Drawing Conclusions

Paired-samples *t* tests determine whether or not two scores are significantly different from each other. Significant values indicate the two scores are different. Values that are not significant indicate the scores are not significantly different.

Phrasing Results That Are Significant

When stating the results of a paired-samples *t* test, you should give the value of *t*, the degrees of freedom, and the **significance** level. You should also give the **mean** and **standard deviation** for each variable, as well as a statement of results that indicates whether you conducted a one- or two-tailed test. Our example above was significant, so we could state the following:

> A paired-samples *t* test was calculated to compare the mean pretest score to the mean final exam score. The mean on the pretest was 63.33 (sd = 8.93), and the mean on the posttest was 86.14 (sd = 9.63). A significant increase from pretest to final was found ($t(20) = -11.646, p < .001$).

Phrasing Results That Are Not Significant

If the **significance** level had been greater than .05 (or greater than .10 if you were conducting a one-tailed test), the result would not have been significant. For example, if *t* had been 1.50, the **significance** level would have been larger than .05, and we could state the following:

> A paired-samples *t* test was calculated to compare the mean pretest score to the mean final exam score. The mean on the pretest was 63.33 (sd = 8.93), and the mean on the posttest was 86.14 (sd = 9.63). No significant difference from pretest to final was found ($t(20) = 1.50, p > .05$).

Practice Exercise

Use the same GRADES.SAV data file, and compute a paired-samples *t* test to determine if scores increased from midterm to final.

Section 6.5 One-Way ANOVA

Description

Analysis of variance (ANOVA) is a procedure that determines the proportion of variability attributed to each of several components. It is one of the most useful and adaptable statistical techniques available.

The one-way ANOVA compares the means of two or more groups of subjects that vary on a single **independent variable** (thus, the one-way designation). When we have three groups, we could use a *t* test to determine differences between groups, but we would have to conduct three *t* tests (Group 1 compared to Group 2, Group 1 compared to Group 3, and Group 2 compared to Group 3). When we conduct multiple *t* tests, we inflate the **Type I error** rate and increase our chance of drawing an inappropriate conclusion.

ANOVA compensates for these multiple comparisons and gives us a single answer that tells us if any of the groups is different from any of the other groups.

Assumptions

The one-way ANOVA requires a single **dependent variable** and a single **independent variable**. Which group subjects belong to is determined by the value of the **independent variable**. Groups should be independent of each other. If our subjects belong to more than one group each, we will have to conduct a repeated measures ANOVA. If we have more than one **independent variable**, we would conduct a factorial ANOVA.

ANOVA also assumes that the **dependent variable** is at the **interval** or **ratio** levels and is normally distributed.

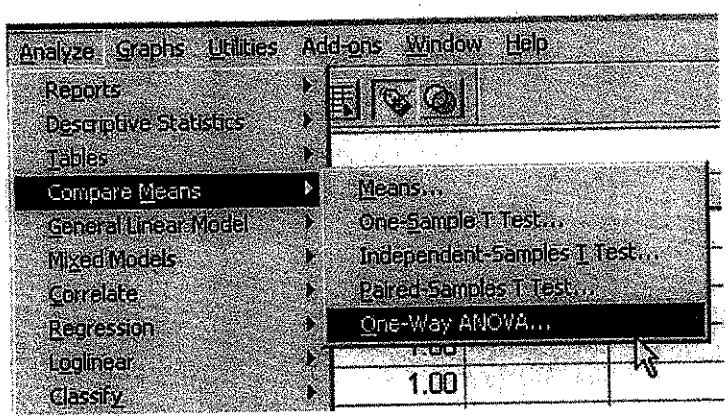
SPSS Data Format

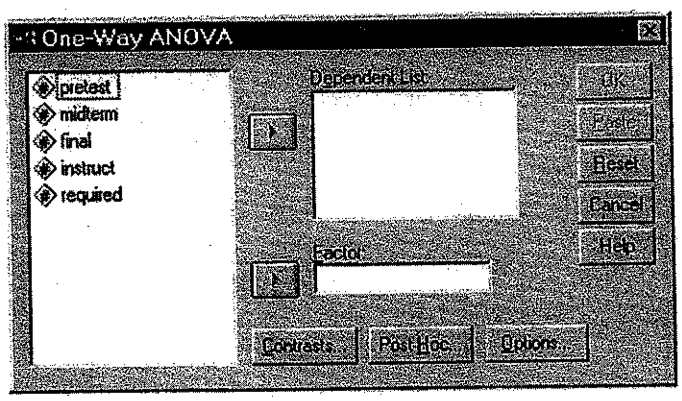
Two variables are required in the SPSS data file. One variable serves as the **dependent variable** and the other as the **independent variable**. Each subject should provide only one score for the **dependent variable**.

Running the Command

For this example, we will use the GRADES.SAV data file we created in the previous section.

To conduct a one-way ANOVA, click *Analyze*, then *Compare Means*, then *One-Way ANOVA*. This will bring up the main dialog box for the One-Way ANOVA command.

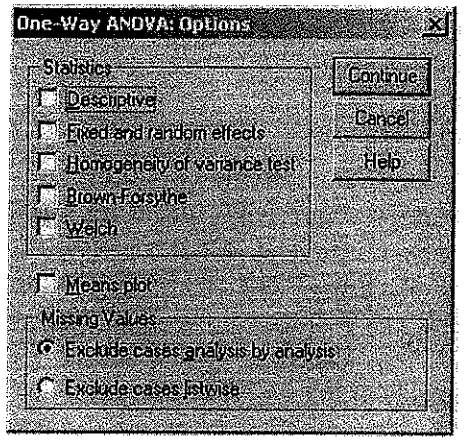




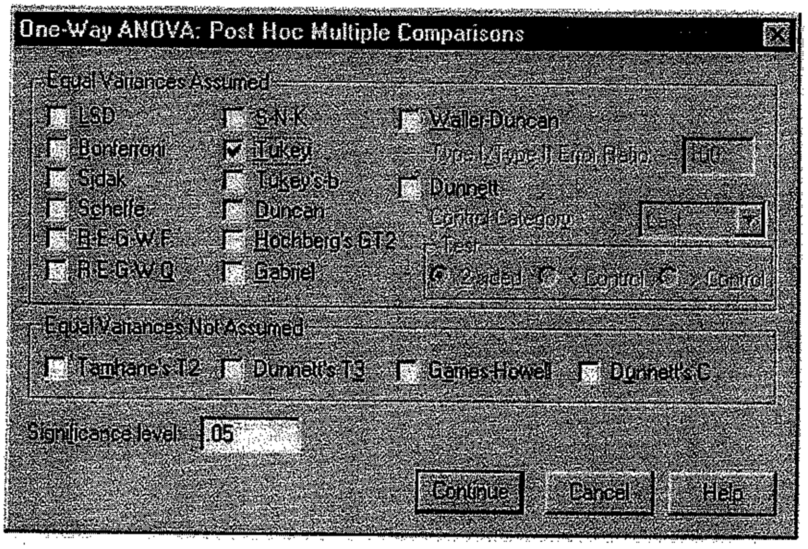
You should place the **independent variable** in the *Factor* box. For our example, INSTRUCT represents three different instructors, and it will be used as our **independent variable**.

Our **dependent variable** will be FINAL. This test will allow us to determine if the instructor has any effect on final grades in the course.

Click on the *Options* box to get the options dialog box. Click *Descriptive*. This will give you means for the **dependent variable** at each **level** of the **independent variable.** Checking this box prevents us from having to run a separate means command. Click *Continue* to return to the main dialog box. Next, click *Post-Hoc* to bring up the Post Hoc Multiple Comparisons dialog box. Click *Tukey*, then *Continue*.



Post-hoc tests are necessary in the event of a significant ANOVA. The ANOVA only indicates if any group is different from any other group. If it is significant, we need to determine which groups are different from which other groups. We could do *t* tests to determine that, but we would have the same problem as before with inflating the **Type I error** rate.



There are a variety of post-hoc comparisons available that correct for the multiple comparisons. The most widely used is Tukey's *HSD*. SPSS will calculate a variety of post-hoc tests for you. Consult an advanced statistics text for a discussion of the differences between these various tests.

Now click *OK* to run the analysis.

Reading the Output

Descriptive statistics will be given for each instructor (i.e., level of the **independent variable**) and the total.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
FINAL	Between Groups	579.429	2	289.714	4.083	.034
	Within Groups	1277.143	18	70.952		
	Total	1856.571	20			

The next section of the output is the ANOVA source table above. This is where the various components of the variance have been listed, along with their relative sizes. For a one-way ANOVA, there are two components to the variance: Between Groups (which represents the differences due to our **independent variable**) and Within Groups (which represents differences within each level of our **independent variable**). For our example, the Between Groups variance represents differences due to different instructors. The Within Groups variance represents individual differences in students.

The primary answer is *F*. *F* is a ratio of explained variance to unexplained **variance**. Consult a statistics text for more details on how it is determined. The *F* has two different degrees of freedom, one for Between Groups (in this case, 2 is the number of **levels** of our **independent variable** [3 – 1] and one for Within Groups (18 is the number of subjects minus the number of **levels** of our **independent variable** [21–3]).

The next part of the output consists of the results of our Tukey's *HSD* post-hoc comparison.

Multiple Comparisons

Dependent Variable: FINAL
Tukey HSD

(I) INSTRUCT	(J) INSTRUCT	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-6.8571	4.502	.304	-18.3482	4.6339
	3.00	-12.8571*	4.502	.027	-24.3482	-1.3661
2.00	1.00	6.8571	4.502	.304	-4.6339	18.3482
	3.00	-6.0000	4.502	.396	-17.4911	5.4911
3.00	1.00	12.8571*	4.502	.027	1.3661	24.3482
	2.00	6.0000	4.502	.396	-5.4911	17.4911

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

This table presents us with every possible combination of levels of our **independent variable**. The first row represents Instructor 1 compared to Instructor 2. Next is Instructor 1 compared to Instructor 3. Next is Instructor 2 compared to Instructor 1. (Note that this is redundant with the first row.) Next is Instructor 2 compared to Instructor 3, and so on.

The column labeled *Sig.* represents the **Type I error** (*p*) rate for the simple (2 level) comparison in that row. In our example above, Instructor 1 is significantly different from Instructor 3, but Instructor 1 is not significantly different from Instructor 2, and Instructor 2 is not significantly different from Instructor 3.

Drawing Conclusions

Drawing conclusions for ANOVA requires that we indicate the value of *F*, the degrees of freedom, and the **significance** level. A significant ANOVA should be followed by the results of a post-hoc analysis and a verbal statement of the results.

Phrasing Results That Are Significant

In our example above, we could state the following:

> We computed a one-way ANOVA comparing the final exam scores of subjects who took a course from one of three different instructors. A significant difference was found among the instructors ($F(2,18) = 4.08$, $p < .05$). Tukey's *HSD* was used to determine the nature of the differences between the instructors. This analysis revealed that students who had Instructor 1 scored lower ($m = 79.57$, $sd = 7.96$) than students who had Instructor 3 ($m = 92.43$, $sd = 5.50$). Students who had Instructor 2 ($m = 86.43$, $sd = 10.92$) were not significantly different from either of the other two groups.

Phrasing Results That Are Not Significant

If we had conducted the analysis using PRETEST as our **dependent variable** instead of FINAL, we would have received the following output:

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PRETEST	Between Groups	240.667	2	120.333	1.600	.229
	Within Groups	1354.000	18	75.222		
	Total	1594.667	20			

The ANOVA was not significant, so there is no need to refer to the Multiple Comparisons table. Given this result, we may state the following:

> The pretest means of students who took a course from three different instructors were compared using a one-way ANOVA. No significant difference was found ($F(2,18) = 1.60$, $p > .05$). The students from the three different classes did not differ significantly at the start of the term.

Practice Exercise

Using Practice Data Set 1 in Appendix B, determine if the average math scores of single, married, and divorced subjects are significantly different. Write a statement of results.

Section 6.6 Factorial ANOVA

Description

The factorial ANOVA is one in which there is more than one **independent variable**. A 2 × 2 ANOVA, for example, has two **independent variables**, each with two **levels**. A 3 × 2 × 2 ANOVA has three **independent variables**. One has three **levels**, and the other two have two **levels**. Factorial ANOVA is very powerful because it allows us to assess the effects of each **independent variable**, plus the effects of the **interaction**.

Assumptions

Factorial ANOVA requires all of the assumptions of one-way ANOVA (i.e., the **dependent variable** must be at the **interval or ratio** levels and normally distributed). In addition, the **independent variables** should be independent of each other.

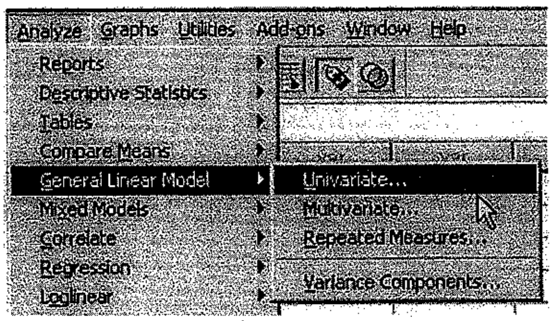
SPSS Data Format

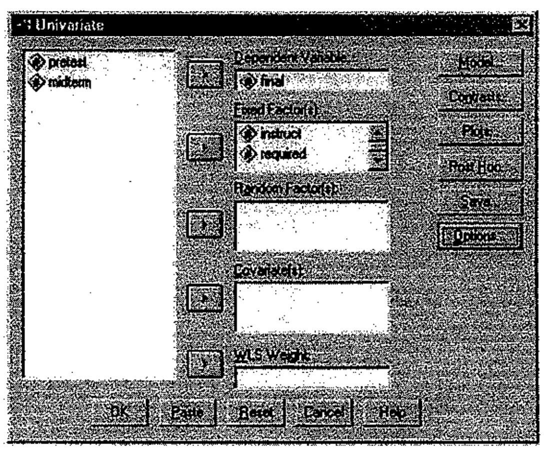
SPSS requires one variable for the **dependent variable**, and one variable for each **independent variable**. If we have *any* **independent variable** that is represented as multiple variables (e.g., PRETEST and POSTTEST), we must use the repeated measures ANOVA.

Running the Command

This example uses the GRADES.SAV data file from earlier in this chapter. Click *Analyze*, then *General Linear Model*, then *Univariate.*

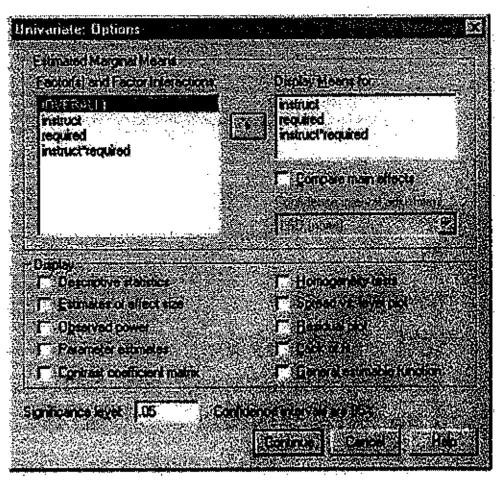
This will bring up the main dialog box for univariate ANOVA. Select the **dependent variable** and place it in the *Dependent Variable* blank (use FINAL for this example). Select one of your **independent variables** (INSTRUCT in this case) and place it in the *Fixed Factor(s)* box. Place the second **independent variable** (REQUIRED) in the *Fixed Factor(s)* box.





After you have defined the analysis, click on *Options*. When the options dialog box comes up, move INSTRUCT, REQUIRED, and INSTRUCT × REQUIRED into the *Display Means for* blank. This will provide you with **means** for each main effect and **interaction** term. Click *Continue.*

If you select *Post-Hoc*, SPSS will run post-hoc analyses for the main effects but not for the **interaction** term. Click *OK* to run the analysis.



Reading the Output

At the bottom of the output, you will find the means for each main effect and **interaction** you selected with the *Options* command.

There were three instructors, so there is a **mean** FINAL for each instructor.

We also have **means** for the two values of REQUIRED.

Finally, we have six **means** representing the interaction of the two variables (this was a 3 × 2 design).

Subjects who had Instructor 1 (for whom the class was not required) had a **mean** final exam score of 79.67. Students who had Instructor 1 (for whom it was required) had a **mean** final exam score of 79.50, and so on.

The example we just ran is called a two-way ANOVA. This is because we had two **independent variables**. With a two-way ANOVA, we get three answers: a main effect for INSTRUCT, a main effect for REQUIRED, and an **interaction** result for INSTRUCT × REQUIRED (see top of next page).

1. INSTRUCT

Dependent Variable: FINAL

INSTRUCT	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	79.583	3.445	72.240	86.926
2.00	86.208	3.445	78.865	93.551
3.00	92.083	3.445	84.740	99.426

2. REQUIRED

Dependent Variable: FINAL

REQUIRED	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
.00	84.667	3.007	78.257	91.076
1.00	87.250	2.604	81.699	92.801

3. INSTRUCT * REQUIRED

Dependent Variable: FINAL

INSTRUCT	REQUIRED	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	.00	79.667	5.208	68.565	90.768
	1.00	79.500	4.511	69.886	89.114
2.00	.00	84.667	5.208	73.565	95.768
	1.00	87.750	4.511	78.136	97.364
3.00	.00	89.667	5.208	78.565	100.768
	1.00	94.500	4.511	84.886	104.114

The source table below gives us these three answers (in the INSTRUCT, REQUIRED, and INSTRUCT * REQUIRED rows). In the example, none of the main effects or **interactions** were significant. In the statements of results, you must indicate *F*, two degrees of freedom (effect and residual), the **significance** level, and a verbal statement for each of the answers (three, in this case). Note that most statistics books give a much simpler version of an ANOVA source table where the Corrected Model, Intercept, and Corrected Total rows are not included.

Tests of Between-Subjects Effects

Dependent Variable: FINAL

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	635.821[a]	5	127.164	1.563	.230
Intercept	151998.893	1	151998.893	1867.691	.000
INSTRUCT	536.357	2	268.179	3.295	.065
REQUIRED	34.321	1	34.321	.422	.526
INSTRUCT * REQUIRED	22.071	2	11.036	.136	.874
Error	1220.750	15	81.383		
Total	157689.000	21			
Corrected Total	1856.571	20			

a. R Squared = .342 (Adjusted R Squared = .123)

Phrasing Results That Are Significant

If we had obtained significant results in this example, we could state the following (these are fictitious results):

> A 3 (instructor) × 2 (required course) between-subjects factorial ANOVA was calculated comparing the final exam scores for subjects who had one of three instructors and who took the course as a required course or as an elective. A significant main effect for instructor was found ($F(2,15) = 10.112$, $p < .05$). Students who had Instructor 1 had higher final exam scores (m = 79.57, sd = 7.96) than students who had Instructor 3 (m = 92.43, sd = 5.50). Students who had Instructor 2 (m = 86.43, sd = 10.92) were not significantly different from either of the other two groups. A significant main effect for whether or not the course was required was found ($F(1,15) = 38.44, p < .01$). Students who took the course because it was required did better (m = 91.69, sd = 7.68) than students who took the course as an elective (m = 77.13, sd = 5.72). The interaction was not significant ($F(2,15) = 1.15, p > .05$). The effect of the instructor was not influenced by whether or not the students took the course because it was required.

Note that in the above example, we would have had to conduct Tukey's *HSD* to determine the differences for INSTRUCT (using the Post-Hoc command). This is not necessary for REQUIRED because it has only two levels (and one must be different from the other).

Phrasing Results That Are Not Significant

Our actual results were not significant, so we can state the following:

> A 3 (instructor) × 2 (required course) between-subjects factorial ANOVA was calculated comparing the final exam scores for subjects who had each instructor and who took the course as a required course or as an elective. The main effect for instructor was not significant ($F(2,15) = 3.30$, $p > .05$). The main effect for whether or not it was a required course was also not significant ($F(1,15) = .42$, $p > .05$). Finally, the interaction was also not significant ($F(2,15) = .136$, $p > .05$). Thus, it appears that neither the instructor nor whether or not the course is required has any significant effect on final exam scores.

Practice Exercise

Using Practice Data Set 2 in Appendix B, determine if salaries are influenced by sex, job classification, or an **interaction** between sex and job classification. Write a statement of results.

Section 6.7 Repeated Measures ANOVA

Description

Repeated measures ANOVA extends the basic ANOVA procedure to a within-subjects **independent variable** (when subjects provide data for more than one **level** of an **independent variable**). It functions like a paired-samples *t* test when more than two **levels** are being compared.

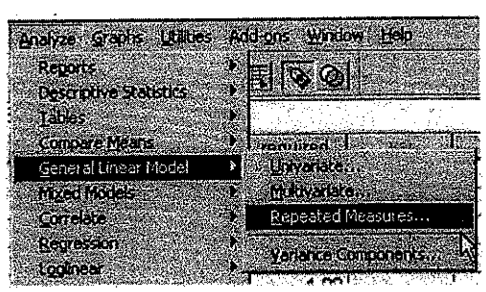
Assumptions

The **dependent variable** should be normally distributed and measured on an **interval** or **ratio scale**. Multiple measurements of the **dependent variable** should be from the same (or related) subjects.

SPSS Data Format

At least three variables are required. Each variable in the SPSS data file should represent a single **dependent variable** at a single **level** of the **independent variable**. Thus, an analysis of a design with four levels of an **independent variable** would require four variables in the SPSS data file.

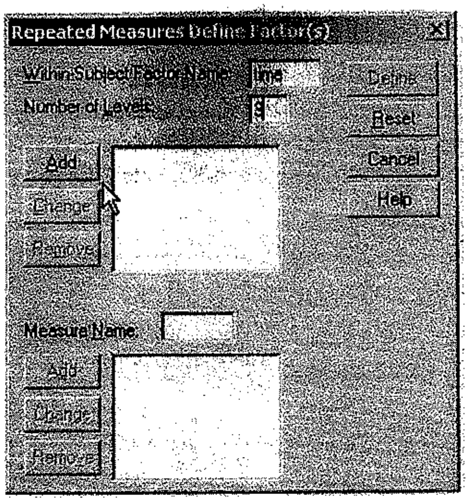
If any variable represents a between-subjects effect, use the mixed design ANOVA command instead.



Running the Command

This example uses the GRADES.SAV sample data set. Recall that GRADES.SAV includes three sets of grades—PRETEST, MIDTERM, and FINAL—that represent three different times during the semester. This allows us to analyze the effects of time on the test performance of our sample population (hence the within-groups comparison). Click *Analyze*, then *General Linear Model*, then *Repeated Measures*.

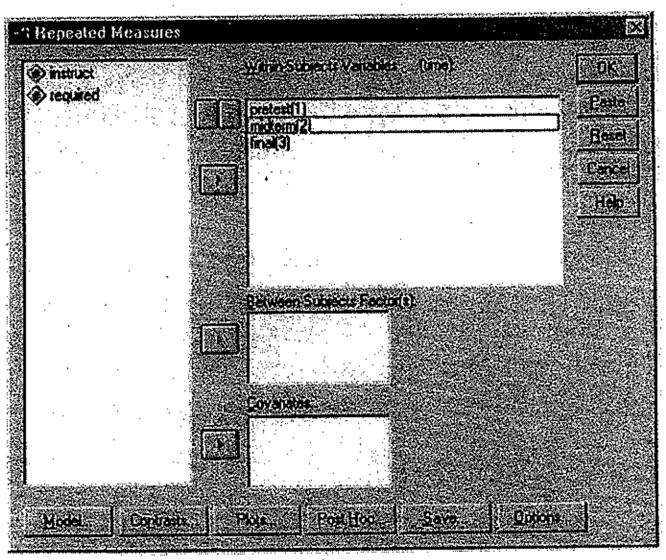
Note that this procedure requires the Advanced Statistics module. If you do not have this command, you do not have the Advanced Statistics module installed.



After selecting the command, you will be presented with the Repeated Measures Define Factor(s) dialog box. This is where you identify the within-subject factor (we will call it TIME). Enter *3* for the number of levels (three exams) and click *Add*.

Now click *Define*. If we had more than one **independent variable** that had repeated measures, we could enter its name and click *Add*.

You will be presented with the Repeated Measures dialog box. Transfer PRETEST, MIDTERM, and FINAL to the *Within-Subjects Variables* section. The variable names should be ordered according to when they occurred in time (i.e., the values of the **independent variable** that they represent).



Click *Options*, and SPSS will compute the means for the TIME effect (see one-way ANOVA for more details about how to do this). Click *OK* to run the command.