PAIRED SAMPLES ANOVA

Definition ● Assumptions ● In SPSS ● Output

Paired samples ANOVA. Definition

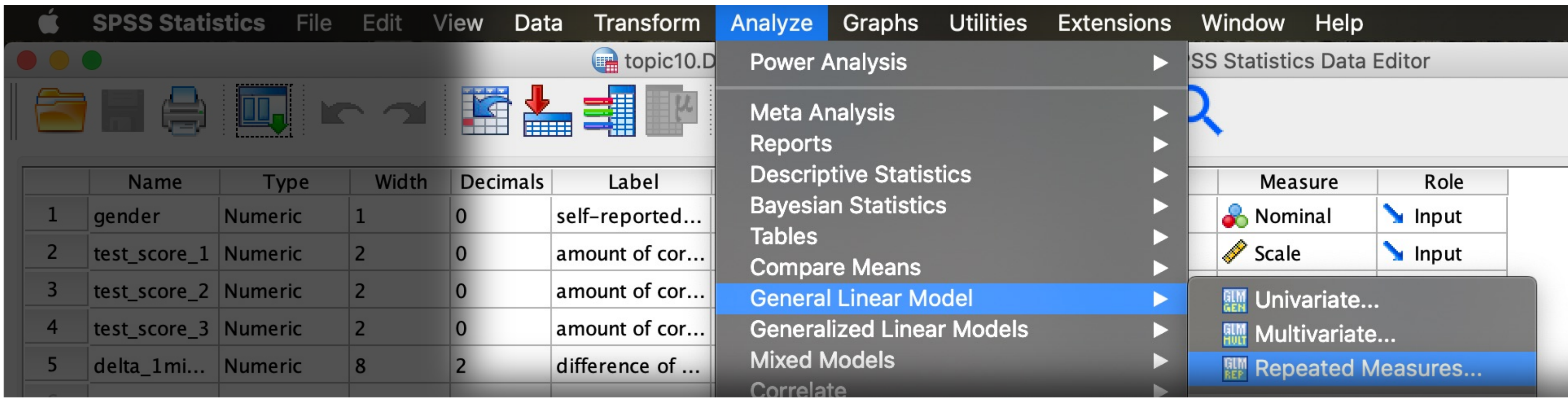
- Also known as repeated measures or within-subjects one-way ANOVA
- This type of one-way ANOVA is used when comparing more than 3 means that were measured on the same group of participants

Paired samples ANOVA. Assumptions in detail

Assumptions			
Num.	Name	Description	How to check for that?
1	Continuous dependent variables	Two or more dependent variables that are either ratio or interval level.	Ensure the data from your dependent variables corresponds to a ratio or interval level
2	Dependent observations	Subjects measured in one of the dependent variables should be the same ones who were measured in the other dependent variable	Ensure the data from the 2 or more continuous dependent variables comes from the same participants
3	No outliers	Removal or correction of outliers	Visual inspection of the boxplots of the dependent variables, ensure there are no indvidual outlier datapoints. If there are, exclude them from the analysis.
4	Normality	Shapiro-Wilk test for the difference between the dependent variables. Test should be not-significant!	Shapiro-Wilk test for the dependent variables. Test should be not-significant!
5	Sphericity	Only required when comparing more than 2 dependent variables (named “levels” in the SPSS box, slide 42). Refers to the condition where the variances of the differences between all combinations of related measurements (levels) are equal.	Mauchly’s test. Test should be not-significant! Test is part of the output of the ANOVA analysis.

Paired samples ANOVA in SPSS

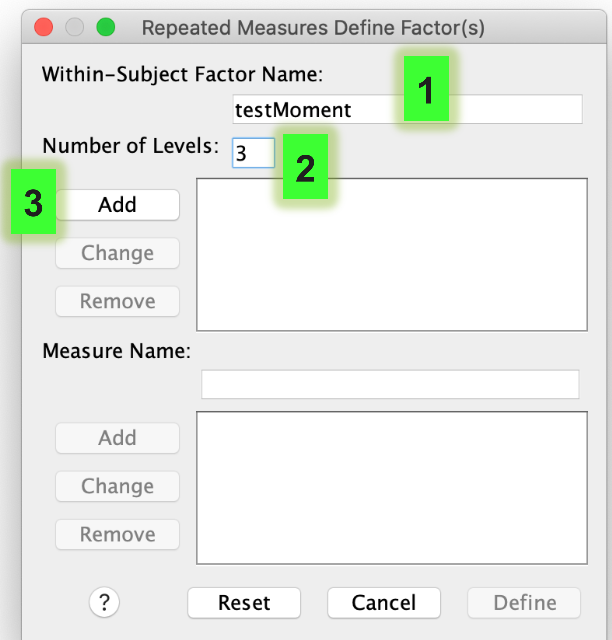
Analyze > General Linear Model > Repeated Measures…

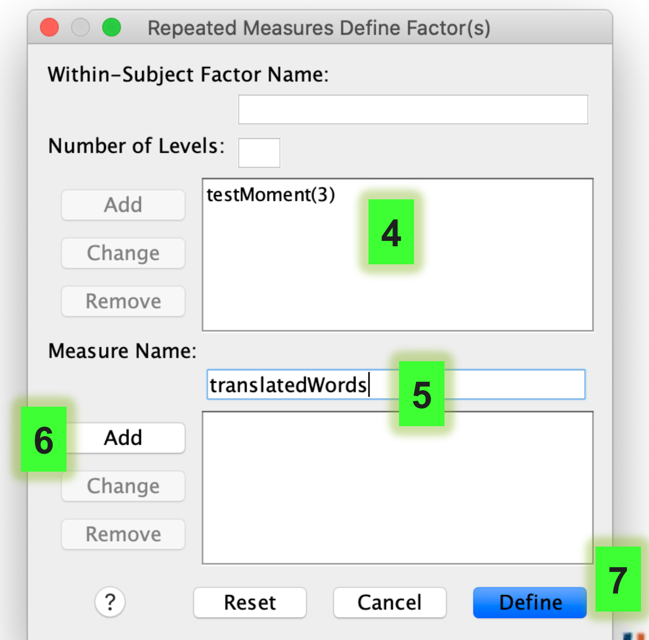


Want to try it out? Use the file "topic10.DepSampl_t-test_ANOVA.sav" provided in the moodle

Paired samples ANOVA in SPSS

The first step in our between-subjects ANOVA setup is to create a single "variable", here called "Factor", that contains the 3 DVs that we want to compare. Therefore, in the window shown here, write the name of the factor in the textbox under the "Within-Subjects Factor Name" section [1]. After that, write the amount of levels [2] this factor should have, which in this case is "3" (test1, test2, test3). Then click on "Add" [3] so the Factor name is moved to the middle box [4].
Then, write the measure name in the corresponding textbox shown [5] here and click on the second "Add" button [6] to add that measure name; this step is optional.
Once completed, click on the "Define" button [7]

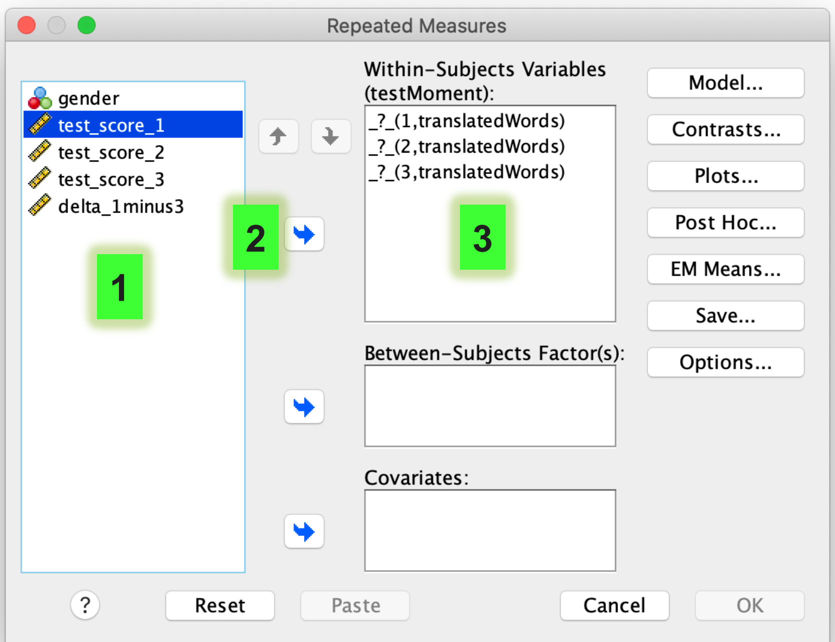


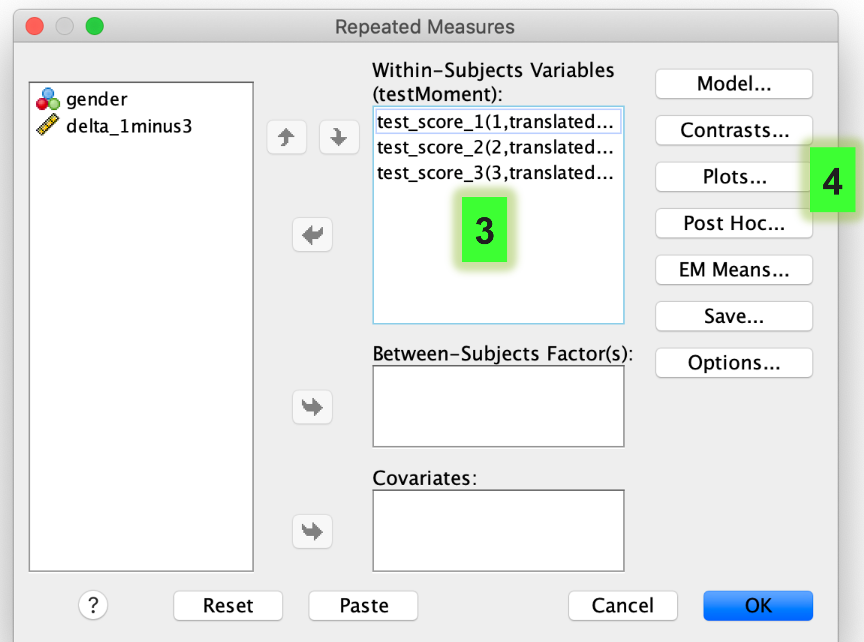


Paired samples ANOVA in SPSS

Now in the “Repeated Measures” window, allocate each of the 3 variables [1] (test_score_1, test_score_2, test_score_3), using the arrow button [2], to each of the rows shown in the “Within-Subject Variables” box [3].

Once completed, click on the “Plots” button [4]

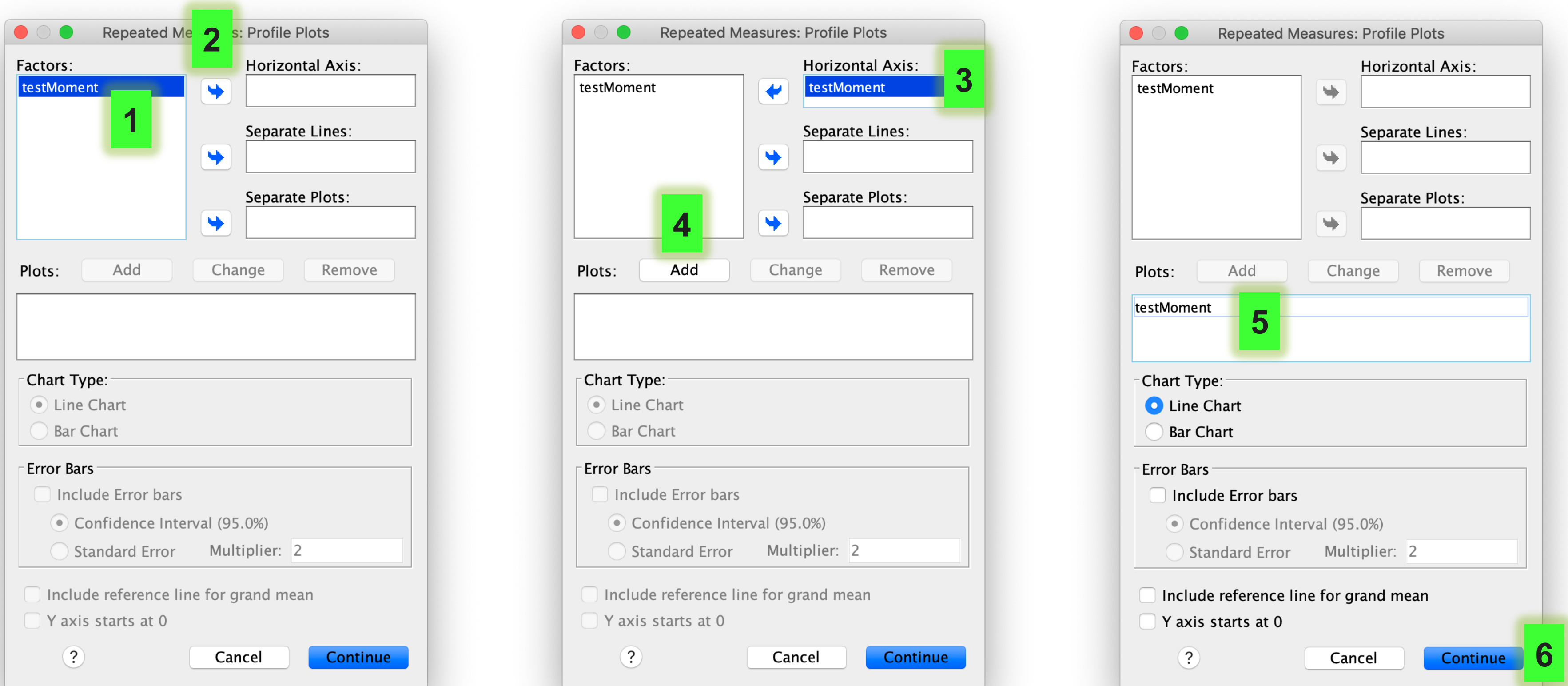




Paired samples ANOVA in SPSS

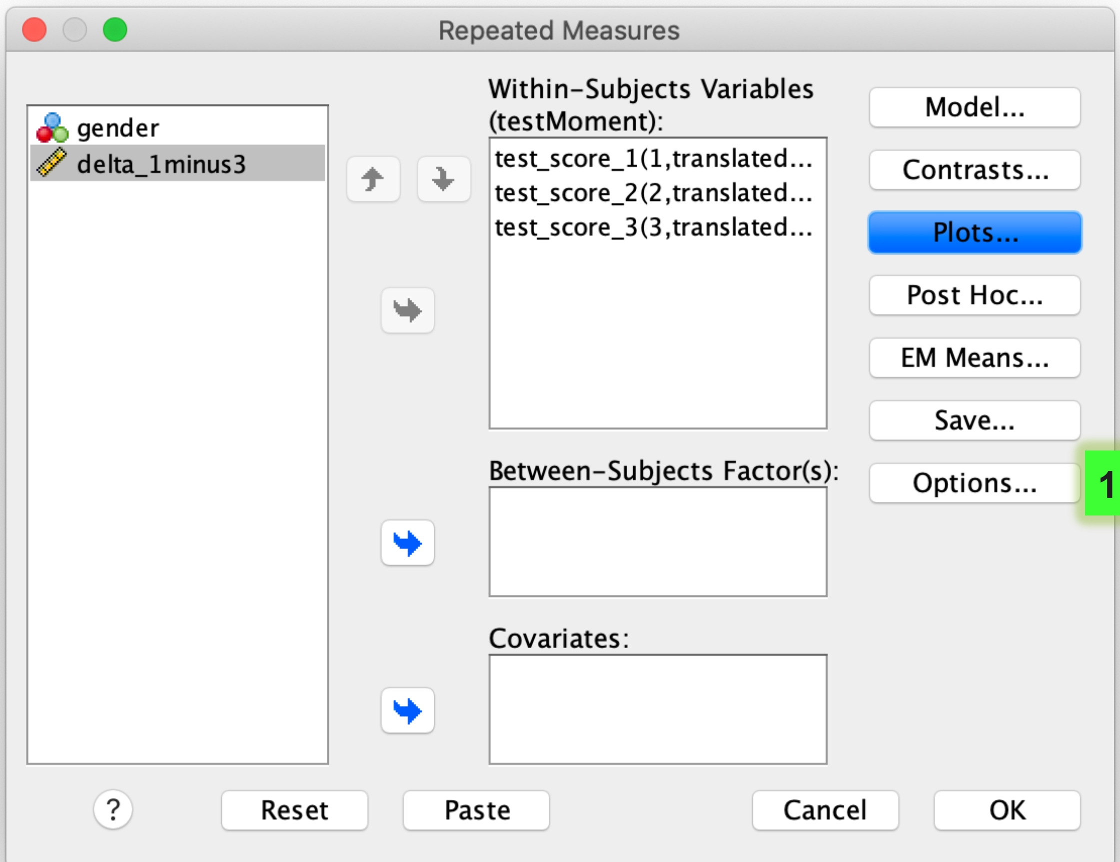
In the “Repeated Measures: Profile Plots” window, click on the “testMoment” factor [1], and using the arrow button [2] move it to the “Horizontal Axis” box [3]. After that, click on the “Add” button [4] to move the factor to the lower box [5].

Once completed, click on the “Continue” button [6].



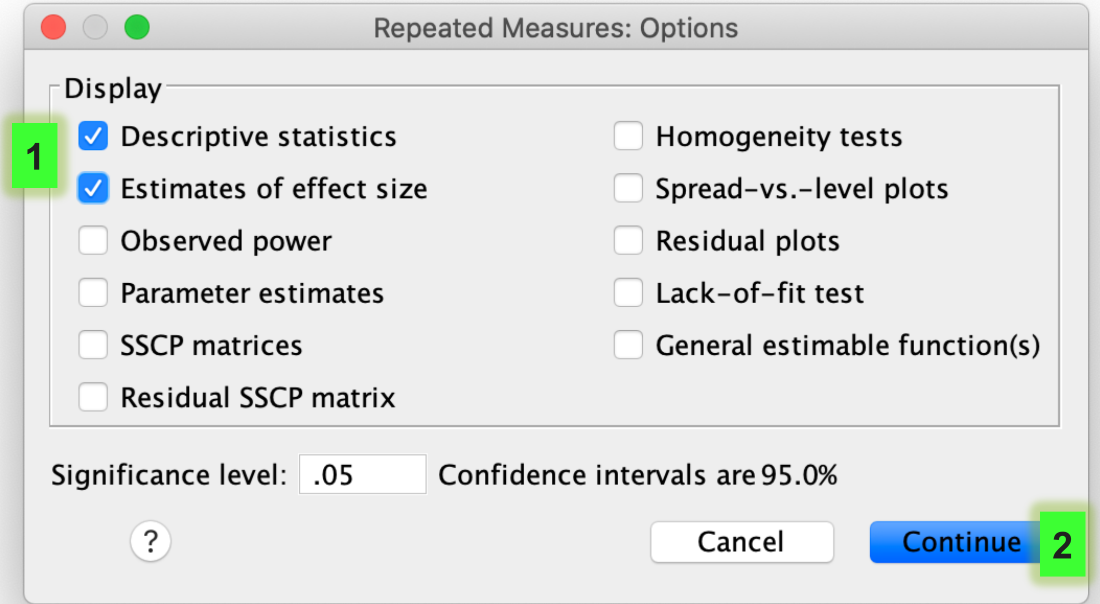
Paired samples ANOVA in SPSS

Once back in the “Repeated Measures” window, click on the “Options…” button [1]



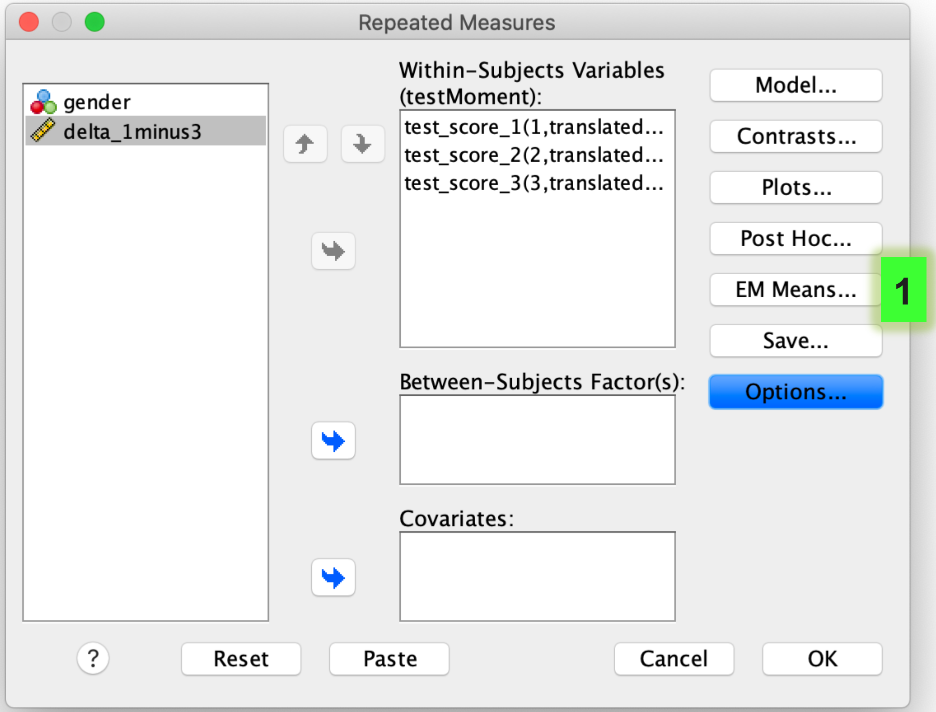
Paired samples ANOVA in SPSS

Here, we only need to select the shown checkboxes [1]. Once done, click on the “Continue” button [2].



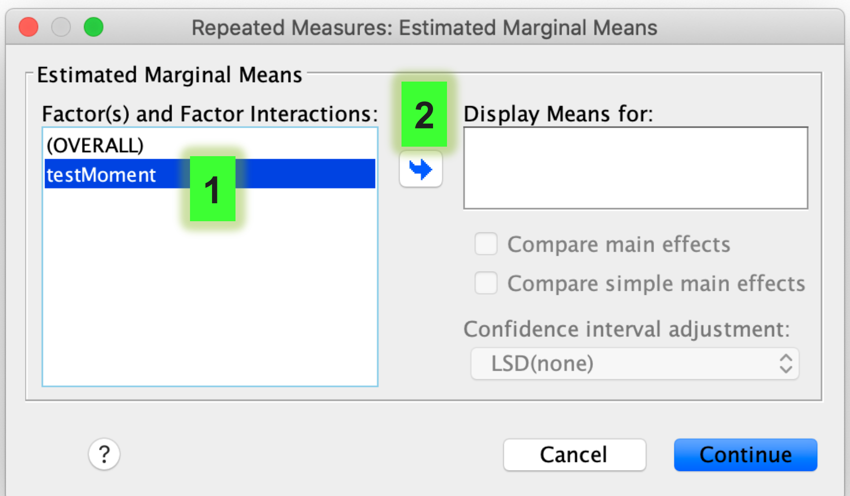
Paired samples ANOVA in SPSS

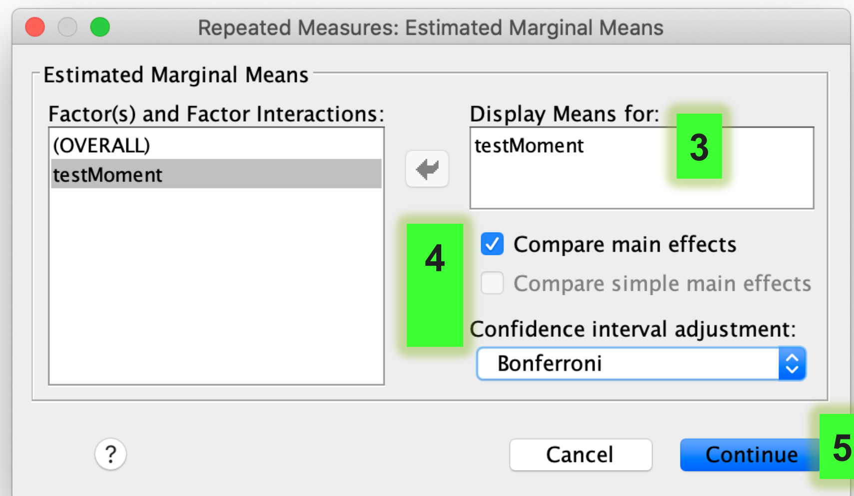
Back again in the "Repeated Measures" window, click on "EM Means…" [1].



Paired samples ANOVA in SPSS

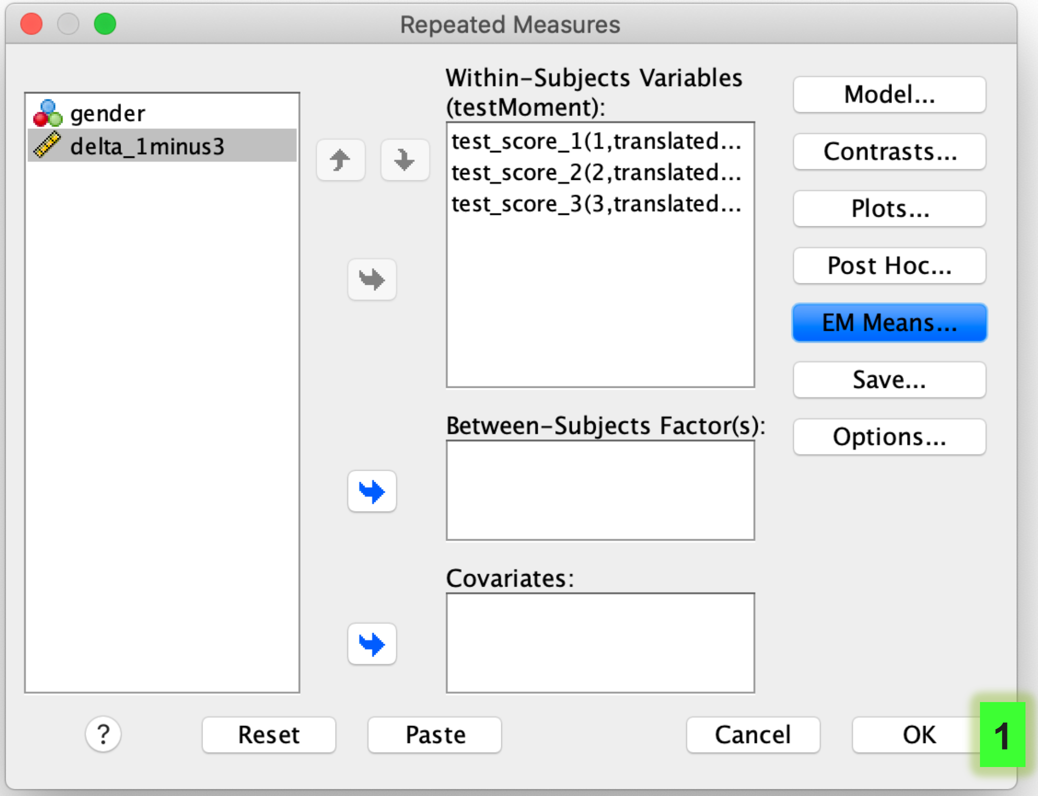
In this window, click on the “testMoment” factor [1], and using the arrow button [2] move it to the box in the right [3].
After that, you should be able to select the “Compare main effects” checkbox and select the “Bonferroni” option [4].
Once done, click on “Continue” [5].





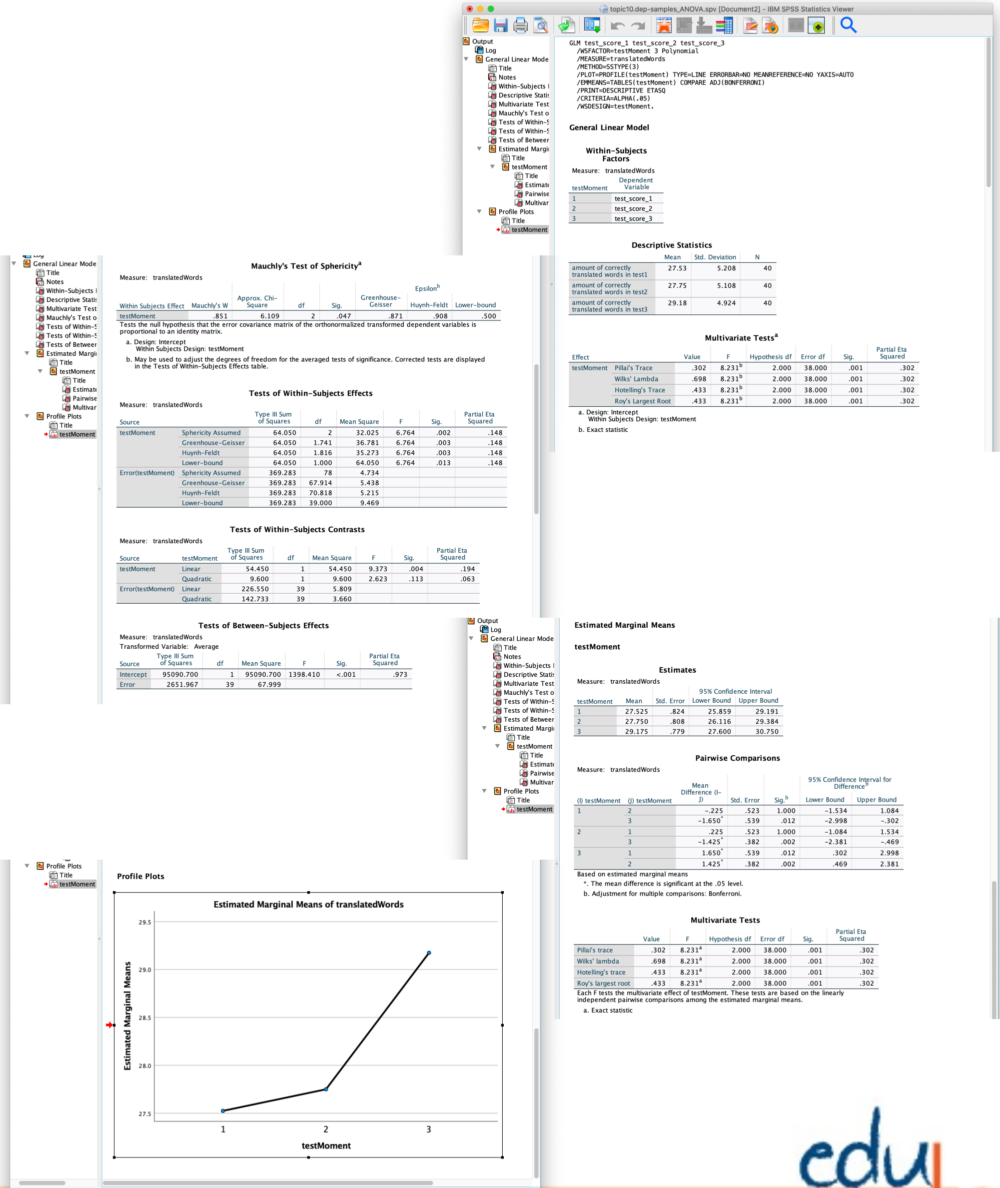
Paired samples ANOVA in SPSS

Back again in the "Repeated Measures" window, we can finally click on "OK" [1]



Paired samples ANOVA in SPSS. Output

The output of this tests consists of a lot of tables and 1 graph. We will review them in order of appearance.



Paired samples ANOVA in SPSS. Output

Within-Subjects Factors

Measure: translatedWords

testMoment	Dependent Variable
1	test_score_1
2	test_score_2
3	test_score_3

Descriptive Statistics

	Mean	Std. Deviation	N
amount of correctly translated words in test1	27.53	5.208	40
amount of correctly translated words in test2	27.75	5.108	40
amount of correctly translated words in test3	29.18	4.924	40

We can start by reviewing the first 2 tables together.

Table on the left is a partial recap of the first steps we did for the set-up of this test: we created a variable (or “factor”) called “testMoment”, with 3 levels, and on each level we added one of the three variables we had on our dataset (i.e. “test_score_1”, “test_score_2”, and “test_score_3)”. We decided to name this “testMoment” variable as “translatedWords”.

Table on the right contains some descriptive information about these 3 levels from our “testMoment” variable

Paired samples ANOVA in SPSS. Output

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
testMoment	Pillai's Trace	.302	8.231[b]	2.000	38.000	.001	.302
	Wilks' Lambda	.698	8.231[b]	2.000	38.000	.001	.302
	Hotelling's Trace	.433	8.231[b]	2.000	38.000	.001	.302
	Roy's Largest Root	.433	8.231[b]	2.000	38.000	.001	.302

a. Design: Intercept
Within Subjects Design: testMoment

b. Exact statistic

For this third table, we can ignore it for now.

The only important things to remember about this table are that:

1. We <u>may</u> need to come back to this table depending on the results of our sphericity test.
2. If we do end up coming back to check this table, the results we can use/report are the ones from the "Pillai's Trace" or "Wilks' Lambda" rows.

Paired samples ANOVA in SPSS. Output

Mauchly's Test of Sphericity[a]

Measure: translatedWords

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
testMoment	.851	6.109	2	.047	.871	.908	.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: testMoment

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.

This table contains the results of our Mauchly's test sphericity test which is the last assumption we had pending to verify (slide 40) for this analysis.

To be able to accept the sphericity assumption, the **sphericity test needs to be non-significant**. Under the "Sig." column we can see the **p-value of the sphericity test (0.047) which indicates that our test was significant and therefore we cannot assume sphericity**. So what now? Thankfully, there are corrections that we can use which are the "Greenhouse-Geisser (epsilon)", "Huynh-Feldt (epsilon)", and "Lower-bound (epsilon)".

For this specific analysis, we will use the "Huynh-Feldt (epsilon)" correction. This decision is made based on the decision tree in the following slide.

Paired samples ANOVA in SPSS. Output

The following decision chart allows us to decide which sphericity correction to pick when interpreting our ANOVA results (slide 56).

We start by defining if our Mauchly's test was significant or not. If it was significant, which was our case (p = 0.047), we need to look at the value of Greenhouse-Geisser correction. In our case, this value was 0.871. Because this value is >0.75, then according to our decision chart we should take the "Huynh-Feldt" correction.

P.S. The other side of the decision chart indicates the choice of using the "Greenhouse-Geisser results" or the "multivariate results". These multivariate results are the ones from the "Multivariate Tests" table in our output (slide 52).

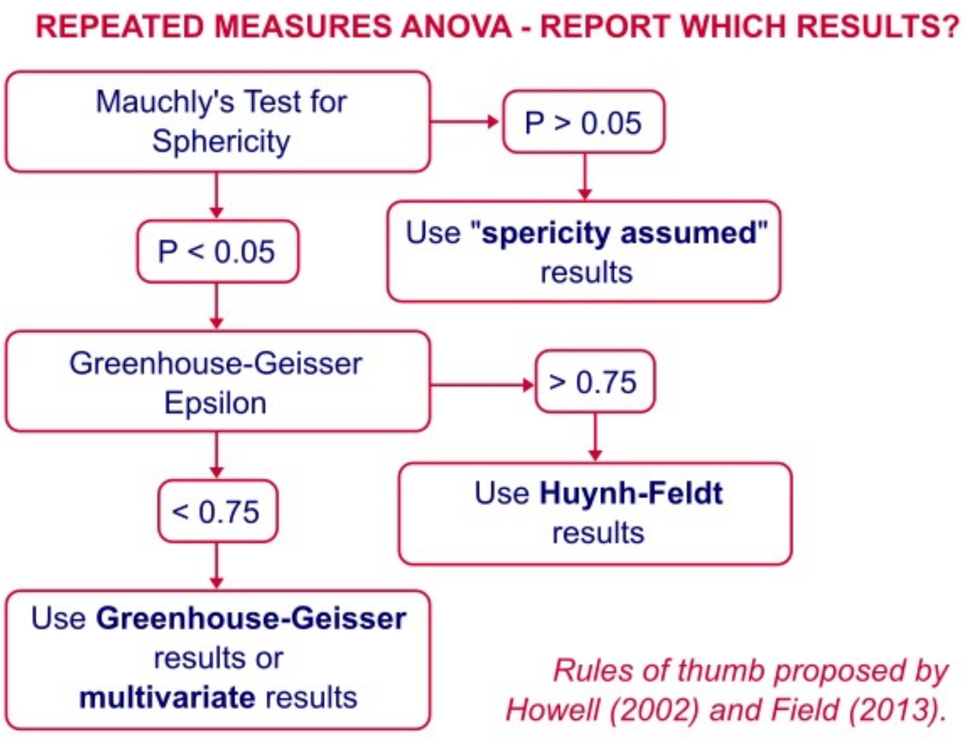


Image: https://www.spss-tutorials.com/spss-repeated-measures-anova-example-2/

Paired samples ANOVA in SPSS. Output

Mauchly's Test of Sphericity[a]

Measure: translatedWords

					Epsilon[b]		
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
testMoment	.851	6.109	2	.047	.871	.908	.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: testMoment

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.

Now that we know that our data didn't meet the sphericity assumption (p = .047) but that we will use the Huynh-Feldt correction, we can proceed.

Paired samples ANOVA in SPSS. Output

Tests of Within-Subjects Effects

Measure: translatedWords

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
testMoment	Sphericity Assumed	64.050	2	32.025	6.764	.002	.148
	Greenhouse-Geisser	64.050	1.741	36.781	6.764	.003	.148
	Huynh-Feldt	64.050	1.816	35.273	6.764	.003	.148
	Lower-bound	64.050	1.000	64.050	6.764	.013	.148
Error(testMoment)	Sphericity Assumed	369.283	78	4.734			
	Greenhouse-Geisser	369.283	67.914	5.438			
	Huynh-Feldt	369.283	70.818	5.215			
	Lower-bound	369.283	39.000	9.469			

This table is the core of our analysis and will tell us if our ANOVA, as a whole, is significant or not.

From the "Source" column, we will only focus on the rows from "testMoment". Here, we see different rows (e.g. "Sphericity Assumed", "Greenhouse-Geiser", etc.) with slightly different values. From the results of our sphericity testing we know that, for this specific paired samples ANOVA, we need to take the Huynh-Feldt correction so that will be the only row we will be looking at. Other paired samples ANOVAs will give you different sphericity results which means you would need to look at other rows from this table!

The statistics shown here are the same as the ones from the ANOVA outputs we have previously seen so we know that as a first step we can focus on the values under the "Sig." and "Partial Eta Squared" columns which indicate significance and effect size, respectively. Therefore we can already determine that our paired-samples ANOVA was significant ($p = .003$) and of a small effect ($\eta_p^2 = .148$).

By the way, for the reporting, the degrees of freedom values that will go in the final report will be the ones from the correction that we're using: "Sphericity Assumed" or "Greenhouse-Geiser" or "Huynh-Feldt" (the case here) or "Lower-bound"

Now that we know that the main results of our dependent-samples ANOVA are significant, we need to check the results of the post-hoc analysis.

Paired samples ANOVA in SPSS. Output

Pairwise Comparisons

Measure: translatedWords

(I) testMoment	(J) testMoment	Mean Difference (I–J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-.225	.523	1.000	-1.534	1.084
	3	-1.650*	.539	.012	-2.998	-.302
2	1	.225	.523	1.000	-1.084	1.534
	3	-1.425*	.382	.002	-2.381	-.469
3	1	1.650*	.539	.012	.302	2.998
	2	1.425*	.382	.002	.469	2.381

Based on estimated marginal means

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

b. Adjustment for multiple comparisons: Bonferroni.

This is the "Pairwise Comparisons" table which contains the results of our post-hoc analysis. This will allow us to identify which pairs of variables are statistically significantly different.

Same as with the post-hoc table from the ANOVA from a previous topic, the mean of each level is compared to each other level mean to look for significance, hence the 6 comparisons. Half of these comparisons are the same.

Highlighted, we see that two out of the three compared means are significantly different from each other : 3 & 1 (p = .012), and 3 & 2 (p = .002). As a reminder, "1" corresponds to our "test_score_1" variable, "2" to "test_score_2" variable, and "3" to "test_score_3".

Paired samples ANOVA in SPSS. Output

Multivariate Tests

	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	.302	8.231[a]	2.000	38.000	.001	.302
Wilks' lambda	.698	8.231[a]	2.000	38.000	.001	.302
Hotelling's trace	.433	8.231[a]	2.000	38.000	.001	.302
Roy's largest root	.433	8.231[a]	2.000	38.000	.001	.302

Each F tests the multivariate effect of testMoment. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

Then we have this "Multivariate Tests" table, again, which we will ignore, again.

Paired samples ANOVA in SPSS. Output

=Context reminder

Research Context: As part of the evaluation of a redesigned online training workshop for translators, we want to determine if the average amount of correctly translated words increases throughout the workshop run.

H0: There is no difference between the average amount of correctly translated words between the start, middle, and end of the workshop.

=Actual final report

We performed a within-subjects ANOVA with a Huynh-Feldt correction to test for a difference in performance of the workshop participants in terms of a translation test. The results indicate a statistically significant small effect concerning the difference between average scores from the three moments (i.e. start, middle-point, and end of the workshop) participants completed the translation test ($F(1.816, 70.818) = 6.764$, $p = .003$, $\eta_p^2 = .148$).

Post hoc analysis with a Bonferroni adjustment revealed that participants significantly correctly translated 1.65 more words on average on their last test compared to their first test, $p = .012$, 95% C.I. = [0.302, 2.998].

Similarly, workshop participants significantly correctly translated 1.43 more words on average on their last test compared to their second test, $p = .002$, 95% C.I. = [0.469, 2.381].

Lastly, no significant difference was found between the average amount of correctly translated words between the first and second test, $p = 1$, 95% C.I. = [-1.084, 1.534].