One-way Analysis of Variance

(ANOVA)

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Aim

The one-way analysis of variance (ANOVA) is an extension of the independent *t* test. It is used when the researcher is interested in whether the means from several (>2) independent groups differ.

For example, if a researcher is interested in investigating whether four ethnic groups differ in their IQ scores, the one-way ANOVA can be used.

Checklist of Requirements

- In any analysis, there must be only one independent variable (e.g., ethnicity).
- There should be more than two levels for that independent variable (e.g., Australian, American, Chinese, African).
- There must be only one dependent variable.

Assumptions

- **Normality**—The dependent variable is normally distributed.

- **Homogeneity of variance**—The groups have approximately equal variance on the dependent variable.

Example

A researcher is interested in fnding out whether intensity of electric shock will affect the time required to solve a set of diffcult problems. Eighteen subjects are randomly assigned to the three experimental conditions of “Low Shock,” “Medium Shock,” and “High Shock.”

The total time (in minutes) required to solve all the problems is the measure recorded for each subject.

Shock Intensity					
Low		Medium		High	
s1	15	s7	30	s13	40
s2	10	s8	15	s14	35
s3	25	s9	20	s15	50
s4	15	s10	25	s16	43
s5	20	s11	23	s17	45
s6	18	s12	20	s18	40

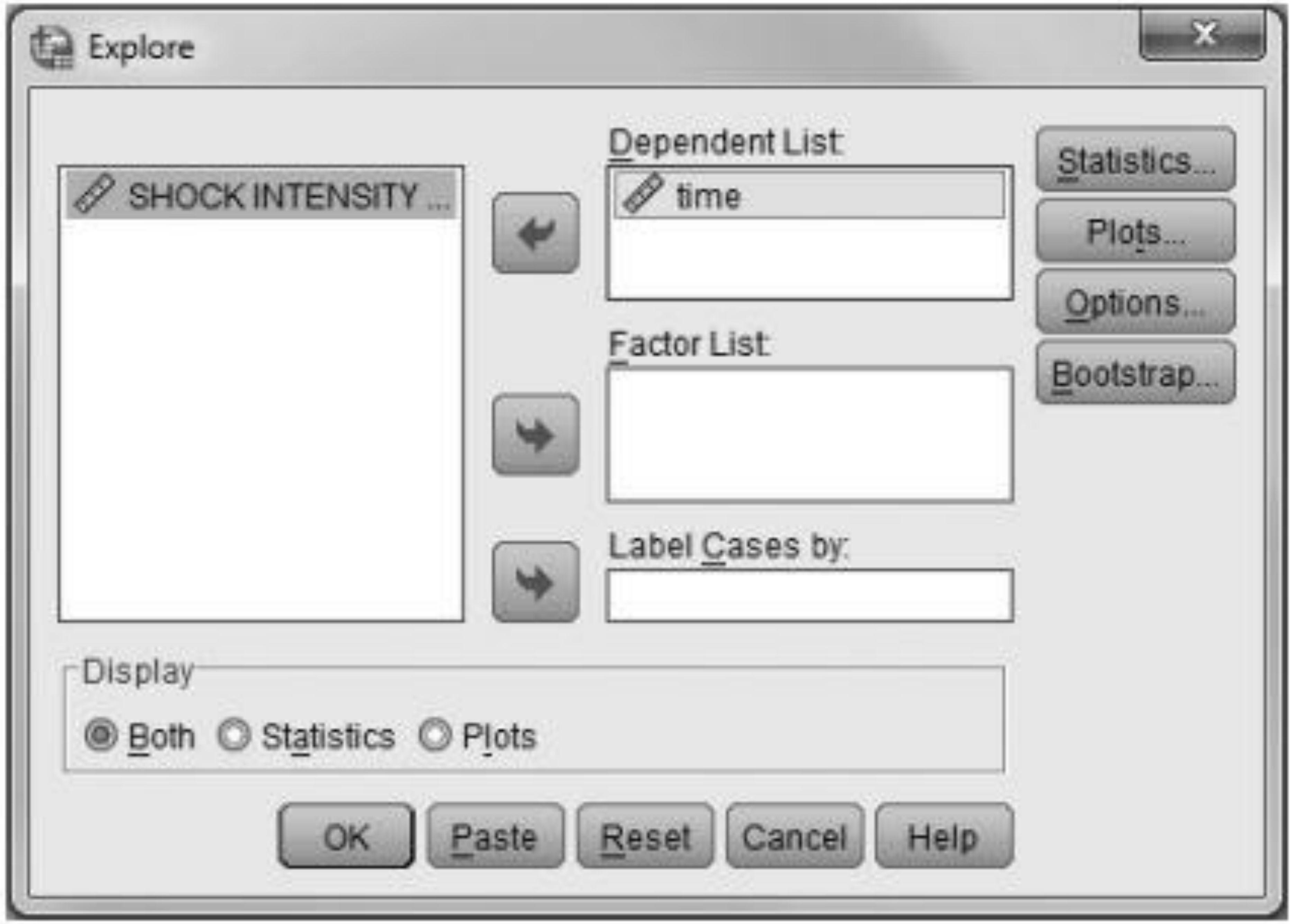
Data Entry Format

Variables	Column(s)	Code
• SHOCK	• 1	• 1 = low, 2 = medium, 3 = high
• TIME	• 2	• Time in minutes

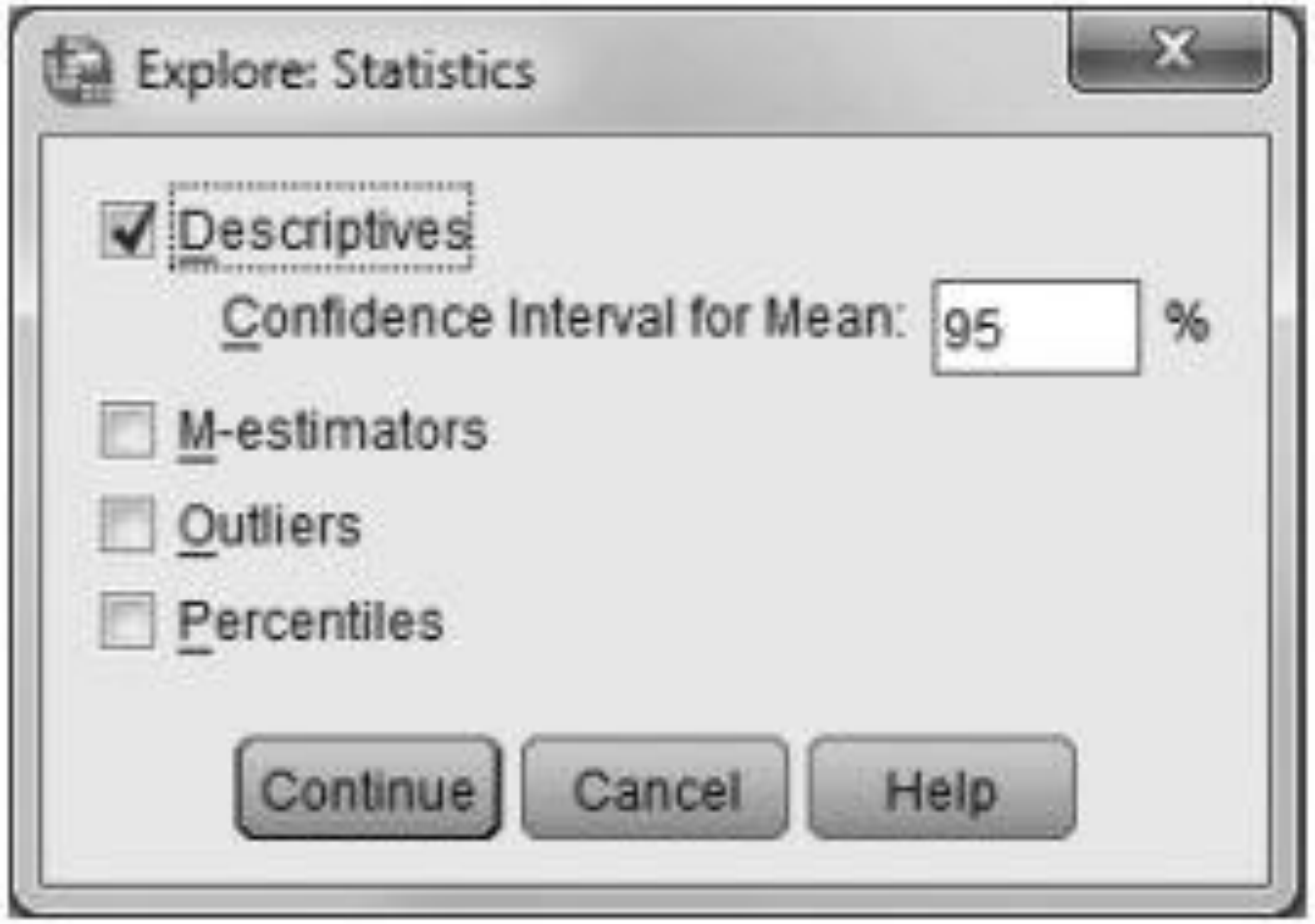
Testing Assumptions

1. From the menu bar, click **Analyze**, then **Descriptive Statistics**, and then **Explore…** . The following **Explore** window will open.

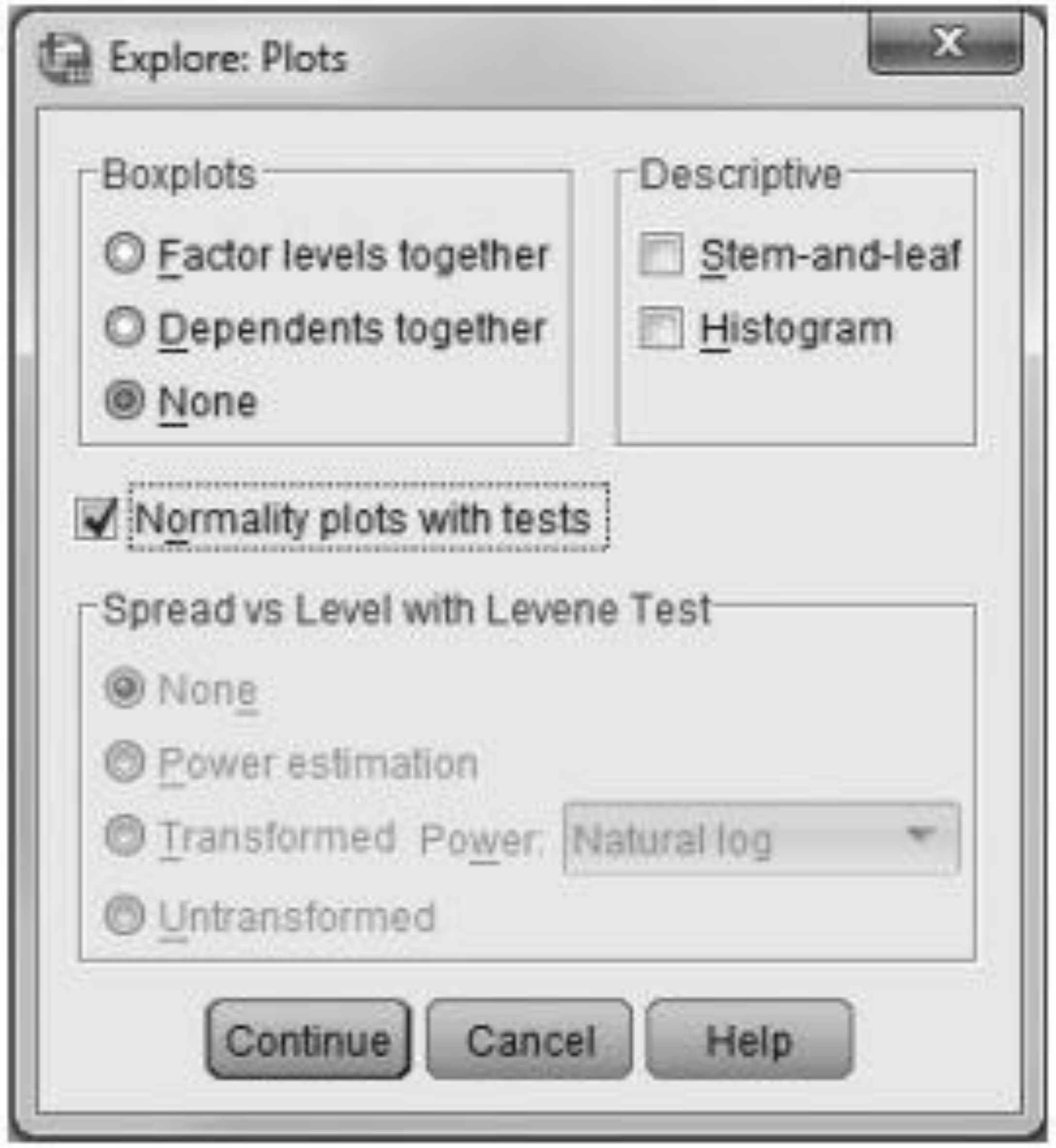
2. Transfer the **TIME** variable to the **Dependent List:** field by clicking this variable (highlight) and then clicking ➔.



3. Click Statistics... to open the **Explore: Statistics** window. Check the **Descriptives** field and click Continue to return to the **Explore** window.

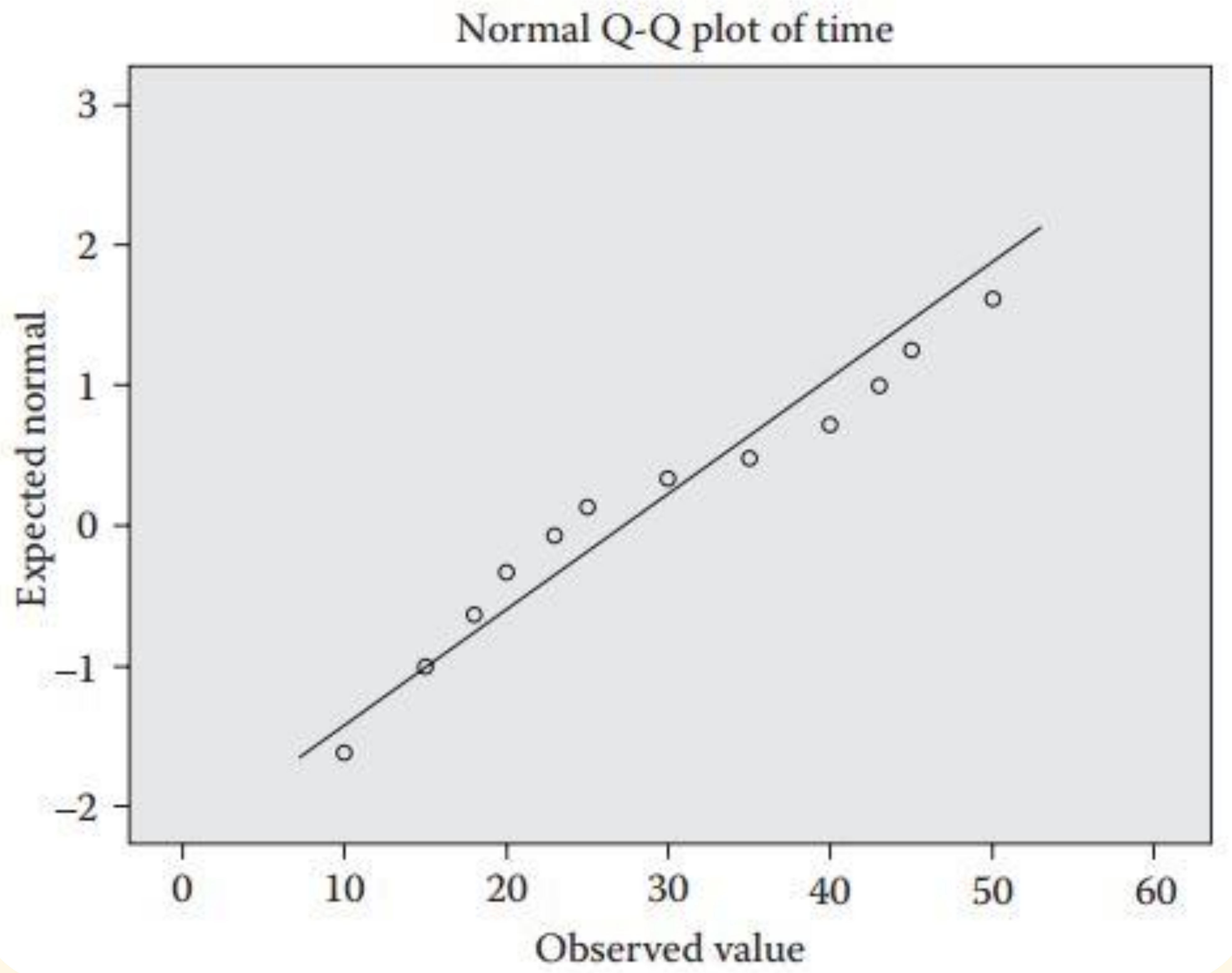


4. In the **Explore** window click [Plots...] to open the **Explore: Plots** window. Check the **Normality plots with tests** field.



Click [Continue] to return to the **Explore** window.

SPSS Output


Normal Q-Q plot of time
Expected normal
3
2
1
0
–1
–2
0
10
20
30
40
50
60
Observed value

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	*df*	Sig.	Statistic	*df*	Sig.
Time	.182	18	.118	.921	18	.136

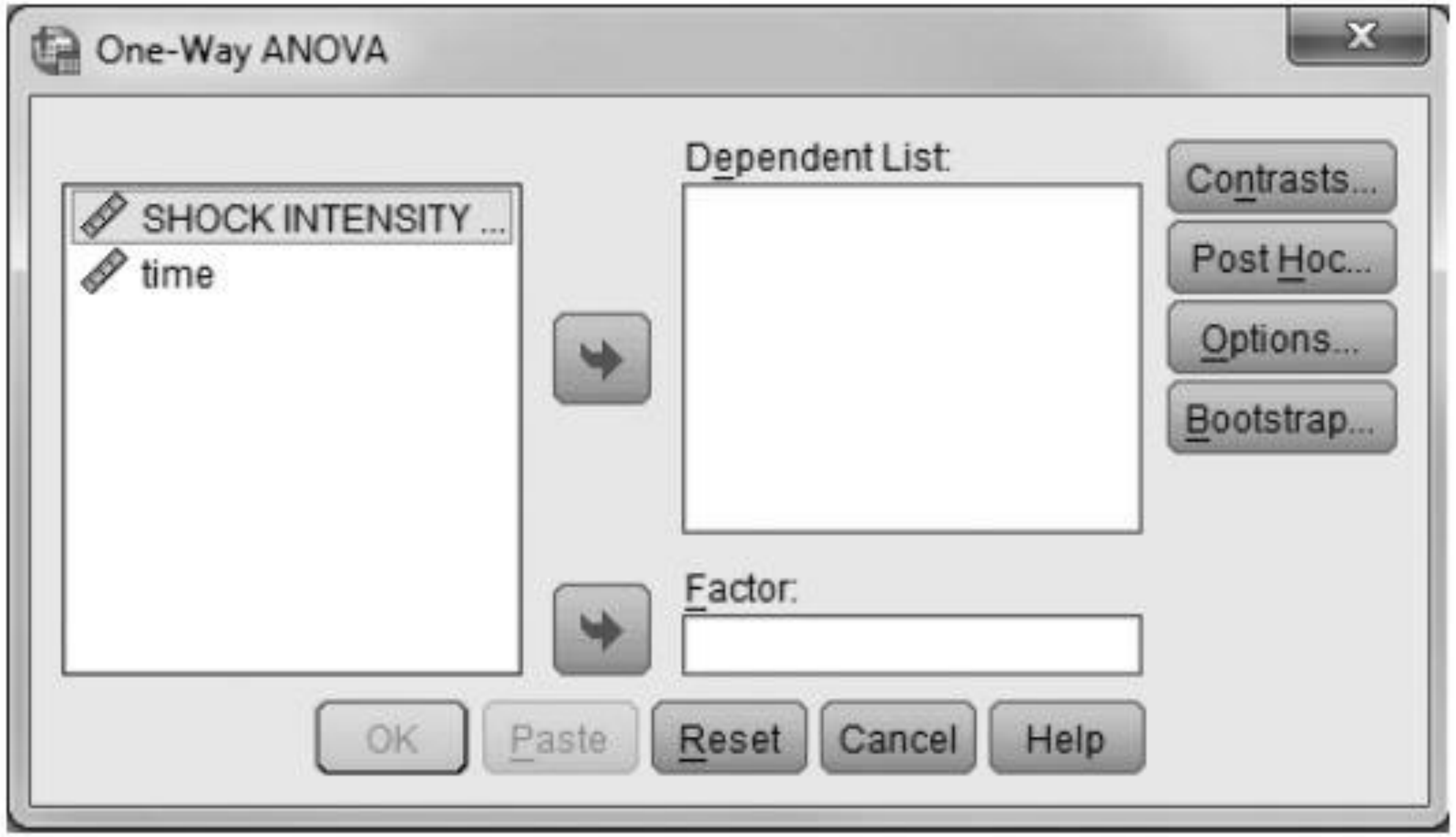
[a] Lilliefors significance correction.

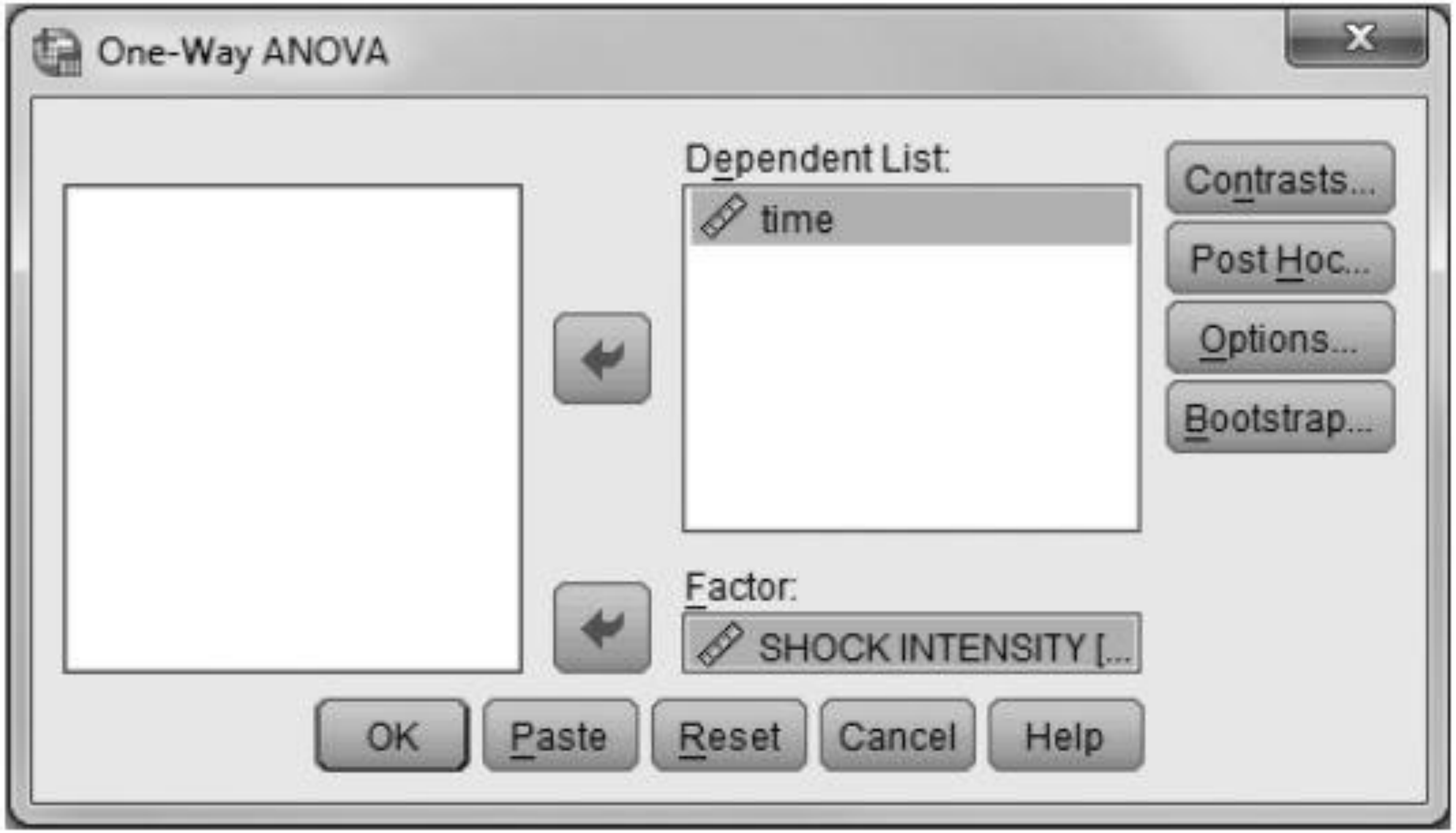
Interpretation

For both the Kolmogorov-Smirnov and the Shapiro-Wilk tests, the computed signifcance levels are greater than 0.05 (0.118 and 0.136, respectively). Therefore, normality can be assumed.

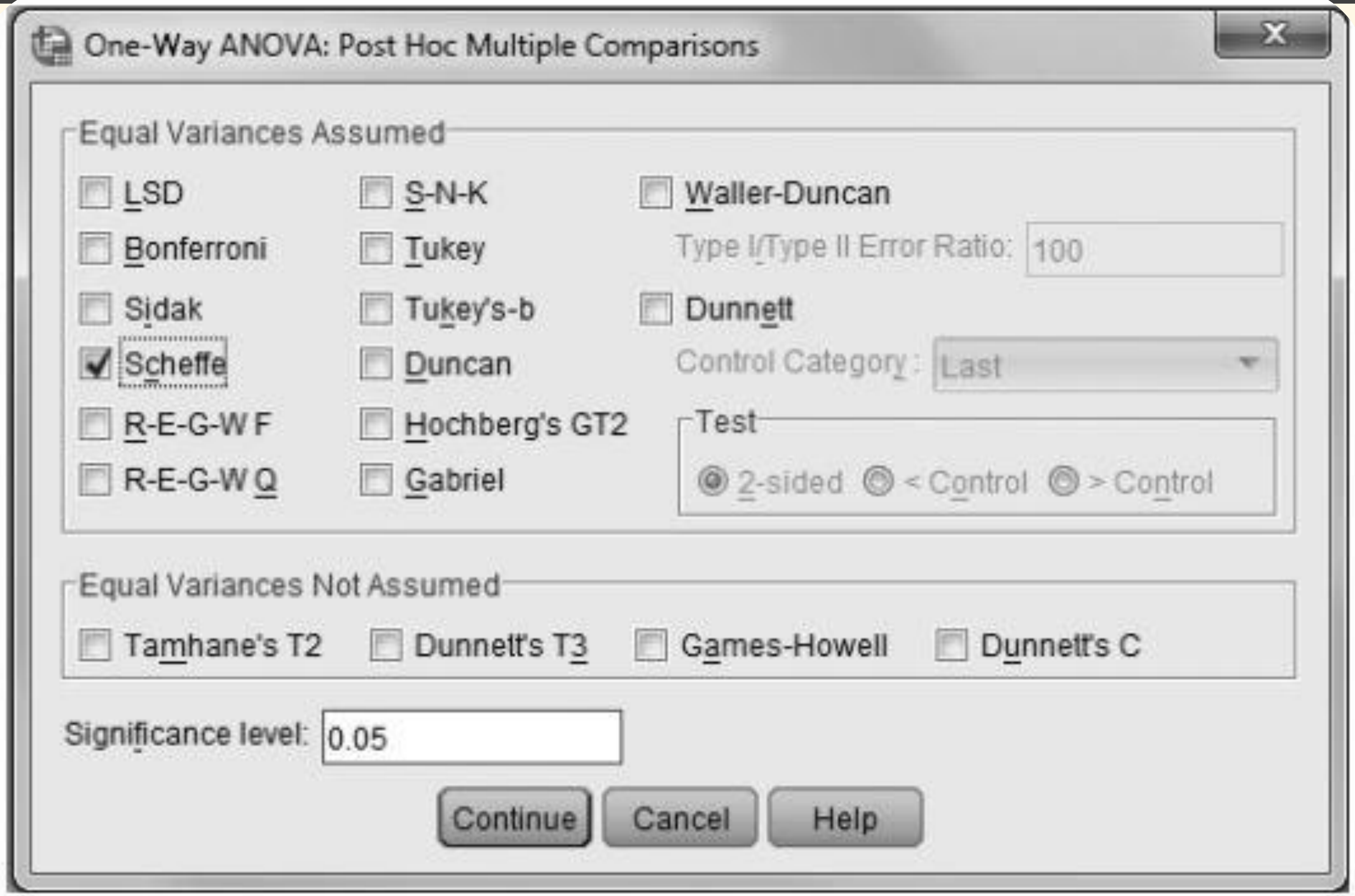
One-Way ANOVA

1. From the menu bar, click **Analyze**, then **Compare Means**, and then **One-Way ANOVA.** The following **One-Way ANOVA** window will open.

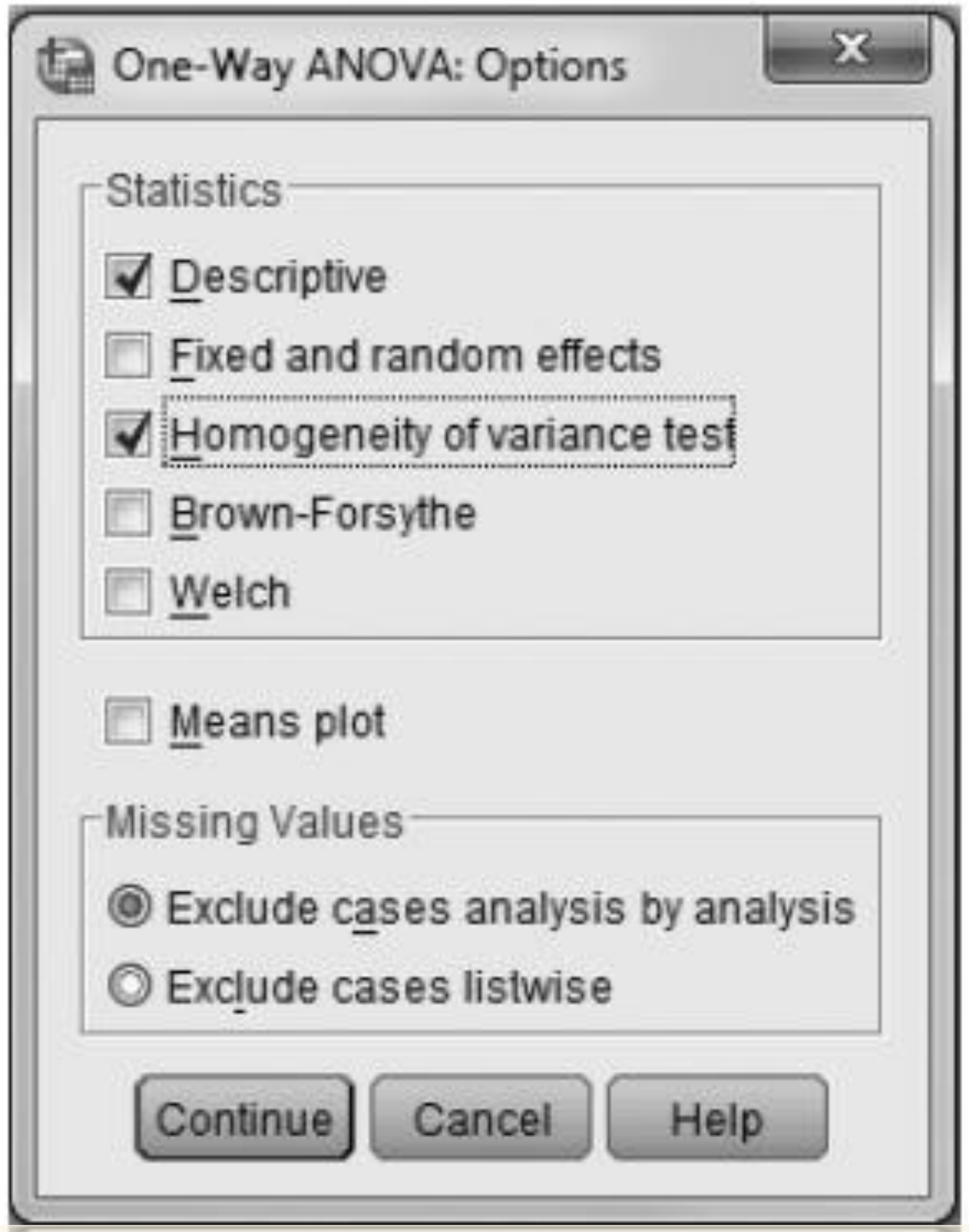



One-Way ANOVA
Dependent List:
time
Factor:
SHOCK INTENSITY [...
Contrasts...
Post Hoc...
Options...
Bootstrap...
OK
Paste
Reset
Cancel
Help

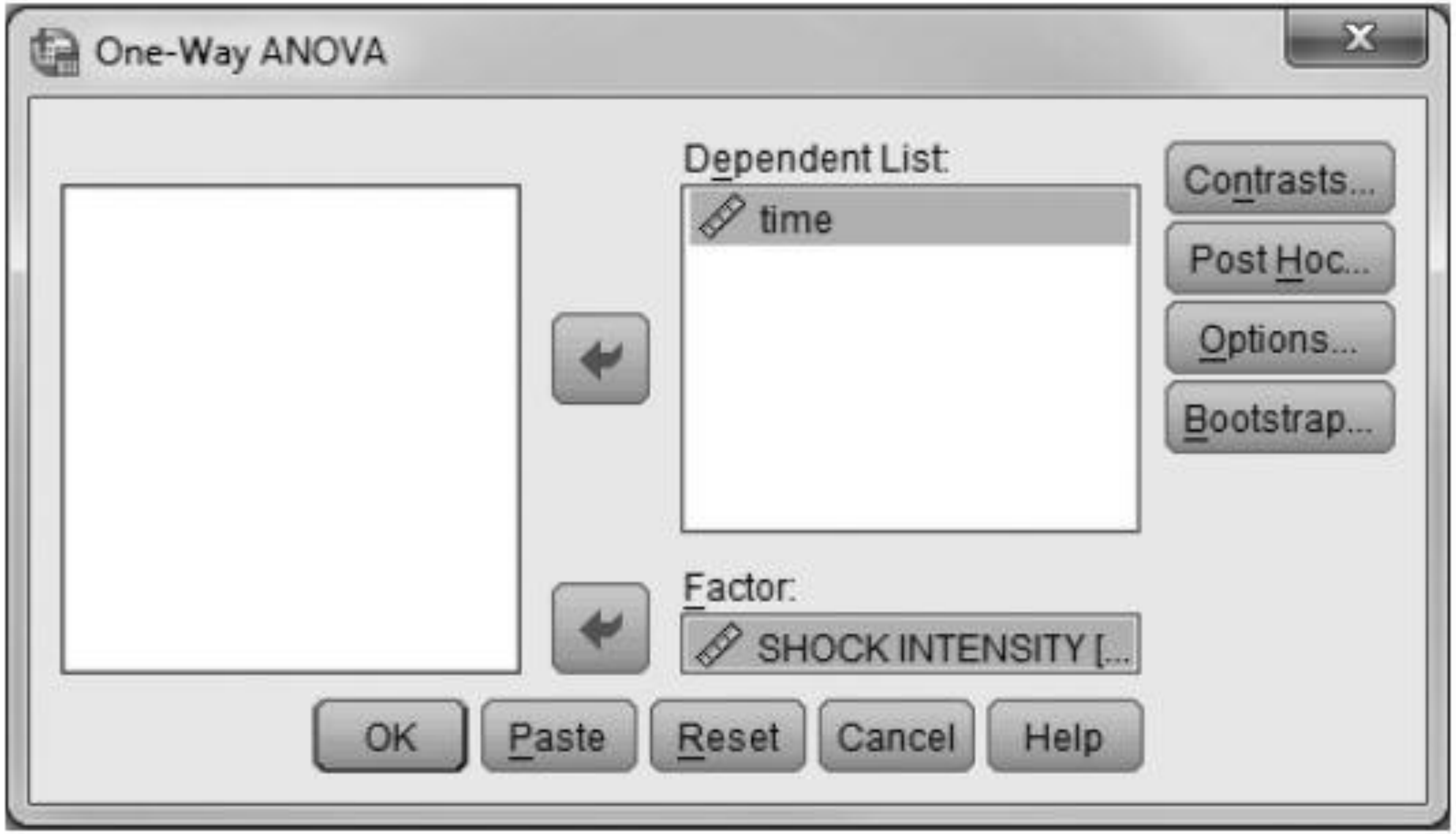
Since the one-way ANOVA will only perform an omnibus analysis of the *overall* differences between the three levels (low, medium, high) of the independent variable **SHOCK**, it will not analyze the differences between the *specific* shock levels. To obtain multiple comparisons between the three shock levels (low shock versus medium shock, low shock versus high shock, medium shock versus high shock), the researcher needs to perform a **post hoc** comparison test. Click Post Hoc... to achieve this. When the following **One-Way ANOVA: Post Hoc Multiple Comparisons** window opens, check the **Scheffe** field to run the Scheffé post hoc test. Next, click Continue.


One-Way ANOVA: Post Hoc Multiple Comparisons
Equal Variances Assumed
LSD
S-N-K
Waller-Duncan
Bonferroni
Tukey
Type I/Type II Error Ratio:
100
Sidak
Tukey's-b
Dunnett
Scheffe
Duncan
Control Category:
Last
R-E-G-W F
Hochberg's GT2
Test
R-E-G-W Q
Gabriel
2-sided
< Control
> Control
Equal Variances Not Assumed
Tamhane's T2
Dunnett's T3
Games-Howell
Dunnett's C
Significance level:
0.05
Continue
Cancel
Help

When the **One-Way ANOVA** window opens, click Options... to open the **One-Way ANOVA: Options** window. Check the **Descriptive** box and the **Homogeneity of variance test** box and then click Continue.



When the following **One-Way ANOVA** window opens, run the analysis by clicking OK. See Table 6.2 for the results.



SPSS Output

One-Way ANOVA Output

Descriptives

Time

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
LOW SHOCK	6	17.1667	5.11534	2.08833	11.7985	22.5349	10.00	25.00
MEDIUM SHOCK	6	22.1667	5.11534	2.08833	16.7985	27.5349	15.00	30.00
HIGH SHOCK	6	42.1667	5.11534	2.08833	36.7985	47.5349	35.00	50.00
Total	18	27.1667	12.10858	2.85402	21.1452	33.1881	10.00	50.00

Test of Homogeneity of Variances

Time

Levene Statistic	$df1$	$df2$	Sig.
.000	2	15	1.000

Anova

Time

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2100.000	2	1050.000	40.127	.000
Within Groups	392.500	15	26.167		
Total	2492.500	17			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: TIME

Scheffe

(I) SHOCK INTENSITY	(J) SHOCK INTENSITY	Mean Difference (I–J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
LOW SHOCK	MEDIUM SHOCK	–5.0000	2.95334	.269	–13.0147	3.0147
	HIGH SHOCK	–25.0000*	2.95334	.000	–33.0147	–16.9853
MEDIUM SHOCK	LOW SHOCK	5.0000	2.95334	.269	–3.0147	13.0147
	HIGH SHOCK	–20.0000*	2.95334	.000	–28.0147	–11.9853
HIGH SHOCK	LOW SHOCK	25.0000*	2.95334	.000	16.9853	33.0147
	MEDIUM SHOCK	20.0000*	2.95334	.000	11.9853	28.0147

* The mean difference significant at the .05 level.

Results and Interpretation

The assumption of **homogeneity of variance** is tested by the **Levene statistic**, which tests the hypothesis that the population variances are equal. In this example, the Levene statistic is $F = 0.000$ and the corresponding level of significance is large (i.e., $p > .05$) (see Table 6.1). Thus, the assumption of homogeneity of variance has not been violated.

The results from the analysis (Table 6.1) indicate that the intensity of the electric shock has a significant effect on the time taken to solve the problems, $F(2,15) = 40.13$, $p < .001$. The mean values for the three shock levels indicate that, as the shock level increased (from low to medium to high), so did the time taken to solve the problems (low: $M = 17.17$; medium: $M = 22.17$; high: $M = 42.17$).

M = 42.17).
time taken to solve the problems (low: M = 17.17; medium: M = 22.17; high:

Post Hoc Comparisons

While the highly significant *F*-ratio ($p < .001$) indicates that the means of the three shock levels differ significantly, it does not indicate the *location* of this difference. For example, the researcher may want to know whether the overall difference is due primarily to the difference between "Low Shock" and "High Shock" levels, or between "Low Shock" and "Medium Shock" levels, or between "Medium Shock" and "High Shock" levels. To test for differences between specific shock levels, a number of post hoc comparison techniques can be used. For this example, the more conservative **Scheffé** test was used.

In the **Multiple Comparisons** table, in the column labeled **Mean Difference (I–J)**, the mean difference values accompanied by asterisks indicate which shock levels differ significantly from each other at the 0.05 level of significance. The results indicate that the high shock level is significantly different from both the low shock and medium shock levels. The low shock level and the medium shock level do not differ significantly. These results show that the overall difference in time taken to solve complex problems between the three shock-intensity levels is due to the significantly greater amount of time taken by the subjects in the high shock condition.

Thank You!

Any Questions?