Universiti Kebangsaan di Persada Antarabangsa

Universiti Kebangsaan Malaysia
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General Linear Model (GLM)

Univariate, Multivariate & Repeated Measures

www.ukm.my

GLM

- a flexible statistical model incorporating analyses involving normally distributed dependent variables and combinations of categorical and continuous independent (predictor) variables.

Predictors

- Categorical predictors are referred to as **factors**,
- while continuous predictors are called **covariates**.

GLM

- Univariate
- Multivariate
- Repeated Measures

Univariate

- univariate models (one dependent variable)
  - Categorical predictors only (ANOVA) - done
  - Continuous predictors only (Regression) - done
  - Combinations of categorical predictors and continuous predictors (ANCOVA) – to learn

Multivariate

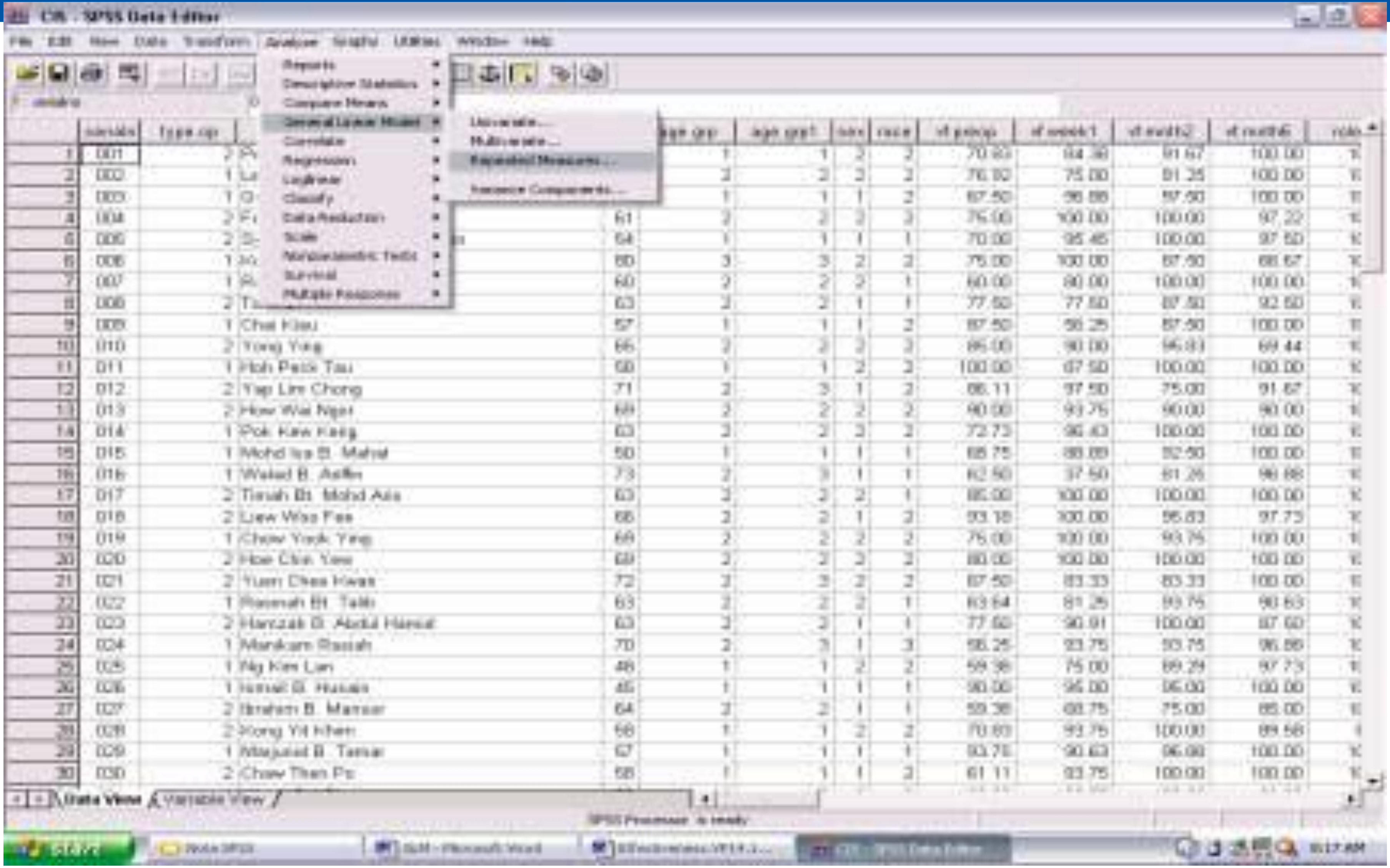
- accommodate two or more dependent variables
- yet the predictors maybe
  - Categorical predictors only
  - Continuous predictors only
  - Combinations of categorical predictors and continuous predictors

Repeated Measures

- can also fit repeated measures or within-subjects models, including doubly multivariate repeated measures models involving multiple measures at each time point or under each combination of conditions.

How?

- To use a GLM procedure, from the menus choose one of the following:
  - **Analyze**
  - **General Linear Model**
  - **Univariate… or**
  - **Multivariate… or**
  - **Repeated Measures…**


Univariate...
Multivariate...
Repeated Measures...
Variance Components...
Data View
Variable View

GLM

- Univariate
- Multivariate
- **Repeated Measures**

Repeated Measurement Analysis

GLM

Introduction

- The simplest repeated measurement analysis is the pre-post type of study, where we have only two timepoints.
- There are many situations where one collects information at baseline and then at regular intervals over time, say three monthly, and is interested to determine whether a treatment is effective over time.

Common techniques

1. Mean response over time – Interest in overall treatment effect. No information on treatment effect changes over time.
2. Separate analyses at each time point – This is most common in medical journals. Repeated testing at each time point causes inflated type I error and results in interpretation problems. Treatment standard errors are less accurate as only observations at each time point used. Must be discouraged!
3. Analyses of response features – Area under the curve, minimum/maximum values, time to max values.

Let us consider a dataset from SPSS (Table I) where the number of errors made by each subject as each repeats the same task over 4 trials were recorded.

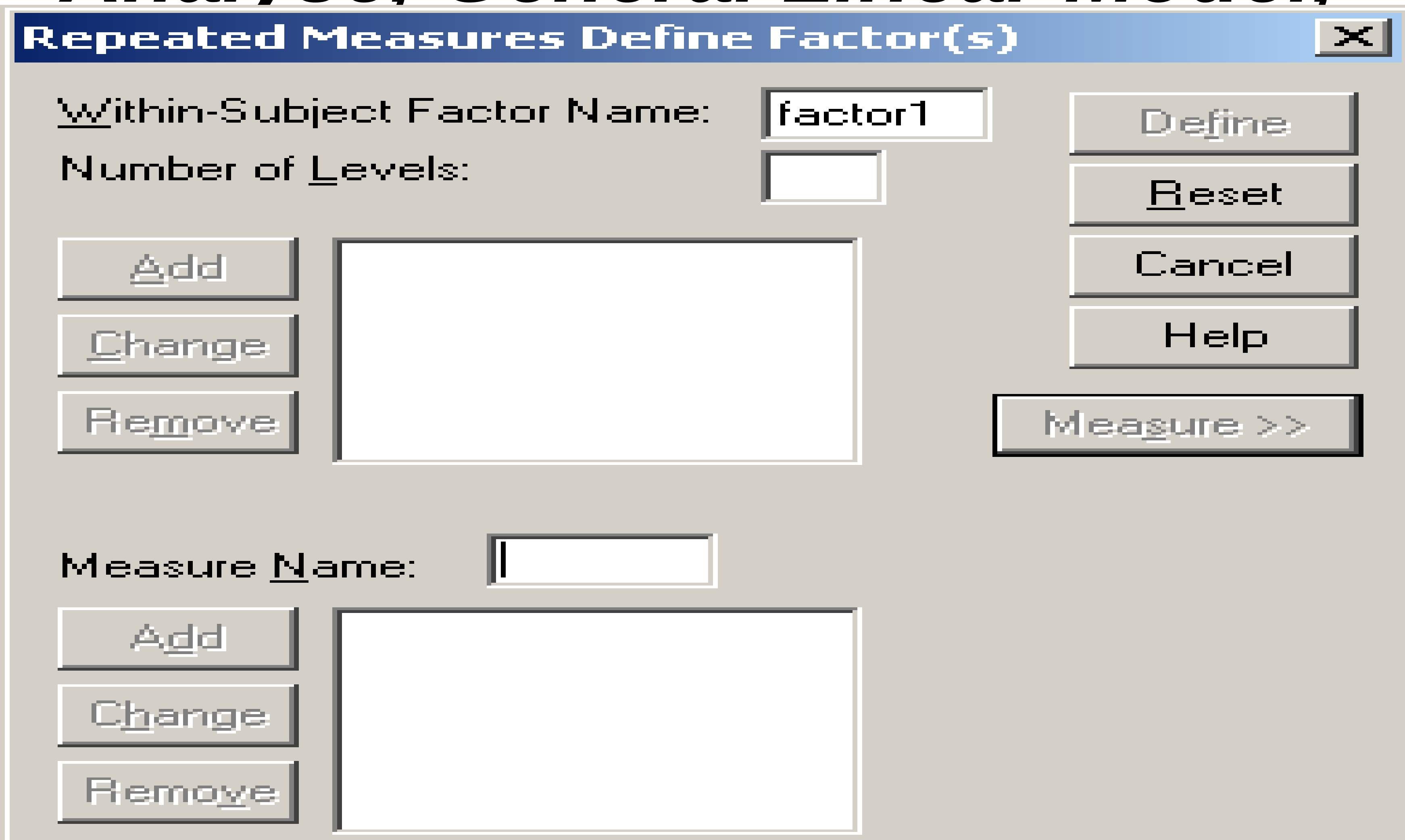
Table I. Anxiety data set (Longitudinal form).

Subject	Anxiety	Trial 1	Trial 2	Trial 3	Trial 4
1	Low	18	14	12	6
2	Low	19	12	8	4
3	Low	14	10	6	2
4	Low	16	12	10	4
5	Low	12	8	6	2
6	Low	18	10	5	1
7	High	16	10	8	4
8	High	18	8	4	1
9	High	16	12	6	2
10	High	19	16	10	8
11	High	16	14	10	9
12	High	16	12	8	8

Three questions one would want to ask are:

1. Is there a difference in the number of errors made between the Low and High anxiety subjects? This is termed as the Between-Subject Factor – a factor that divides the sample of subjects into distinct subgroups.
2. Is there a reduction in the number of errors made over trials – a time trend? This is termed as the Within-Subject Factor - distinct measurements made on the same subject, for example, BP over time, thickness of the vertebrae of animals.
3. Is there a group time interaction? If there is a time trend, whether this trend exists for all groups or only for certain groups?

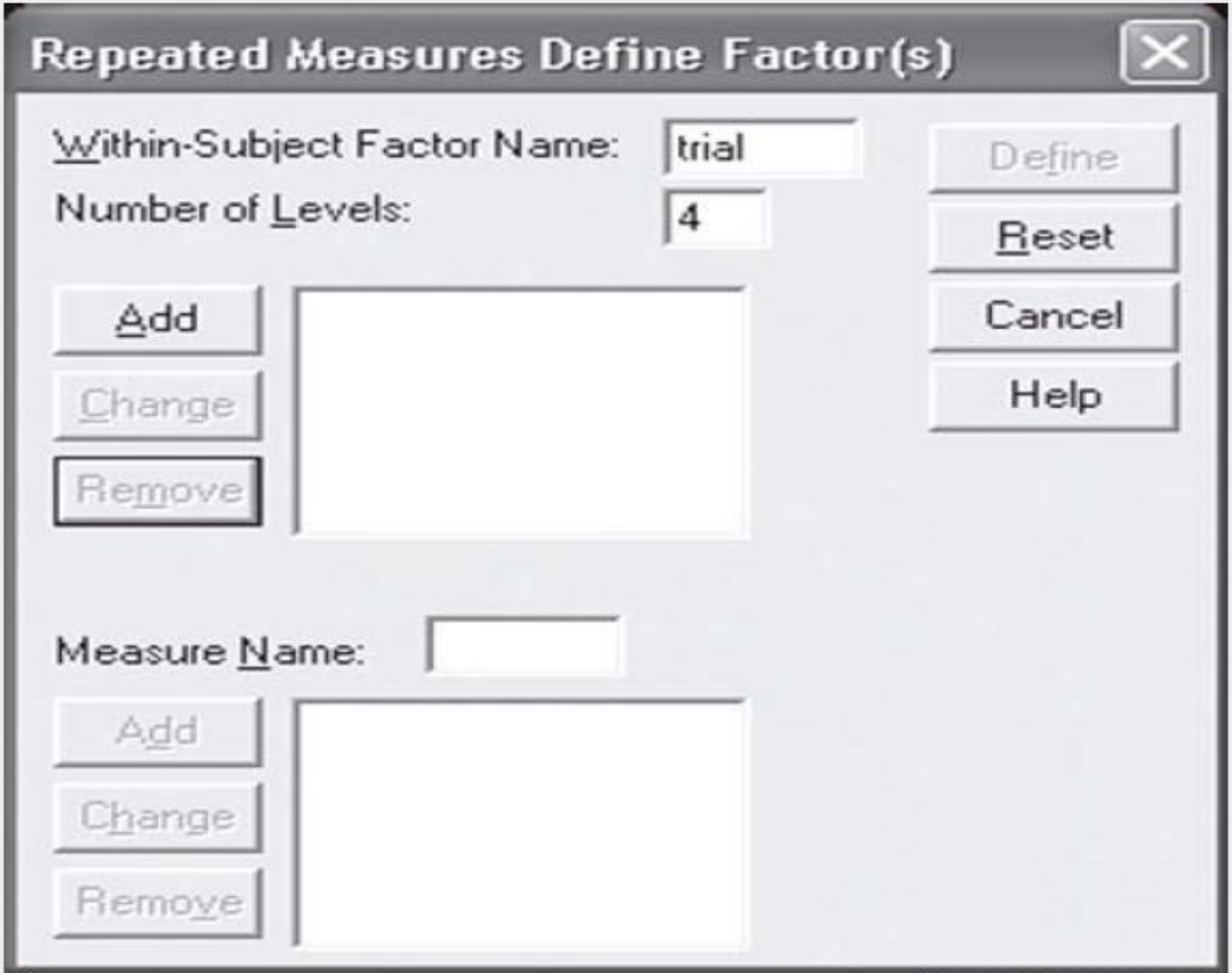
Analyse, General Linear Model,



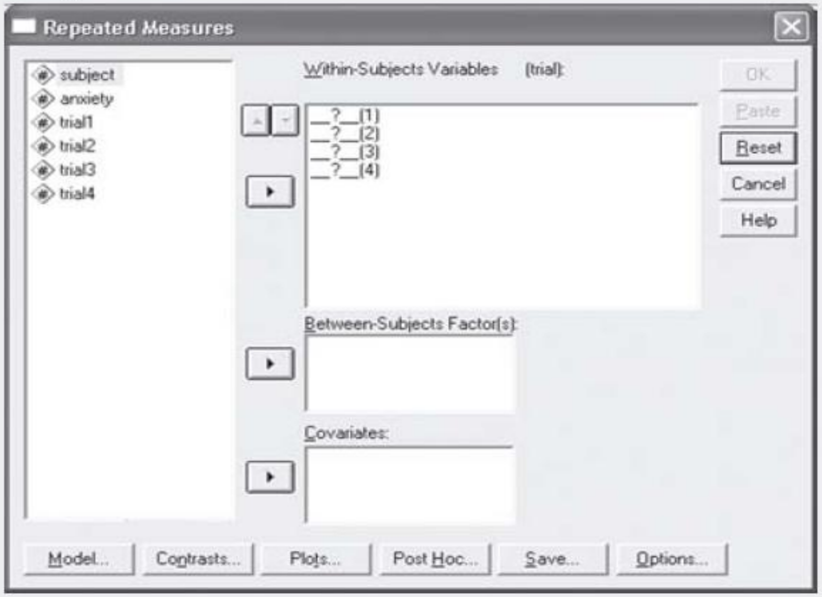
GLM – Repeated Measures

- Change the Within-Subject Factor Name to “trial” (or any suitable term) and put “4” in the Number of Levels (number of repeated measurements) – see Template II.

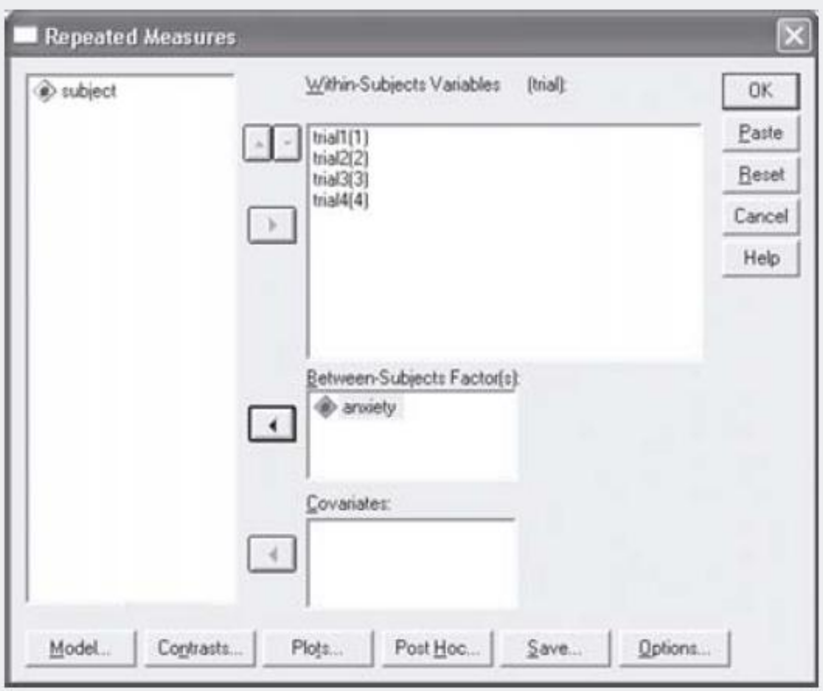
Template II. Defining the number of levels.



Template III.



Template IV.



1. Click Add, then Define.
2. Bring the variables “trial1” to “trial4” over to within-Subjects Variables panel and “anxiety” to the Between-Subjects Factor panel.
3. The above steps set up the “basic” analyses for a repeated measurement analysis.

1. THE BETWEEN-SUBJECTS DIFFERENCE

Table IIa. Between-Subjects difference.

Tests of Between-Subjects effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III sum of squares	df	Mean square	F	Sig.
Intercept	4800.000	1	4800.000	280.839	.000
Anxiety	10.083	1	10.083	.590	.460
Error	170.917	10	17.092		

Table IIa shows that there were no differences in the mean number of errors made over time between the Low and High anxiety groups (p=0.460).

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.521	1	2.521	.590	.460
Within Groups	42.729	10	4.273		
Total	45.250	11			

Further Analysis

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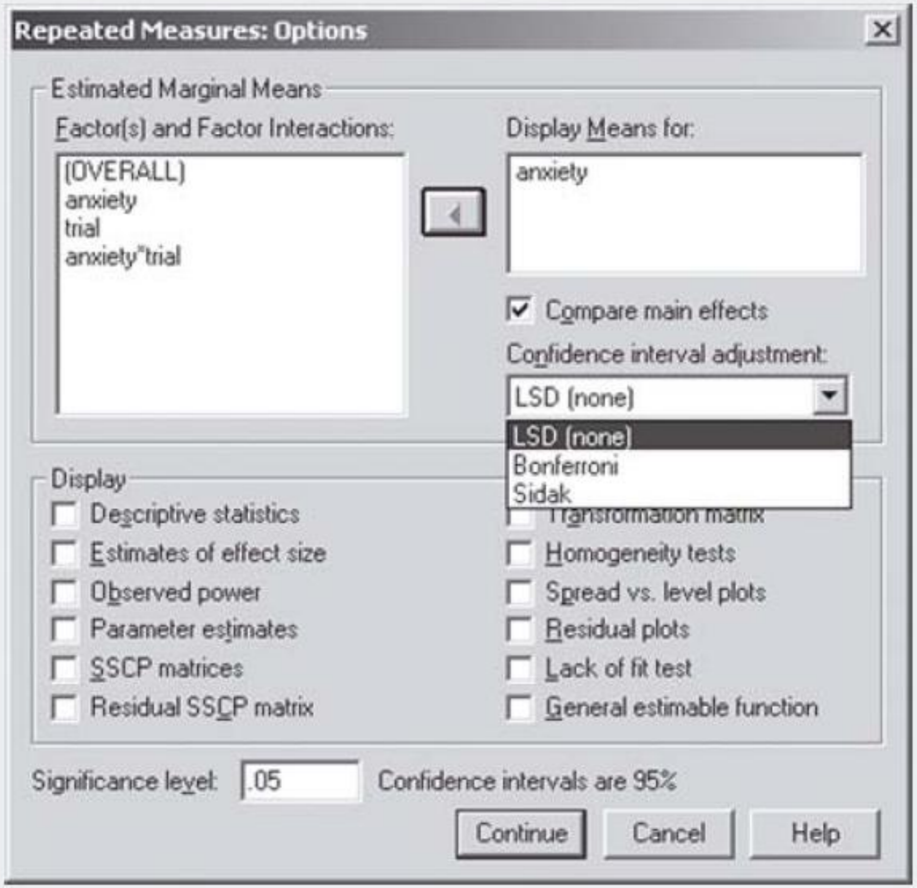
Template V. Options for Comparing Main effects.



- Put “anxiety” in the Display Means panel- this will give Table IIb. To get Table IIc, tick the Compare main effects box and choose Bonferroni (using the most conservative technique to adjust the p value for multiple comparisons(4)).
- The LSD (none) does not adjust the p value for the multiple comparisons.

Table IIb. Descriptive statistics by anxiety.

Anxiety				
Measure: MEASURE_1				
			95% Confidence interval	
Anxiety	Mean	Std. error	Lower bound	Upper bound
Low anxiety	9.542	.844	7.661	11.422
High anxiety	10.458	.844	8.578	12.339

Results

Table IIc. Pairwise comparisons by anxiety.

Pairwise Comparisons

Measure: MEASURE_1

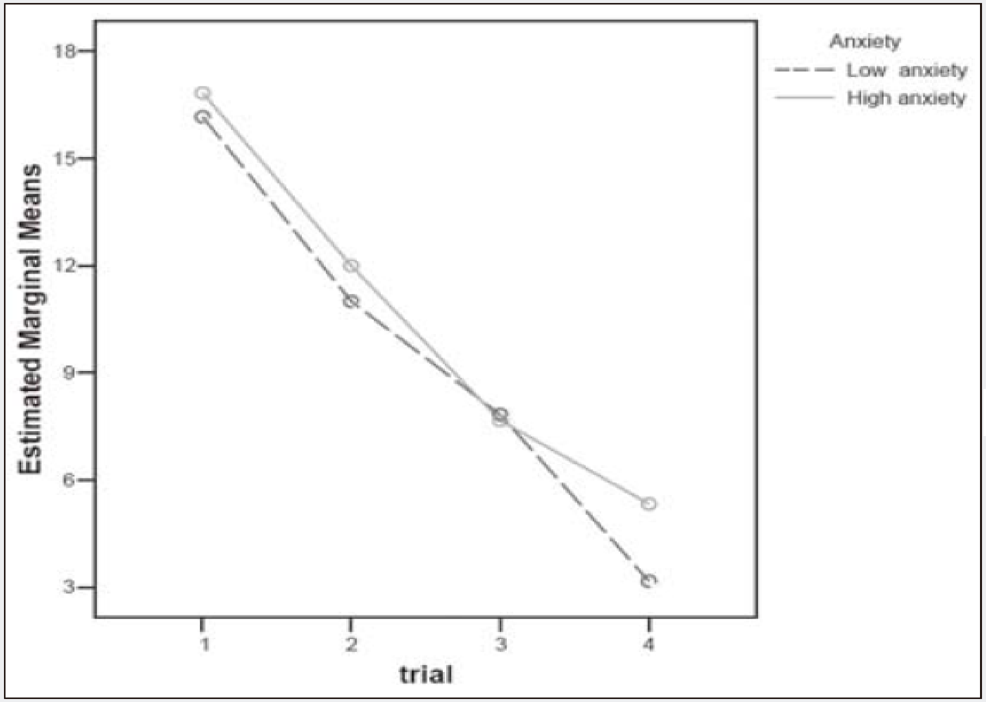
(I) Anxiety	(J) Anxiety	Mean difference (I-J)	Std. error	Sig.[a]	95% Confidence interval for Difference[a] Lower bound	Upper bound
Low anxiety	High anxiety	-.917	1.193	.460	-3.576	1.742
High anxiety	Low anxiety	.917	1.193	.460	-1.742	3.576

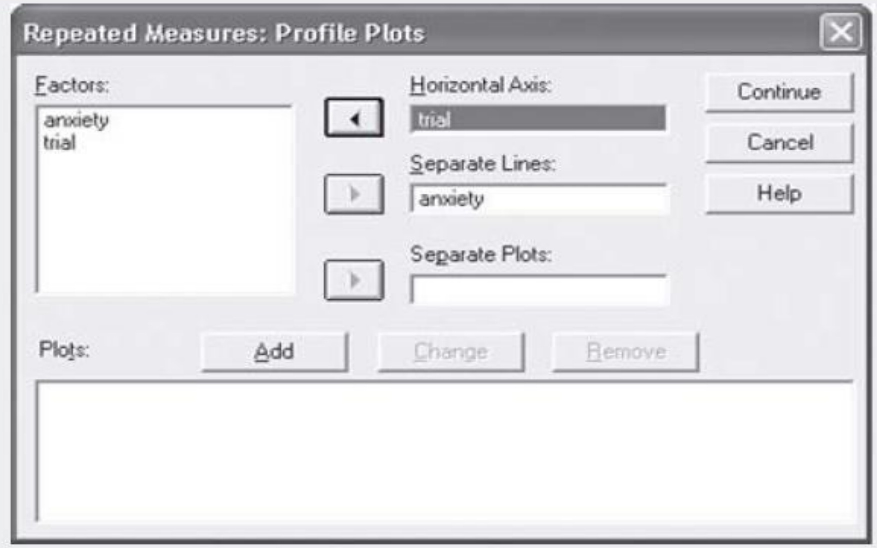
Based on estimated marginal means.

[a] Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

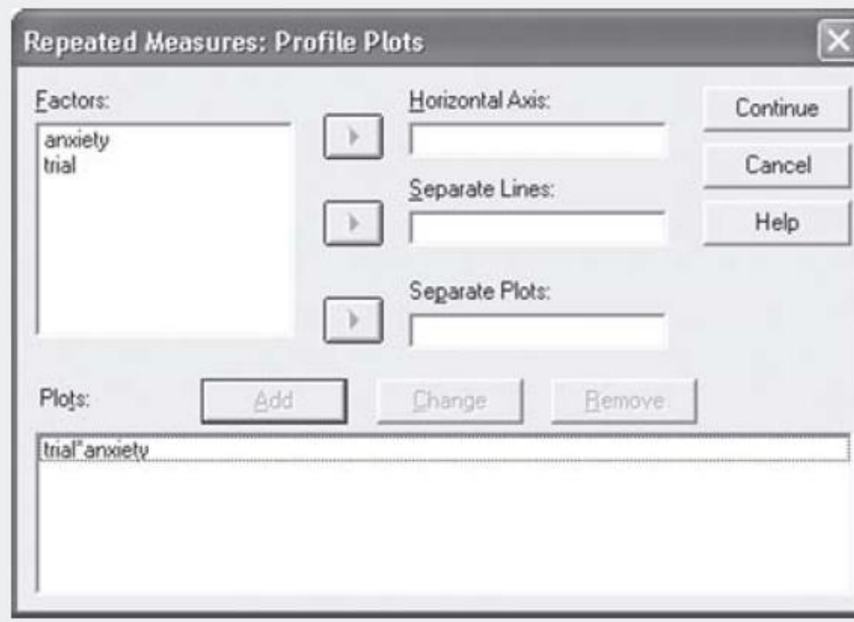
Plots

Fig. 1. Graphical plot for repeated measurement analysis





Template VIII. Requesting for plots.



To get a helpful graphical plot (Fig. 1), click on the Plots folder in Template IV to get Template VII.

Put "trial" in the Horizontal Axis and "anxiety" in the Separate Lines – the Add button becomes visible, click on it to get Template VIII.

Click Continue and then click on OK in Template IV to run the analysis.

Within Subjects Analysis

Table IIIa. Descriptive statistics of trial by anxiety.

	Anxiety	Mean	Std. deviation	N
Trial 1	Low anxiety	16.17	2.714	6
	High anxiety	16.83	1.329	6
	Total	16.50	2.067	12
Trial 2	Low anxiety	11.00	2.098	6
	High anxiety	12.00	2.828	6
	Total	11.50	2.431	12
Trial 3	Low anxiety	7.83	2.714	6
	High anxiety	7.67	2.338	6
	Total	7.75	2.417	12
Trial 4	Low anxiety	3.17	1.835	6
	High anxiety	5.33	3.445	6
	Total	4.25	2.864	12

- Both anxiety groups do display a reduction in the number of errors over time, as observed from Fig. 1.
- Is this reduction trend significant for both groups or just for one group?
- Repeated measurement analysis give us 2 "approaches" to analyse the Within-Subjects effect: **Univariate** and **Multivariate** (both approaches give the same result for the Between-Subject effect).

Univariate Approach Within GLM RM

Univariate

- The **Univariate** approach needs the Within-Subjects variance-covariance to have a Type H structure (or circular in form – correlation between any two levels of Within-Subjects factor has the same constant value). This assumption is checked using the Mauchly's Sphericity test (Table IIIb).

Mauchly’s test of Sphericity

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Table IIIb. Sphericity test.

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
Trial	.283	11.011	5	.053	.544	.701	.333

Tests the null hypothesis that the error covariance matrix of the orthonormalised 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 + anxiety
Within Subjects Design: trial

We want the Sig to be >0.05 for the assumption of sphericity to be valid. If Sig <0.05, we can use the adjusted p values given by Greenhouse-Geisser, Huynh-Feldt or Lower-bound.

Table IIIc. Univariate test of Within-Subjects effects.

Tests of Within-Subjects effects

Measure: MEASURE_1

Source		Type III sum of squares	df	Mean square	F	Sig.
Trial	Sphericity Assumed	991.500	3	330.500	128.627	.000
	Greenhouse-Geisser	991.500	1.632	607.468	128.627	.000
	Huynh-Feldt	991.500	2.102	471.773	128.627	.000
	Lower-bound	991.500	1.000	991.500	128.627	.000
Trial * anxiety	Sphericity Assumed	8.417	3	2.806	1.092	.368
	Greenhouse-Geisser	8.417	1.632	5.157	1.092	.346
	Huynh-Feldt	8.417	2.102	4.005	1.092	.357
	Lower-bound	8.417	1.000	8.417	1.092	.321
Error (trial)	Sphericity Assumed	77.083	30	2.569		
	Greenhouse-Geisser	77.083	16.322	4.723		
	Huynh-Feldt	77.083	21.016	3.668		
	Lower-bound	77.083	10.000	7.708		

Table IIIc shows that there is a reduction of errors committed over trials ($p<0.001$ given by the Sig value of the Source = trial with sphericity assumed).

The Sig of source = trial*anxiety with sphericity assumed is 0.368 which means that there is no time*group interaction, i.e. both low and high anxiety groups had a reduction in the number of errors made over trials.

Multivariate Approach Within GLM RM

Multivariate Approach

- The **Multivariate** approach assumes that the correlation for each level of Within-Subjects factor is different and the vector of the dependent variables follows a multivariate normal distribution with the variance-covariance matrices being equal across the cells formed by the Between-subject effects.
- This homogeneity of the Between-Subjects variance-covariance is checked by using Box's M test (Table IIId); obtained by ticking the Homogeneity test box in Template V.

Table IIId. Box's M test.

Box's test of equality of Covariance Matrices[a]	
Box's M	21.146
F	1.161
df1	10
df2	478.088
Sig.	.315

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

[a] Design: Intercept + anxiety
Within-Subjects design: trial

- The p value for the Box's test is 0.315 (we want p>0.05), implying that the homogeneity assumption holds.

Table IIIe. Multivariate test of Within-Subjects effects.

Multivariate tests[b]						
Effect		Value	F	Hypothesis df	Error df	Sig.
Trial	Pillai's Trace	.961	64.854[a]	3.000	8.000	.000
	Wilk's Lambda	.039	64.854[a]	3.000	8.000	.000
	Hotelling's Trace	24.320	64.854[a]	3.000	8.000	.000
	Roy's Largest Root	24.320	64.854[a]	3.000	8.000	.000
Trial * anxiety	Pillai's Trace	.479	2.451[a]	3.000	8.000	.138
	Wilk's Lambda	.521	2.451[a]	3.000	8.000	.138
	Hotelling's Trace	.919	2.451[a]	3.000	8.000	.138
	Roy's Largest Root	.919	2.451[a]	3.000	8.000	.138

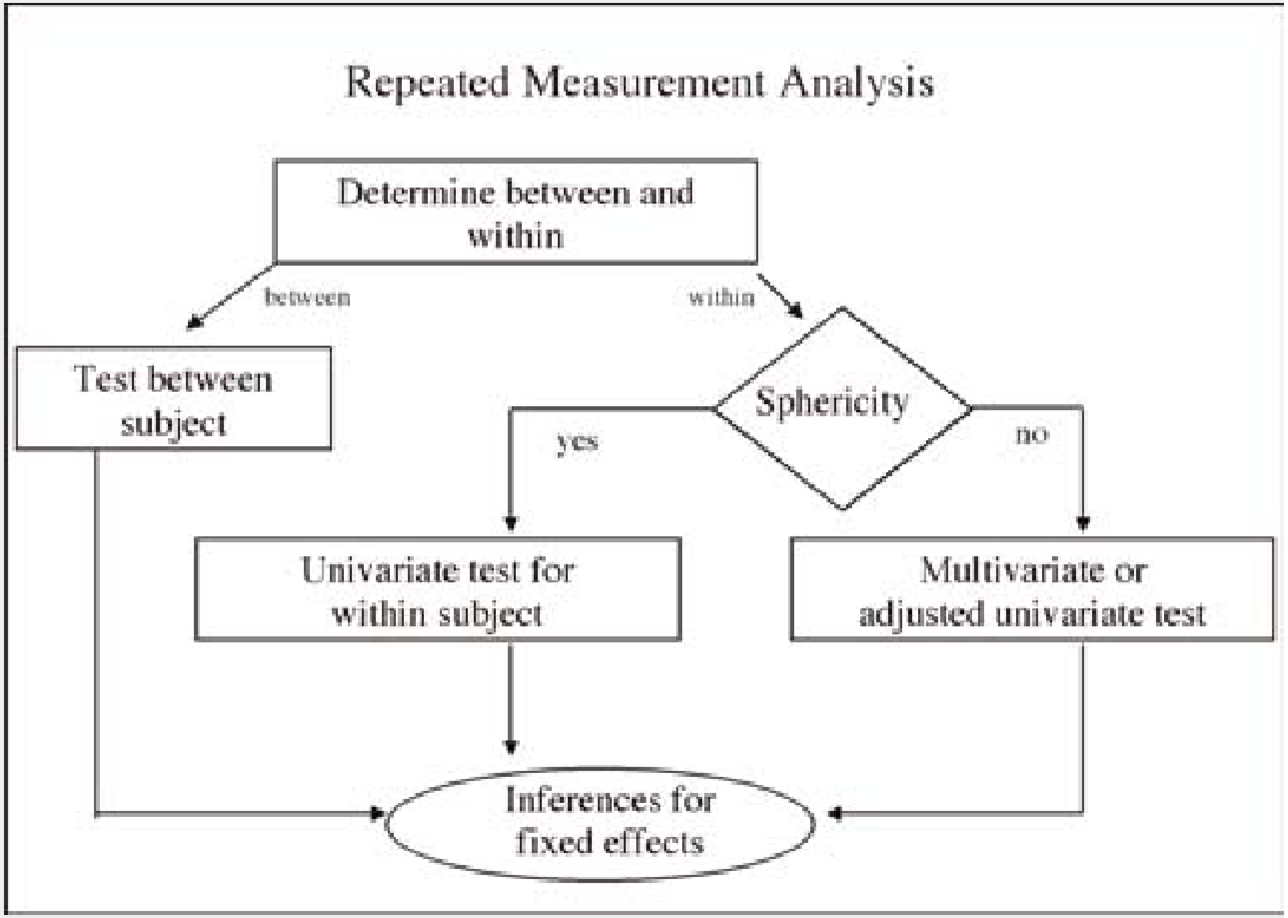
[a] Exact statistic
[b] Design: Intercept + anxiety
Within-Subjects design: trial

- Table IIIe shows the Within-Subjects analysis from the Multivariate procedure. Once again, there is a time trend effect ($p<0.001$) with no time*group interaction effects ($p=0.138$).
- Most of the time the results from Pillai's Trace, Wilks' Lambda, Hotelling's Trace and Roy's Largest Root should be the similar. In the event when the results are different, Wilks' Lambda should be chosen.

Univariate or Multivariate Within GLM RM?

- Now both assumptions for Univariate and Multivariate procedures were valid. Which procedure should we use?
- Figure II gives the flowchart for the decision.
- Check the Sphericity assumption first- if satisfied, use the results from the Univariate procedure.
- Otherwise, proceed with the adjusted Univariate or Multivariate tests.

Fig. 2 Flow chart for Repeated Measurement Analysis.



ANOVA

errors

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.521	1	2.521	.590	.460
Within Groups	42.729	10	4.273		
Total	45.250	11			

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	4800.000	1	4800.000	280.839	.000
Anxiety	10.083	1	10.083	.590	.460
Error	170.917	10	17.092		

Terima Kasih

MEAN(Trial1,Trial2,Trial3,Trial4)

GLM

- **Univariate**
- Multivariate
- Repeated Measures

Two Way ANOVA, ANCOVA & Factorial ANOVA

GLM

Univariate

- **Two-way between-groups ANOVA**

Two-way between-groups ANOVA

- Two-way means that there are two independent variables
- between-groups indicates that different people are in each of the groups.
- This technique allows us to look at the individual and joint effect of two independent variables on one dependent variable.

Two-Way ANOVA

- The advantage of using a two-way design is that we can test the ‘main effect’ for each independent variable and also explore the possibility of an ‘interaction effect’.
- An interaction effect occurs when the effect of one independent variable on the dependent variable depends on the level of a second independent variable.

Example

- the influence of age on quality of life is different for males and females.
- for males, quality of life may increase with age, while for females it may decrease.

Example

- A total of 100 patients who needed cataract operation
- They were randomly allocated into two groups;
  - 50 in ECCE and
  - 50 in Phaco group.
- Effectiveness of cataract operation was assessed by generic quality of life questionnaire (Short-form 36, SF-36).
- The score ranges from 0 (unable to do all applicable activities) and a maximum of 100 (able to do all applicable items without difficulty).
- SF-36 questionnaire was administered
  - prior to operation,
  - one week,
  - two months and
  - six months after operation.
- For this analysis we will use physical dimension of quality of life.

Data

File name	Variable name	Variable label	Coding instructions
CIS	phys1	Quality of life (physical dimension) pre-operation.	Total score on the quality of life (physical dimension) before cataract operation. Scores can range from 0 to 100 with high scores indicating higher levels of quality of life.
	age.grp	Age coded into 3 groups	This variable is a recoded variable, dividing age into three equal groups: Group 1: 45 – <60 = 1 Group 2: 60 – <75 = 2 Group 3: 75 + = 3
	sex	Sex	Males = 1 , Females = 2

Research question

- What is the impact of age and gender on quality of life (physical dimension)?
- Does gender moderate the relationship between age and quality of life (physical dimension)?

Involves 3 variables

- Two categorical independent variables (e.g: sex: males/females; age group: group 1, 2 & 3)
- One continuous dependent variable (e.g: quality of life (physical dimension) - phys1)
- Two-way ANOVA allows you to simultaneously test for the effect of each of your independent variables on the dependent variable and also identifies any interaction effect.

It allows you to test for;

- Sex difference in quality of life (physical dimension)
- Differences in quality of life (physical dimension) for age group 1, 2, and 3 patients
- The interaction of these two variables – is there a difference in the effect of age on quality of life (physical dimension) for males and females?

Assumptions

- Normal distribution
- Homogeneity of variance

Normal distribution

- Kolmogorov-Smirnov statistic (a non-significant result, $p>0.05$ indicates normality)
- Skewness and kurtosis values (if the distribution is perfectly normal, the value of skewness and kurtosis are 0)
- Histograms (appear to be reasonably normally distributed)
- Normal Q-Q Plots (a reasonably straight line between observed value for each score against the expected value from the normal distribution, suggests a normal distribution)
- Detrended Normal Q-Q Plots (there should be no real clustering of points, with most collecting around the zero line)
- Boxplot (the rectangle represents 50% of the cases, with the whiskers (the lines protruding from the box) going out to the smallest and largest values. Additional circles outside the range is called outliers. The line inside the rectangle is the median value.

Homogeneity of variance

- The samples are assumed to be obtained from populations of equal variances. This means that the variability of scores for each of the groups is similar.
- Levene's test can be performed to test the equality of variances as part of the t-test and analysis of variances analyses.
- A significance value of less than 0.05, suggests that variances for the two groups are not equal, and therefore the assumption of homogeneity of variance is violated.
- Analysis of variance is reasonably robust to violations of this assumption, provided the size of the groups is reasonably similar (largest/smallest = 1.5).

Procedure

- **Choose, General Linear Model then Univariate…**
- Click on your dependent variable (phys1) and move it into the box labeled **Dependent variable**.
- Click on your two independent variables (sex, age.grp) and move these into the box labeled **Fixed factors**.
- Under **Options,** click on **Descriptive Statistics, Estimates of effect size, Observed power,** and **Homogeneity tests.**
- Under **Post Hoc,** choose the independent variable(s) you are interested in eg: age.grp and choose Tukey as the test.
- **Under Plots;**
  - In the **Horizontal** box put the independent variable that has the most groups (eg: age.grp).
  - In the box labeled **Separate Lines** put the other independent variable (eg: sex)

INTERPRETATION

Descriptive statistics

- These provide the mean scores, standard deviations and N for each subgroup. Check that these values are correct.

Descriptive statistics

Descriptive Statistics

Dependent Variable: PHYS1

Age group	Sex of patient	Mean	Std. Deviation	N
45 - <60	Male	90.5882	21.49726	17
	Female	85.0000	15.94261	13
	Total	88.1667	19.18527	30
60 - <75	Male	80.8000	18.29617	25
	Female	84.6053	17.13940	38
	Total	83.0952	17.56161	63
75 +	Male	55.0000	.	1
	Female	50.8333	20.35109	6
	Total	51.4286	18.64454	7
Total	Male	84.0698	20.27360	43
	Female	81.1404	19.88847	57
	Total	82.4000	20.00606	100

Levene's Test of Equality of Error Variances

- This test provides a test of one of the assumptions underlying analysis of variance.
- The value you are most interested in is the Sig. level. You want this to be greater than 0.05 (not significant).
- A significant result suggest that the variance of your dependent variable across the group is not equal.

Levene's Test of Equality of Error Variances

Levene's Test of Equality of Error Variances[a]

Dependent Variable: PHYS1

F	df1	df2	Sig.
.644	5	94	.667

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

a. Design: Intercept+AGE.GRP+SEX+AGE.GRP * SEX

Levene's Test of Equality of Error Variances

- In the example displayed above the Sig. level is 0.667. As this is larger than 0.05, we can conclude that we have not violated the homogeneity of variance assumption.

Main effects

- The main output from two-way ANOVA is a table labeled **Tests Of Between-Subjects Effects**.
- In the left-hand column the independent variables are listed.
- To determine if there is a main effect for each independent variable, check in the column marked **Sig.** next to each variable.
- If the value is less than 0.05, then there is a significant main effect for that independent variable.

Main effects

Tests of Between-Subjects Effects

Dependent Variable: PHYS1

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Corrected Model	8205.970[b]	5	1641.194	4.910	.000	.207	24.552	.977
Intercept	145868.326	1	145868.326	436.425	.000	.823	436.425	1.000
AGE.GRP	3781.092	2	1890.546	5.656	.005	.107	11.313	.851
SEX	25.862	1	25.862	.077	.781	.001	.077	.059
AGE.GRP * SEX	456.420	2	228.210	.683	.508	.014	1.366	.162
Error	31418.030	94	334.234					
Total	718600.000	100						
Corrected Total	39624.000	99						

a. Computed using alpha = .05

b. R Squared = .207 (Adjusted R Squared = .165)

Main effects

- In the example shown, there is a significant main effect for age group (p=0.005), but no significant main effect for sex (p=0.781).
- This means that males and females do not differ in terms of their quality of life (physical dimension) scores,
- However there is a difference in scores for age groups patient 1, 2 and 3.

Effect size

- The effect size for the age.grp variable is provided in the column labeled **Eta Squared** (0.107).
- Using Cohen's criterion, this can be classified as small effect.
- This means that the difference in quality of life (physical dimension) between the groups is small and it's significant.

Cohen's Criterion

- small if d = .20 or r = .10.
- medium if d = .50 or r = .30.
- large if d = .80 or r = .50

Interaction effects

- SPSS tells you whether there is an interaction between the two independent variables in their effect on the dependent variable.
- The line you need to look at in the table lists your two independent variables separated by an asterisk (sex*age.grp).
- To find out if the interaction is significant, check the Sig. column for that line.
- If the value is less than 0.05, then there is a significant interaction effect.

Interaction effects

- In the example, the interaction effect is not significant (sex*age.grp: p=0.508).
- This indicates that there is no significant difference in the effect of age on quality of life (physical dimension) for males and females.

Post-hoc tests

- Although we know that our age group differ, we do not know where these difference occur:
  - is group 1 different to group 2,
  - is group 2 different to group 3, or
  - is group 1 different to group 3 ?
- To investigate these questions, we need to conduct post-hoc tests.
- Post-hoc tests are only relevant if you have more than two level (groups) to your independent variable. However you are not supposed to look at them, until you find a significant main effect or interaction effect in the overall analysis.
- The results of the post-hoc tests are provided in the table labeled **Multiple Comparisons**.
- We have requested the Tukey, as this is one of the more commonly used tests. Look down the column labeled **Sig.** for any values less than 0.05 (indicated by an asterisk).

Post-hoc tests

Multiple Comparisons

Dependent Variable: PHYS1

Tukey HSD

(I) Age group	(J) Age group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
45 - <60	60 - <75	5.0714	4.05542	.427	-4.5862	14.7290
	75 +	36.7381*	7.67391	.000	18.4634	55.0128
60 - <75	45 - <60	-5.0714	4.05542	.427	-14.7290	4.5862
	75 +	31.6667*	7.28375	.000	14.3211	49.0122
75 +	45 - <60	-36.7381*	7.67391	.000	-55.0128	-18.4634
	60 - <75	-31.6667*	7.28375	.000	-49.0122	-14.3211

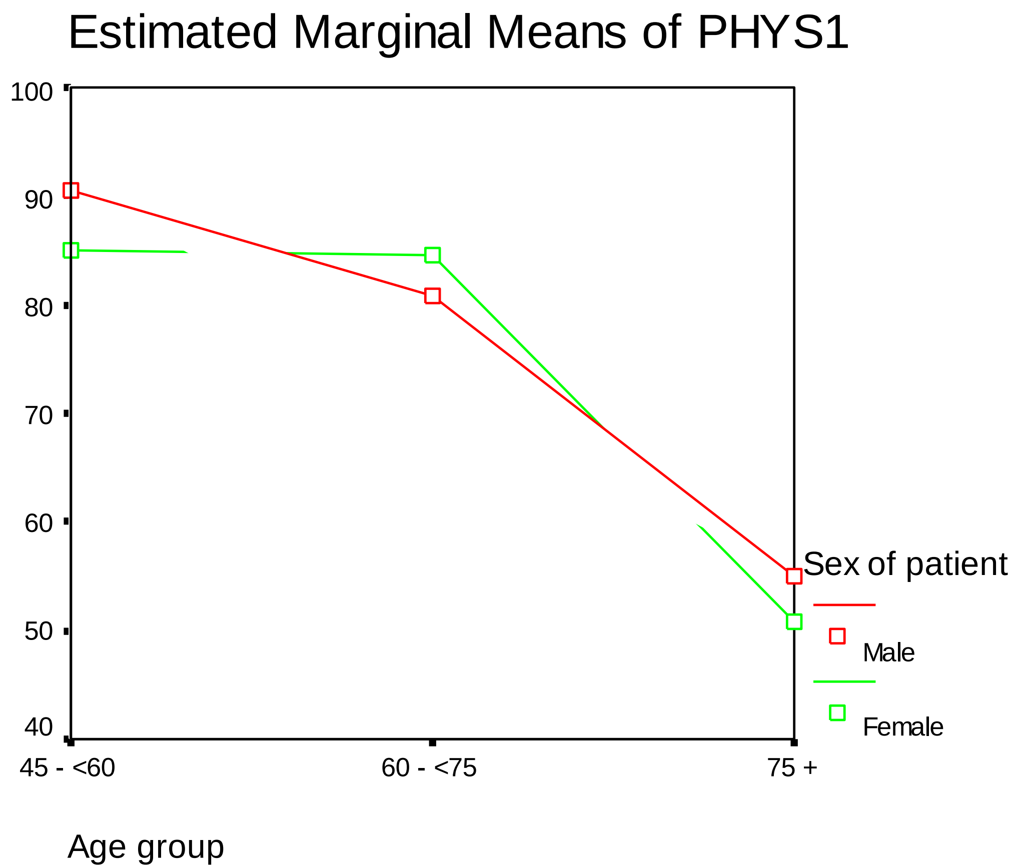
Based on observed means.

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

Post-hoc tests

- In the example, only group 1 (45 – <60) and group 3 (75 +), and group 2 (60 - <75) and group 3 (75 +) differ significantly from one another.

Plots


Estimated Marginal Means of PHYS1
100
90
80
70
60
50
40
45 - <60
60 - <75
75 +
Sex of patient
Male
Female
Age group

GLM

- Univariate
- **Multivariate**
- Repeated Measures

MANOVA

GLM

Multivariate

- accommodate two or more dependent variables
- yet the predictors maybe
  - Categorical predictors only
  - Continuous predictors only
  - Combinations of categorical predictors and continuous predictors

Multivariate

- Multivariate analysis of variance (MANOVA) is an extension of analysis of variance for use when you have *more than one dependent variable. These dependent variables should* be related in some way, or there should be some conceptual reason for considering them together.

Multivariate analysis of variance

- why not just conduct a series of ANOVAs separately for each dependent variable?
- By conducting a whole series of analyses you run the risk of an ‘inflated Type 1 error’.
- The more analyses you run, the more likely you are to find a significant result, even if in reality, there are no real differences between your groups.

Research question

- Do patients in ECCE and Phaco groups differ in terms of overall wellbeing?
- Are patients in ECCE better in their wellbeing than Phaco in terms of their VF-14, quality of life (physical dimension) and (mental dimension) before undergoing cataract operation ?

Assumptions

a) Sample size

b) Normality

c) Outliers

d) Linearity

e) Homogeneity of regression

f) Multicollinearity and singularity

g) Homogeneity of variance-covariance matrices

Sample size

- Some of these tests are not strictly necessary provided that our sample size is large enough.
- Having a large sample can also help you 'get away with' violations of some of the other assumptions (eg. normality).
- The minimum required number of cases in each cell in this example is three (the number of dependent variables).
- We have a total of six cells (two levels of independent variable (ECCE/Phaco); and three dependent variables for each).

Normal distribution

- Although the significance tests of MANOVA are based on the multivariate normal distribution, in practice it is reasonably robust to modest violations of normality (except where the violations are due to outliers).
- According to Tabachnick and Fidell (1996), a sample size of at least 20 in each cell should ensure 'robustness'.
- You need to check both univariate normality and multivariate normality (using Mahalanobis distances).

Outliers

- MANOVA is quite sensitive to outliers (data points or scores that are different from the remainder of the scores). Check for outliers by using **Explore.**

Outliers

1. From the menu at the top of the screen, click on:

Analyze->Descriptive Statistics->Explore

2. Click on the variable that you want to detect any outliers. Move this into the **Dependents box.**
3. Click on your identifying variable (eg. ID, no.resp), and move it into the box labeled **Label Cases by.**
4. Click on the **Statistics button. Tick Descriptive and Outliers.**
5. Click on **Continue and then OK.** The **Extreme Values box gives you the highest and lowest values for the variable and** the ID number of the sample that recorded these scores. If the score is not too high/low, we will use the data. If there had been a lot of outlying cases, we may need to consider transforming this group of variables or remove the cases from the data file.

Linearity

- This assumption refers to the presence of a straight-line relationship between each pair of your dependent variables.
- This can be assessed in a number of ways, the most straightforward of which is to generate scatterplots between each pair of your variables.
- This involves splitting the file by type of operation, and then generating scatterplots.

Split the file:

1. From the menu at the top of the screen click on: **Data, then click on Split File.**
2. Click on **Organize output by groups.**
3. Click on your independent categorical variable that will be used to create the group (eg. type.op).
4. Move this variable into the box labeled; **Groups based on. Click on OK.**

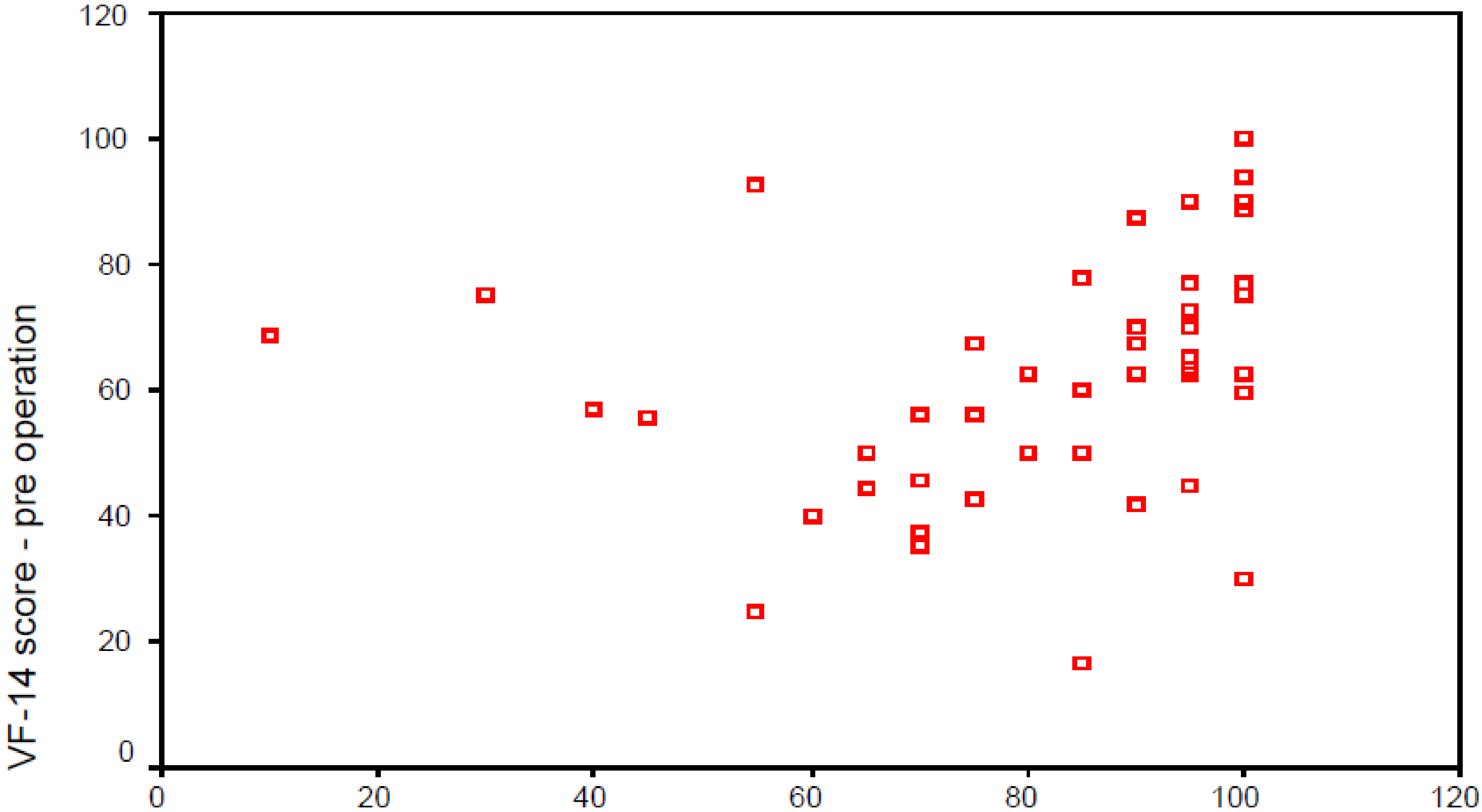
Generate Scatterplots

1. From the menu at the top of the screen click on: **Graphs, then click on Scatter.**
2. Click on **Simple. Click on the Define button.**
3. Click on one of your dependent variables and move it into the box labeled **Y axis.**
4. Click on another of your dependent variables and move it into the box labeled **X axis (it does not matter in which order you enter your variables). Click on OK.**
5. Remember to go back and turn your Split File option off when you have finished.

Click on **Data, then click on Split File.**

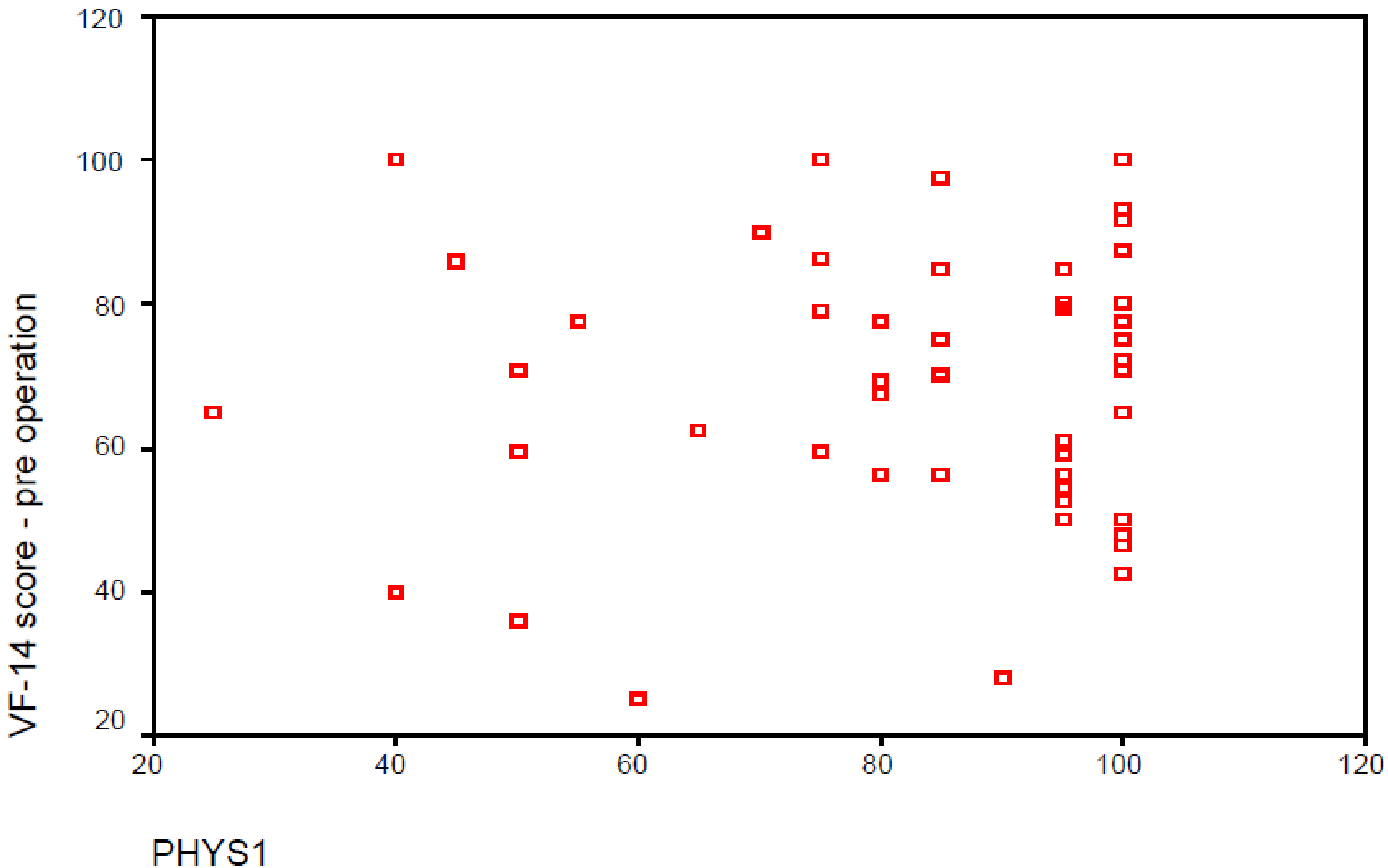
6. Click on **Analyze all cases, do not create groups. Click on OK.**

TYPE.OP: 1 ECCE



PHYS1

TYPE.OP: 2 Phaco



Homogeneity of regression

- This assumption is important if you are intending to perform a step-down analysis.
- This approach is used when you have some theoretical or conceptual reason for ordering your dependent variables and this is quite a complex procedure.

Multicollinearity and singularity

- MANOVA works best when the dependent variables are only moderately correlated. With low correlations you should consider running separate univariate analysis of variance for your various dependent variables.
- When the dependent variables are highly correlated this is referred to as multicollinearity.
- This can occur when one of your variables is a combination of other variables (eg. the total scores of a scale that is made up of subscales that are also included as dependent variables). This is referred to as singularity, and can be avoided by knowing what your variables are, and how the scores are obtained.

Multicollinearity and singularity

- While there are quite sophisticated ways of checking for multicollinearity, the simplest way is to run **Correlation and to check the strength of the correlations** among your dependent variables.
- Correlations up around 0.8 or 0.9 are reason for concern. If you any of these, you may need to consider removing one of the strongly correlated pairs of dependent variables, or alternatively combining them to form a single measure.

Homogeneity of variance-covariance matrices

- Fortunately, the test of this assumption is generated as part of your MANOVA output.
- The test used to assess this is Box's M Test of Equality of Covariance Matrices.

Example

- A total of 100 patients who needed cataract operation
- They were randomly allocated into two groups;
  - 50 in ECCE and
  - 50 in Phaco group.
- Effectiveness of cataract operation was assessed by generic quality of life questionnaire (Short-form 36, SF-36).
- The score ranges from 0 (unable to do all applicable activities) and a maximum of 100 (able to do all applicable items without difficulty).
- SF-36 questionnaire was administered
  - prior to operation,
  - one week,
  - two months and
  - six months after operation.
- For this analysis we will use pre-op VF-14, physical & mental dimension of quality of life, compared between Phaco & ECCE.

This example involves:

- a) One categorical independent variable (eg. type of operation)
- b) Two or more continuous dependent variables (eg. VF-14 (pre-op), quality of life (physical dimension) and (mental dimension) before operation).
- MANOVA compares two or more groups in terms of their means on a group of dependent variables.

Procedure

- **Choose, General Linear Model then Multivariate…**
- Click on your dependent variables (preop-VF14, phys1 & mental1) and move it into the box labeled **Dependent variables**.
- Click on your grouping variable (type.op) and move these into the box labeled **Fixed factors**.
- Click on the **Model button. Make sure that the Full Factorial button is selected** in the **Specify Model box.**
- **Down the bottom in the Sum of Squares box, Type III should be displayed.** Click on **Continue.**
- Click on the **Options button. In the section labeled Factor and factor Interactions, click on your independent variable (eg. type.op). Move it into the** box marked **Display Means for:**
- In the **Display section of this screen, put a tick in the boxes labeled:**
  - **a. Descriptive Statistics**
  - **b. Estimated of Effect Size**
  - **c. Observed Power**
  - **d. Homogeneity tests**
- Click on **Continue and then OK.**

INTERPRETATION

Descriptive statistics

Descriptive Statistics

	Type of Operation	Mean	Std. Deviation	N
VF-14 score - pre operation	ECCE	64.0544	19.7875	50
	Phaco	68.3704	18.6770	50
	Total	66.2124	19.2653	100
PHYS1	ECCE	82.4000	20.3098	50
	Phaco	82.4000	19.9039	50
	Total	82.4000	20.0061	100
MENTAL1	ECCE	69.3600	3.9267	50
	Phaco	66.4000	5.0467	50
	Total	67.8800	4.7382	100

Make sure that you have more subjects (cases) in each cell, than the number of dependent variables.

p>0.01, then not violated the assumption.

Box's Test of Equality of Covariance Matrices[a]

Box's M	14.613
F	2.355
df1	6
df2	69584
Sig.	.028

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

a. Design: Intercept+TYPE.OP

Multivariate Tests

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Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	Pillai's Trace	.996	657.991[b]	3.000	96.000	.000	.996	5973.973	1.000
	Wilks' Lambda	.004	657.991[b]	3.000	96.000	.000	.996	5973.973	1.000
	Hotelling's Trac	270.562	657.991[b]	3.000	96.000	.000	.996	5973.973	1.000
	Roy's Largest R	270.562	657.991[b]	3.000	96.000	.000	.996	5973.973	1.000
TYPE.OI	Pillai's Trace	.102	3.641[b]	3.000	96.000	.015	.102	10.924	.783
	Wilks' Lambda	.898	3.641[b]	3.000	96.000	.015	.102	10.924	.783
	Hotelling's Trac	.114	3.641[b]	3.000	96.000	.015	.102	10.924	.783
	Roy's Largest R	.114	3.641[b]	3.000	96.000	.015	.102	10.924	.783

a. Computed using alpha = .05

b. Exact statistic

c. Design: Intercept+TYPE.OP

Use Wilks' Lambda. Since p less than 0.05, then you can conclude that there is a difference among your groups. In the example shown above, we obtained a Wilks' Lambda value of 0.898, with a significance value of 0.015. This is less than 0.05, therefore there is a statistically significant difference between ECCE and Phaco patients in terms of their overall wellbeing..

Levene's Test of Equality of Error Variances

- This test provides a test of one of the assumptions underlying analysis of variance.
- The value you are most interested in is the Sig. level. You want this to be greater than 0.05 (not significant).
- A significant result suggest that the variance of your dependent variable across the group is not equal.

Levene's Test of Equality of Error Variances

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
VF-14 score - pre operation	.029	1	98	.866
PHYS1	.002	1	98	.969
MENTAL1	2.726	1	98	.102

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

- In the example displayed above the Sig. level is 0.866, 0.969 & 0.102. As this is larger than 0.05, we can conclude that we have not violated the homogeneity of variance assumption.

Main effects

- The main output from MANOVA is a table labeled **Tests Of Between-Subjects Effects**.
- In the left-hand column the independent variables are listed.
- To determine if there is a main effect for each independent variable, check in the column marked **Sig.** next to each variable.
- If the value is less than 0.017 (0.05/3 for 3 dependents), then there is a significant main effect for that independent variable.

Main effects

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Tests of Between-Subjects Effects

Source	Dependent Var	ype III Sum of Squares	df	lean Square	F	Sig.	ta Squared	Noncent. Parameter	Observed Power[a]
Corrected Mc	VF-14 score - p operation	465.683[b]	1	465.683	1.258	.265	.013	1.258	.199
	PHYS1	.000[c]	1	.000	.000	1.000	.000	.000	.050
	MENTAL1	219.040[d]	1	219.040	10.714	.001	.099	10.714	.900
Intercept	VF-14 score - p operation	8408.105	1	38408.105	184.284	.000	.924	1184.284	1.000
	PHYS1	8976.000	1	78976.000	679.276	.000	.945	1679.276	1.000
	MENTAL1	0769.440	1	60769.440	538.036	.000	.996	2538.036	1.000
TYPE.OP	VF-14 score - p operation	465.683	1	465.683	1.258	.265	.013	1.258	.199
	PHYS1	.000	1	.000	.000	1.000	.000	.000	.050
	MENTAL1	219.040	1	219.040	10.714	.001	.099	10.714	.900
Error	VF-14 score - p operation	6278.468	98	370.188					
	PHYS1	9624.000	98	404.327					
	MENTAL1	2003.520	98	20.444					
Total	VF-14 score - p operation	5152.256	100						
	PHYS1	8600.000	100						
	MENTAL1	2992.000	100						
Corrected To	VF-14 score - p operation	6744.151	99						
	PHYS1	9624.000	99						
	MENTAL1	2222.560	99						

a. Computed using alpha = .05

b. R Squared = .013 (Adjusted R Squared = .003)

c. R Squared = .000 (Adjusted R Squared = -.010)

d. R Squared = .099 (Adjusted R Squared = .089)

Tests of Between-Subjects Effects

- In the **Sig. column look for any values that are less than 0.017 (our new adjusted alpha** level).
- In our example, only one of the dependent variables ie. Quality of life (mental dimension) before operation (MENTAL1) recorded a significance value less than our cutoff (with a Sig. value of 0.001).
- In this study, the only significant difference between ECCE and Phaco patients was on their Quality of life (mental dimension) before operation.

Effect size

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- The impact of type of operation on Quality if life (mental dimension) can be evaluated using the effect size statistic provided by SPSS: **Eta Squared.**
- Eta squared represent the proportion of the variance in the dependent variable (mental) that can be explained by the type of operation. The value in this case is 0.099 which considered *moderate to large effect*.
- This represents that 9.9 percent of the variance in Quality of life (mental dimension) scores explained by type of patient (whether ECCE or Phaco).

Cohen’s Criterion

- small if d = .20 or r = .10.
- medium if d = .50 or r = .30.
- large if d = .80 or r = .50

Descriptive Statistics

	Type of Operation	Mean	Std. Deviation	N
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	Total	66.2124	19.2653	100
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	Total	82.4000	20.0061	100
MENTAL1	ECCE	69.3600	3.9267	50
	Phaco	66.4000	5.0467	50
	Total	67.8800	4.7382	100

Estimated Marginal Means

Estimated Marginal Means

Type of Operation

Dependent Variable	Type of Operation	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
VF-14 score - pre operation	ECCE	64.054	2.721	58.655	69.454
	Phaco	68.370	2.721	62.971	73.770
PHYS1	ECCE	82.400	2.844	76.757	88.043
	Phaco	82.400	2.844	76.757	88.043
MENTAL1	ECCE	69.360	.639	68.091	70.629
	Phaco	66.400	.639	65.131	67.669

Comparing group means

- Although we know that ECCE and Phaco patients differed in terms of Quality of life (mental dimension), we do not know who had the higher scores. We refer to the output table provided in the section labeled **Estimated Marginal Means.**
- **For** Quality of life (mental dimension) the mean score for ECCE patients was 69.36 and for Phaco patients, 66.40. Although statistically significant, the actual difference in the two mean scores was very small, less than 3 scale points.

A one-way between-groups multivariate analysis of variance was performed to investigate type of patient (who underwent cataract operation) differences in overall wellbeing. Three dependent variables were used: VF-14 pre-operation,Quality of life (physical dimension) and Quality of life (mental dimension) before operation. The independent variable was type of patient (ECCE / Phaco). Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. There was a statistically significant difference between ECCE and Phaco patients on the combined dependent variables: F = 3.641, p = 0.015; Wilks' Lambda = 0.898; partial eta squared = 0.102. When the results for the dependent variables were considered separately, the only difference to reach statistical significance using a Bonferroni adjusted alpha level of 0.017, was Quality of life (mental dimension) before operation: F = 10.714, p = 0.001, partial eta squared = 0.099. An inspection of the mean scores indicated that ECCE patients reported slightly higher levels of Quality of life (mental dimesion) (M = 69.36, s.d = 0.639) than Phaco patients (M = 66.40, s.d = 0.639) before operation.