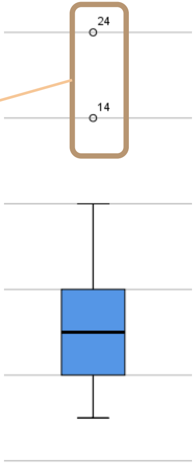


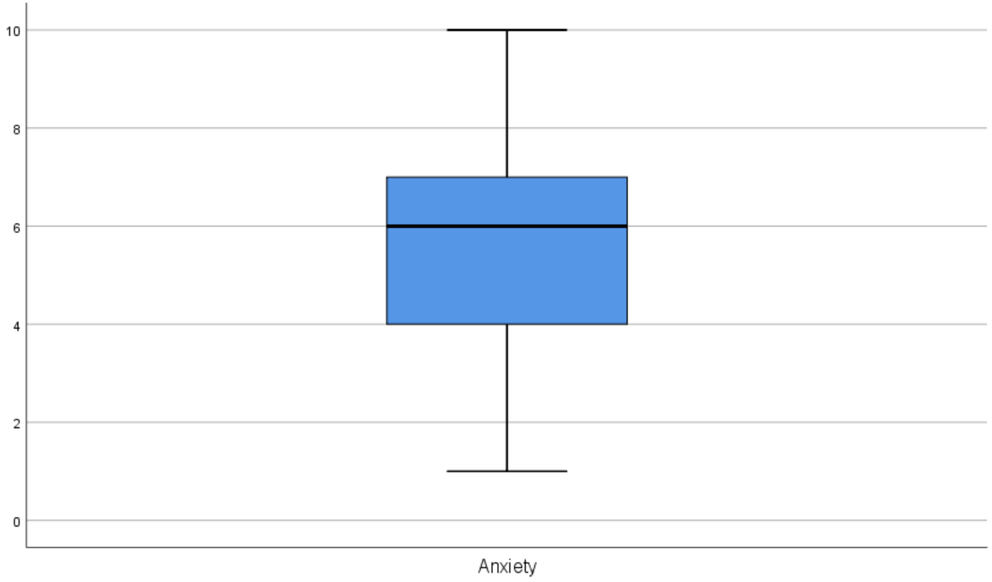
1. Outliers

A ‘clear’ boxplot (on the right) indicates no outliers

Example of outliers would be displayed as such:

Outliers!





Assumptions Testing

JAMES COOK UNIVERSITY SINGAPORE

01
Outliers

02
Normality

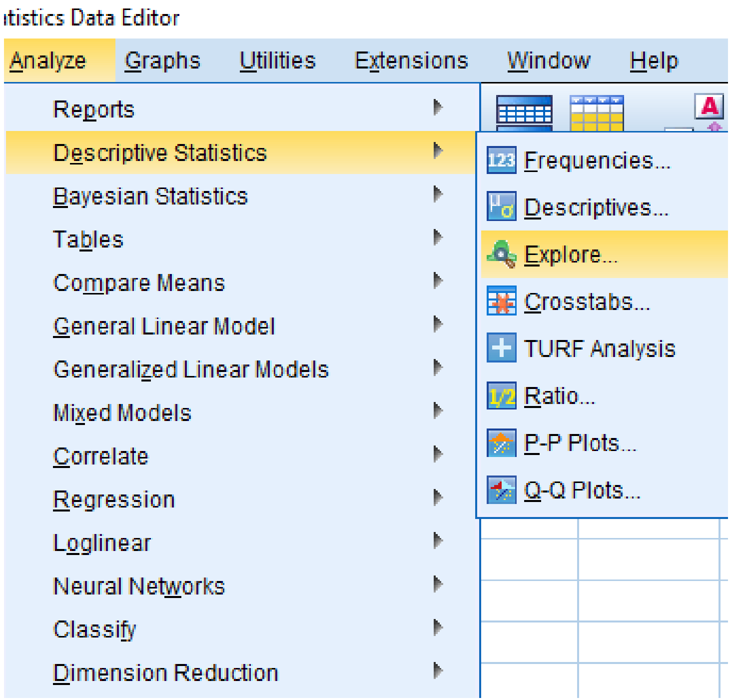
03
Independence of Observations

04
Homogeneity of Variance

2. Normality

To check normality, we use the Shapiro Wilk statistic

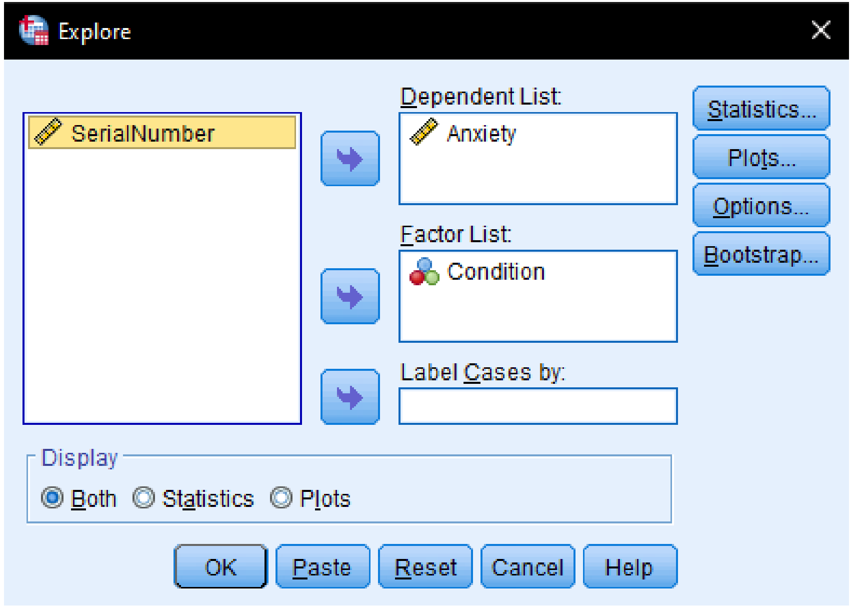
Analyze -> Descriptive Statistics -> Explore



2. Normality

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

Click on ***Statistics***

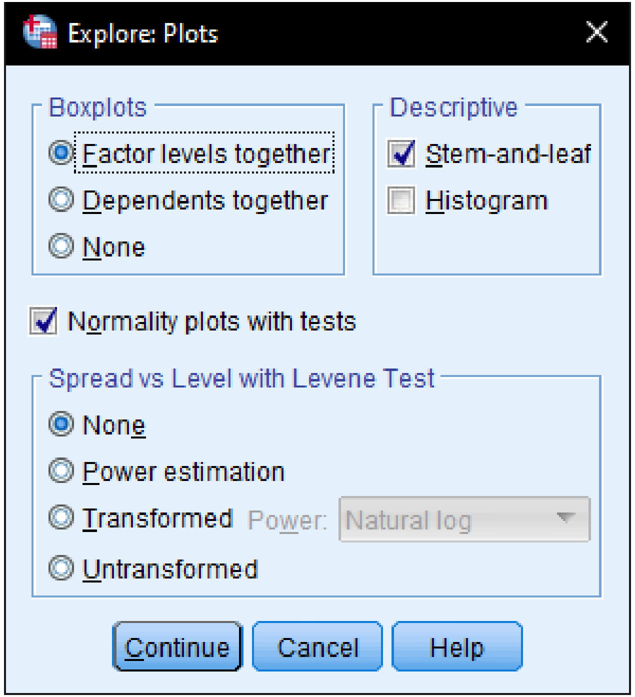


2. Normality

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!



2. Normality

Tests of Normality

	Condition	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		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

*. 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

JAMES COOK UNIVERSITY SINGAPORE

01
Outliers

02
Normality

03
Independence of Observations

04
Homogeneity of Variance

3. Independence of Observations

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

JAMES COOK UNIVERSITY SINGAPORE

01
Outliers

02
Normality

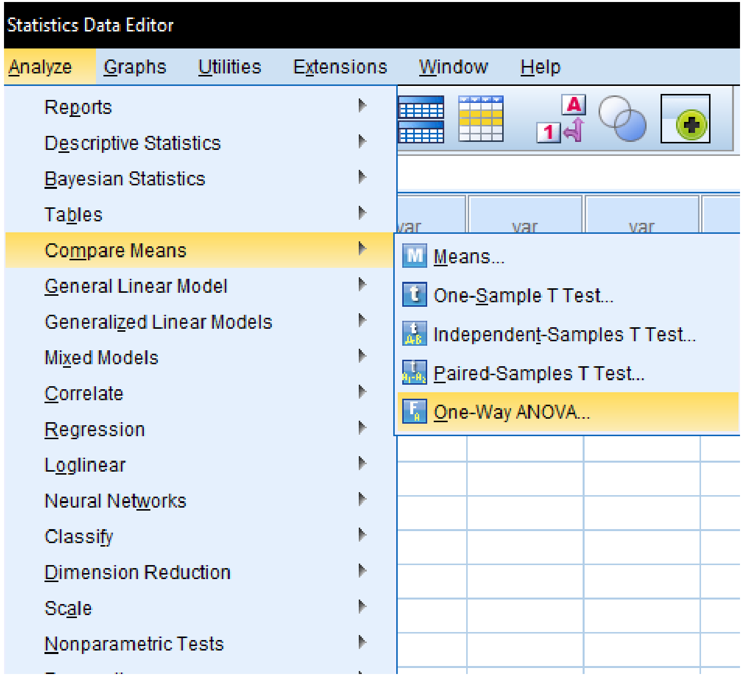
03
Independence of Observations

04
Homogeneity of Variance

4. Homogeneity of Variance

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

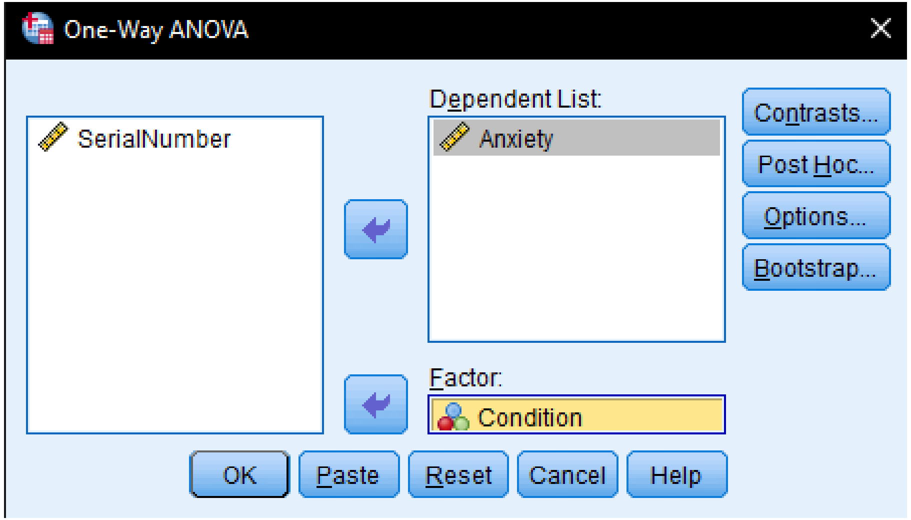
Analyze -> Compare Means -> One-Way ANOVA



4. Homogeneity of Variance

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

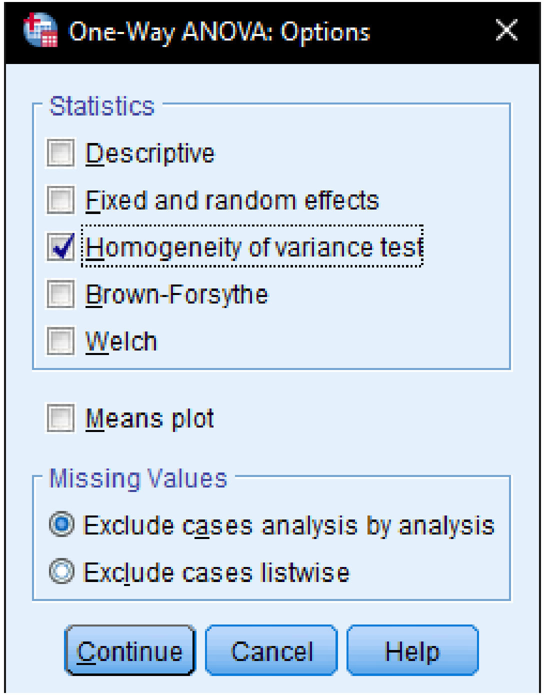
Click on ***Options***



4. Homogeneity of Variance

Select ***Homogeneity of variance test***

Continue, and OK



4. Homogeneity of Variance

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?

JAMES COOK UNIVERSITY SINGAPORE

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

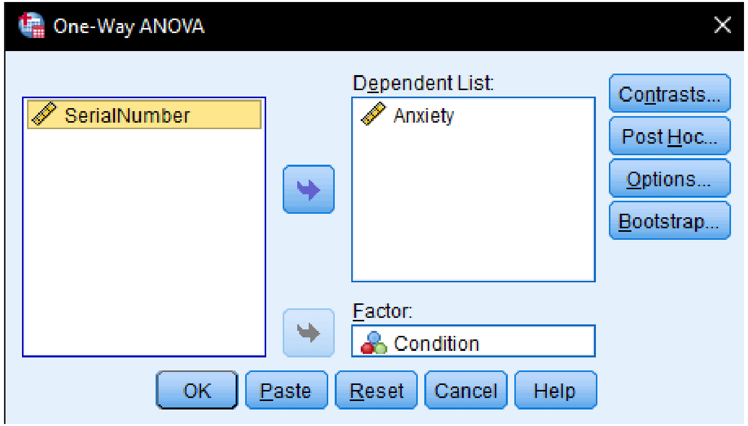
Outliers – remove

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!



- 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

➔ **Oneway**

ANOVA

Anxiety

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	98.467	2	49.233	18.235	.000
Within Groups	72.900	27	2.700		
Total	171.367	29			

df is written as 2, 27

The *F* value

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?

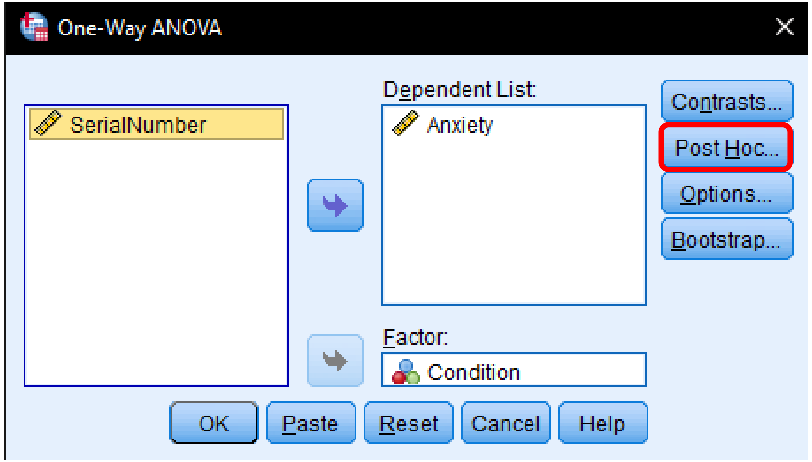
To find out, we can run a ***post-hoc test***

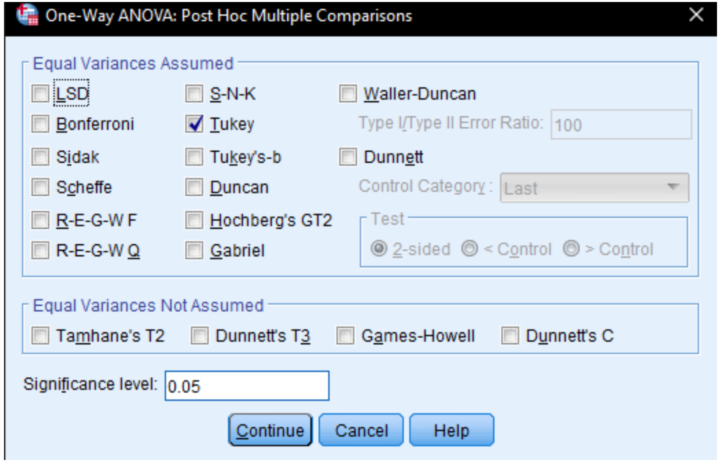
Post-Hoc Tests

JAMES COOK UNIVERSITY SINGAPORE

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





Post-Hoc Tests

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

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Anxiety
Tukey HSD

(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					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.

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

Within Subjects ANOVA: Example

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

01
Outliers

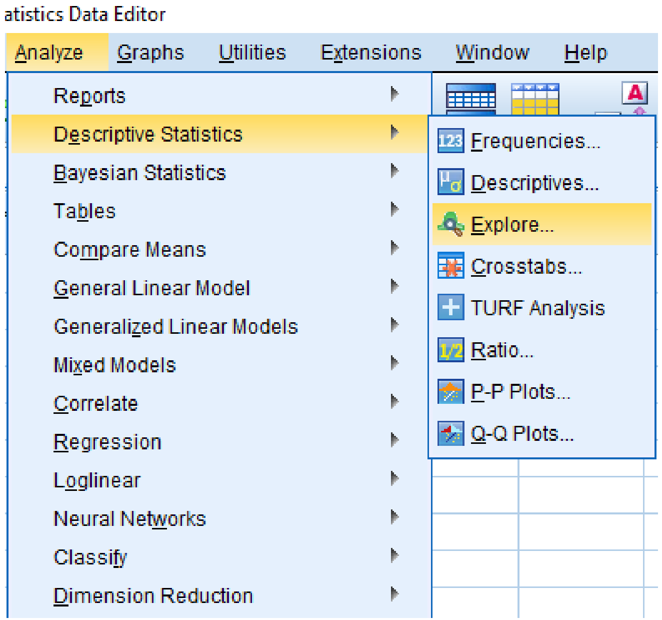
02
Normality

03
Sphericity

1. Outliers

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

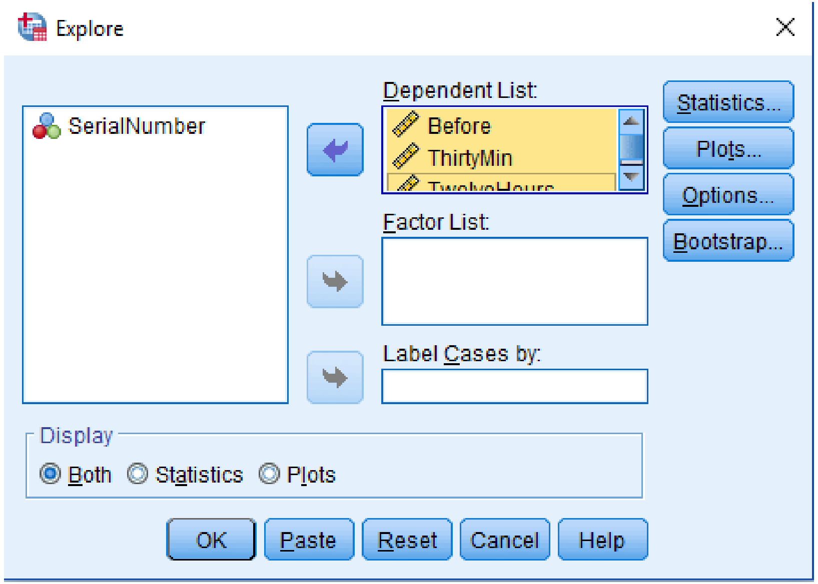
Analyze -> Descriptive Statistics -> Explore



1. Outliers

Move the 3 different times (Before, ThirtyMin, and TwelveHours) as the Dependent List

Then OK!

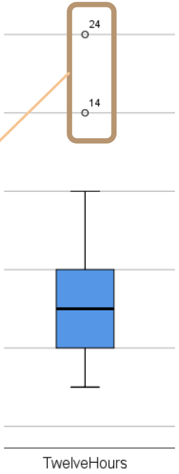


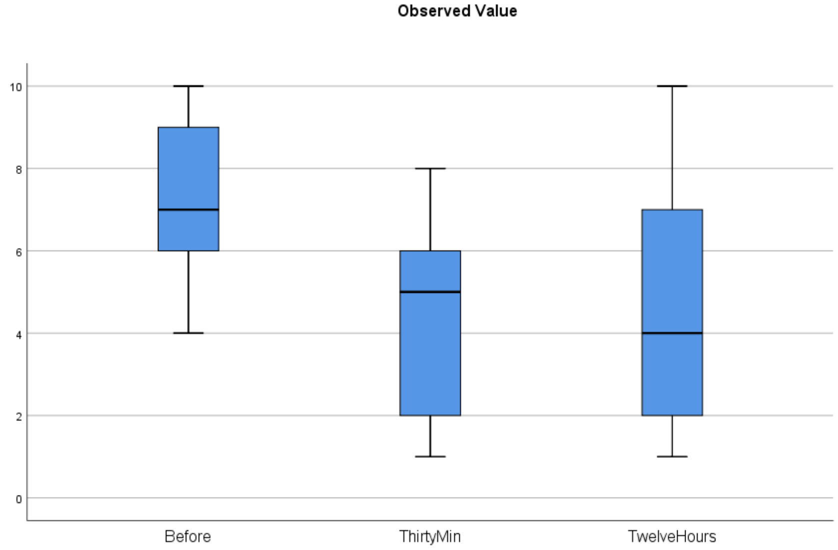
1. Outliers

The boxplots indicate that there are no outlier in the dataset

*If there were outliers, they would be annotated with a small circle/asterisk, and labelled with the case number

Outliers!





Assumptions Testing

JAMES COOK UNIVERSITY SINGAPORE

01
Outliers

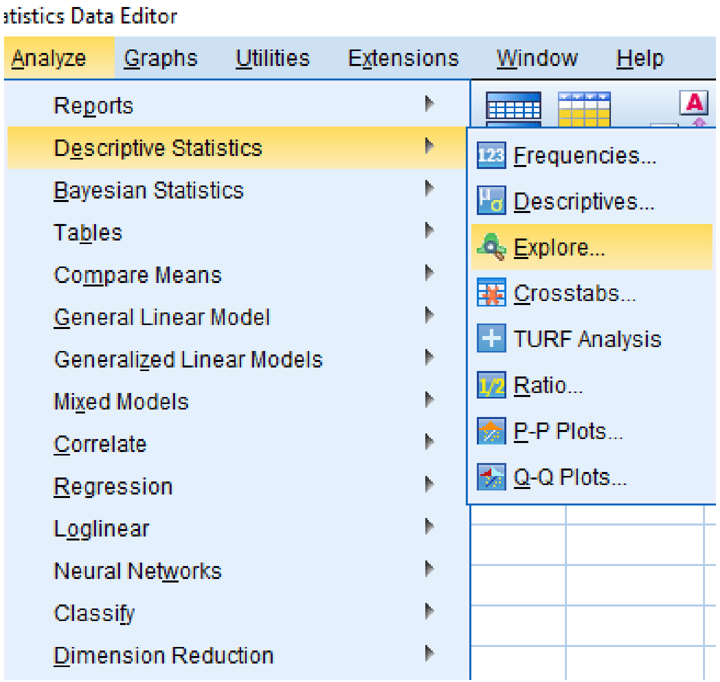
02
Normality

03
Sphericity

2. Normality

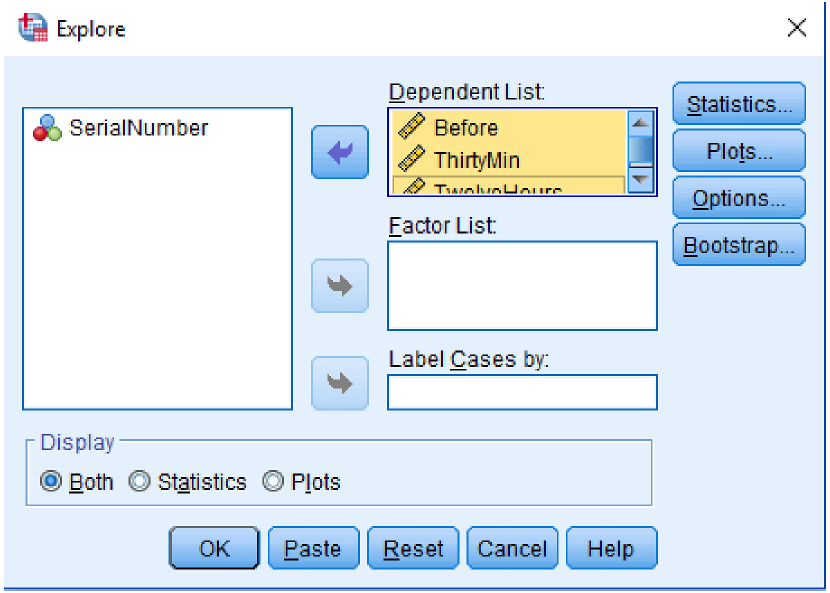
To check normality, we use the Shapiro Wilk statistic

Analyze -> Descriptive Statistics -> Explore



2. Normality

Move the 3 different times (Before, ThirtyMin, and TwelveHours) as the Dependent List

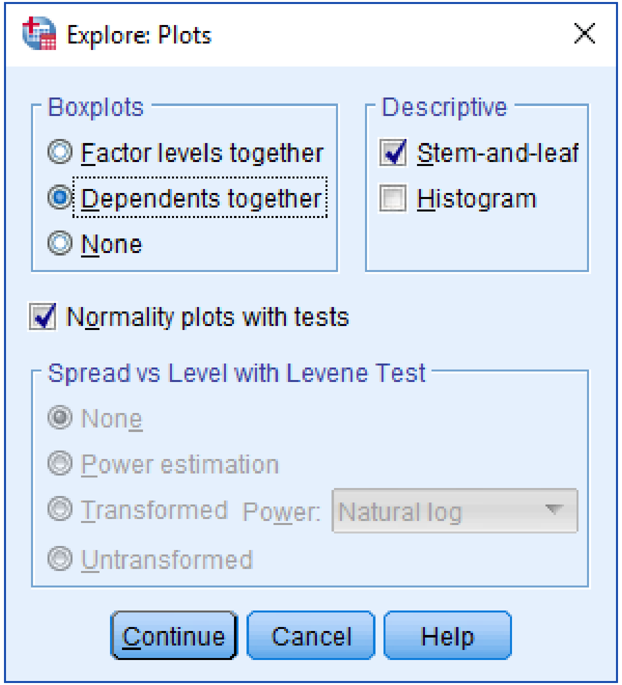


2. Normality

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!



2. Normality

Tests of Normality

	Kolmogorov-Smirnov[a]			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

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

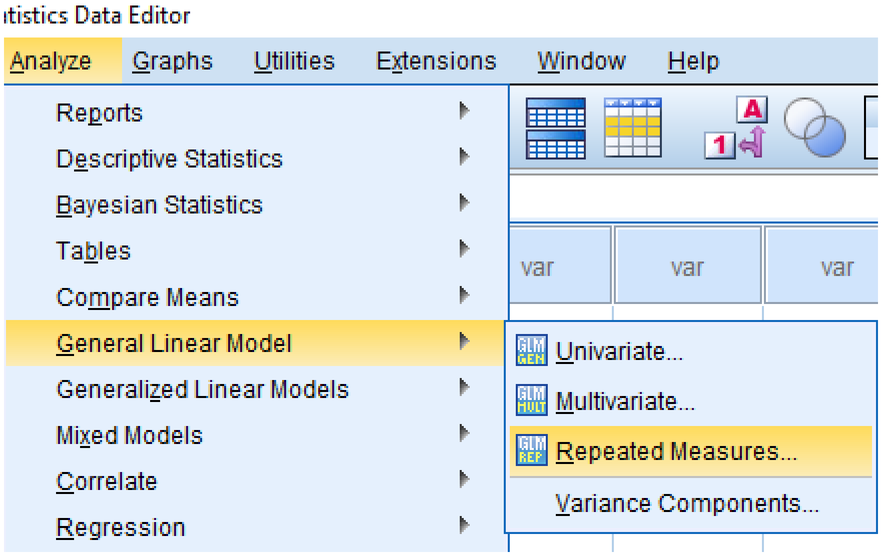
01
Outliers

02
Normality

03
Sphericity

3. Sphericity

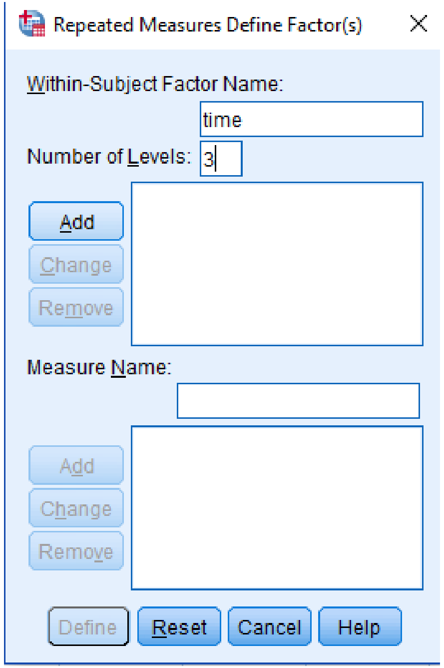
To check for sphericity, **go to Analyze -> General Linear Model -> Repeated Measures**



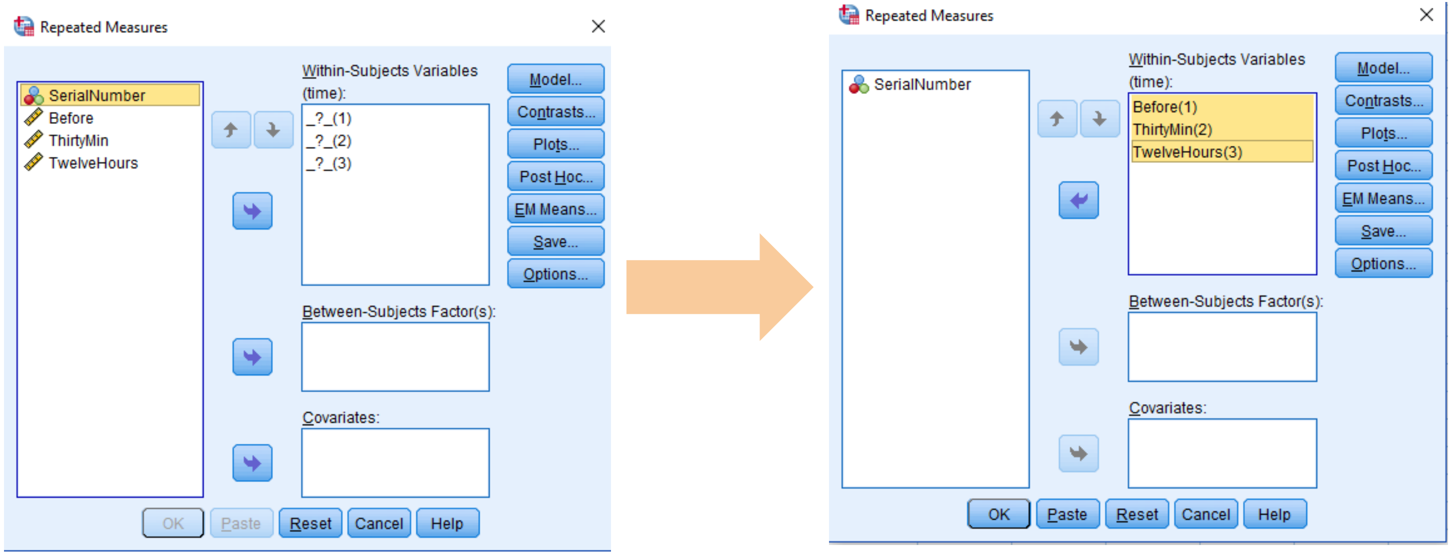
3. Sphericity

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



3. Sphericity



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

Click OK

3. Sphericity

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					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.

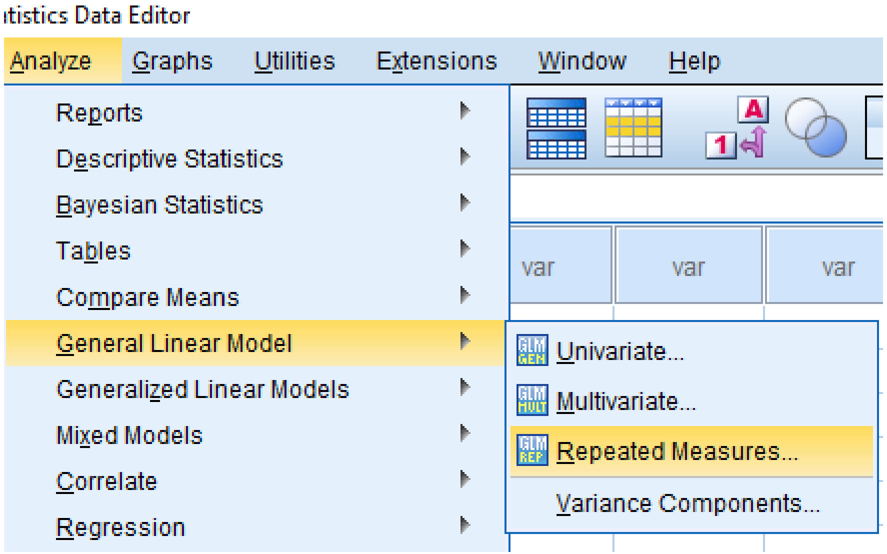
If the Mauchly's Test of Sphericity is non-significant, the assumption for sphericity is not violated

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

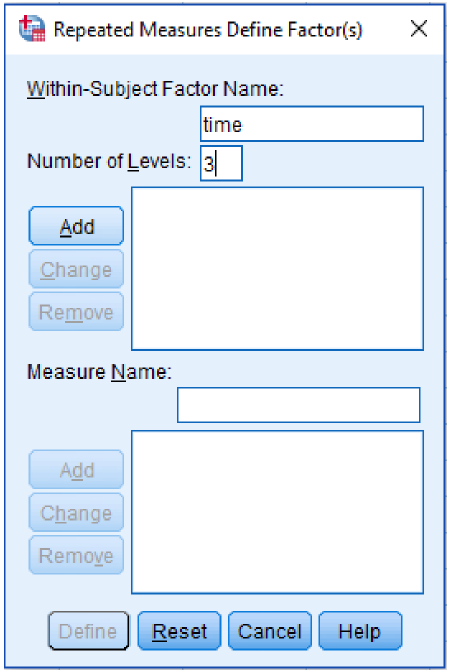


ANOVA!

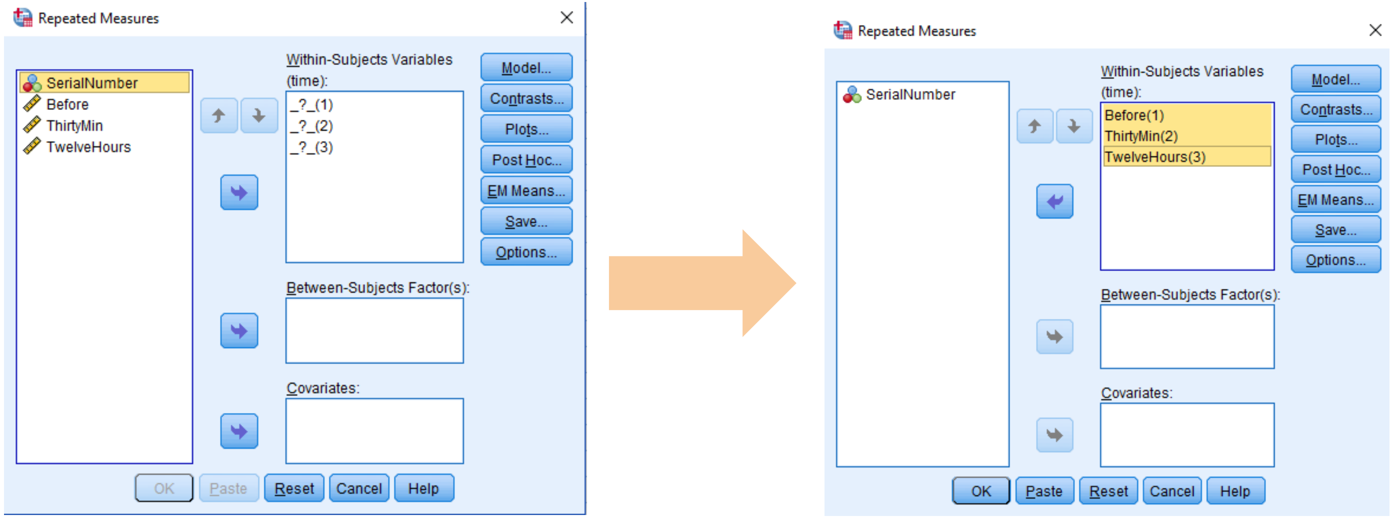
Since we are measuring pain across 3 different timings, we can name the within-subject factor as 'Time', with '3' levels.

Click Add, and Define

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



ANOVA!



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

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

ANOVA!

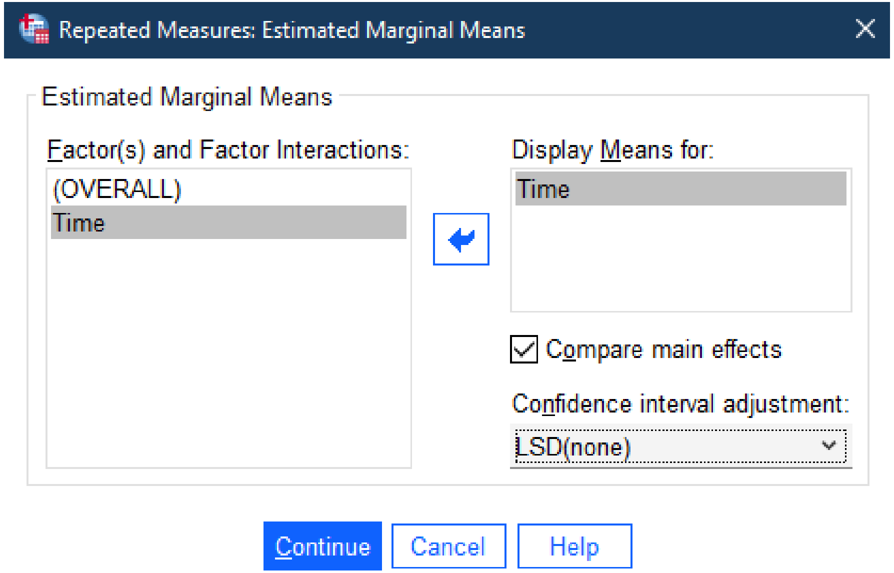
Click on ***EM Means*** (this is for pairwise comparison)

Select ‘Time’ and move it to the right side column

Select compare main effects

Choose the confidence interval adjustment as LSD

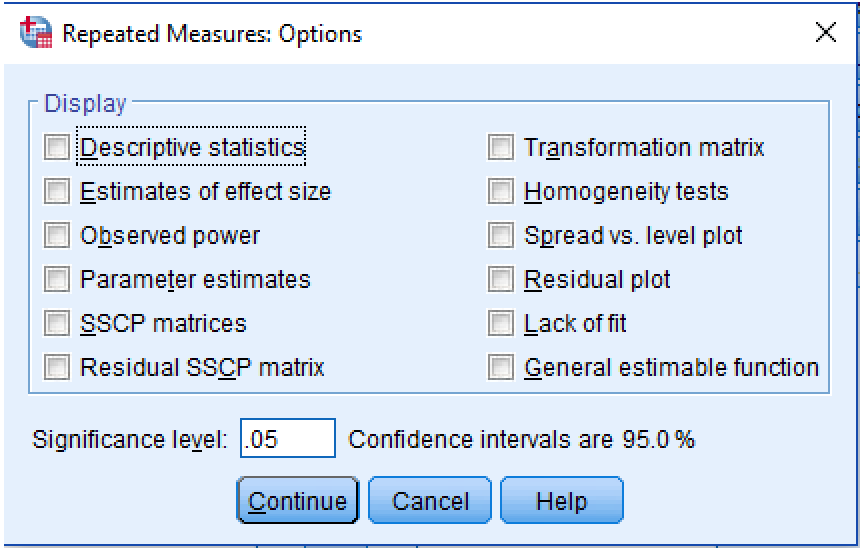
Continue



ANOVA!

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



ANOVA!

Tests of Within-Subjects Effects

Measure: MEASURE_1

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		

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.

ANOVA!

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

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	3.067*	.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

Based on estimated marginal means

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

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

ANOVA!

JAMES COOK UNIVERSITY SINGAPORE

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)

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	3.067*	.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

Based on estimated marginal means

*. 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

A Note…

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?

learningcentre-singapore@jcu.edu.au