means on the dependent variable and that there are no differences on the dependent variable scores within each of the groups (i.e., perfect replication). In general, η^2 is interpreted as the proportion of variance of the dependent variable that is related to the factor. What is a small versus a large η^2 is dependent on the area of investigation. However, η^2 of .01, .06, and .14 are, by convention, interpreted as small, medium, and large effect sizes, respectively.

The Data Set

The data set used to illustrate a one-way ANOVA is named *Lesson 25 Data File 1* on the Web at http://www.prenhall.com/greensalkind. It represents data from the vitamin C example described earlier. The variables in the data set are presented in Table 18.

Table 18
Variables in Lesson 25 Data File 1

Variables	Definition
group	1 = Placebo 2 = Low doses of vitamin C 3 = High doses of vitamin C
diff	Number of days with cold symptoms in the second year minus the number of days with cold symptoms in the first year

The Research Question

The research question can be stated to reflect mean differences or relationships between variables.

1. Mean differences. Does the mean change in the number of days of cold symptoms differ among the three experimental populations: those who take placebo, those who take low doses of vitamin C, and those who take high doses of vitamin C?
2. Relationship between variables. Is there a relationship in the population between the amount of vitamin C taken and the change in the number of days that individuals show cold symptoms?

Conducting a One-Way ANOVA

To conduct an overall one-way ANOVA and pairwise comparisons among the three vitamin C treatment means, follow these steps:

1. Click **Analyze**, click **General Linear Model**, then click **Univariate**. You'll see the Univariate dialog box in Figure 149.
2. Click **diff**, then click ▶ to move it to the Dependent Variable box.
3. Click **group**, then click ▶ to move it to the Fixed Factor(s) box.
4. Click **Options**. You'll see the Univariate: Options dialog box in Figure 150.
5. Click **group** in the Factor(s) and Factor Interactions box, then click ▶ to make it appear in the Display Means for box.
6. Click **Homogeneity tests**, **Estimates of effect size**, and **Descriptive statistics** in the Display box.
7. Click **Continue**.
8. Click **Post Hoc**. You'll see the Univariate: Post Hoc Multiple Comparisons for Observed Means dialog box in Figure 151.
9. In the Factor(s) box, click **group**, and click ▶ to make it appear in the Post Hoc Tests for box.

TIP

One-Way ANOVA assumes equality of population variances. If this assumption is violated, use the Browne-Forsythe or the Welch statistic available within One-Way ANOVA in Compare Means. For further discussion, see the section labeled "Assumptions Underlying One-Way ANOVA."

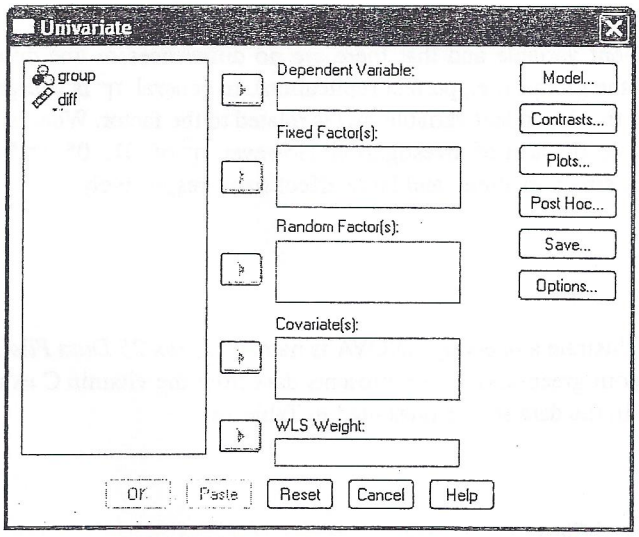

Figure 149. **The Univariate dialog box.**

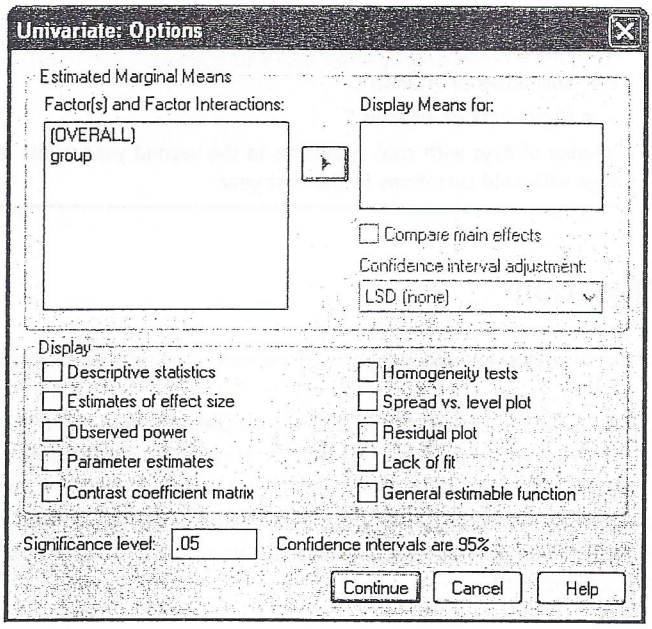

Figure 150. **The Univariate: Options dialog box.**

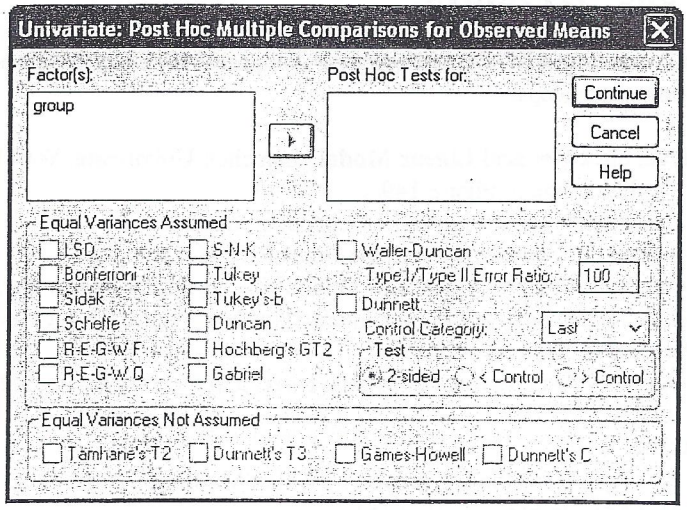

Figure 151. **The Univariate: Post Hoc Multiple Comparisons for Observed Means dialog box.**

10. In the Equal Variances Assumed box, click **Tukey** and **R-E-G-W-Q**. Other post hoc tests assuming equal variances are equally valid.
11. In the Equal Variances Not Assumed box, click **Dunnett's *C***. Other post hoc tests not assuming equal variances are equally valid.
12. Click **Continue**.
13. Click **OK**.

Selected SPSS Output for One-Way ANOVA

The results of analyses are shown in Figure 152, including the means and standard deviations, the homogeneity-of-variance test, and the one-way ANOVA F test. To determine whether the overall ANOVA was significant, examine the table labeled Tests of Between-Subjects Effects. The test is significant, $F(2,27) = 4.84$, $p = .02$. The p value is located in the column labeled Sig. Because the p value is less than .05, we reject the null hypothesis that there are no differences among the groups. The η^2 (labeled Partial Eta Squared in the output) of .26 indicates a strong relationship between the vitamin C factor and the change in the number of days with cold symptoms.

Descriptive Statistics

Dependent Variable: Difference in Days with Colds

Vitamin C Treatment	Mean	Std. Deviation	N
Placebo	3.50	4.143	10
Low Vitamin C Dose	-2.10	4.067	10
High Vitamin C Dose	-2.00	5.477	10
Total	-.20	5.182	30

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

Dependent Variable: Difference in Days with Colds

F	df1	df2	Sig.
1.343	2	27	.278

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

a. Design: Intercept+group

Tests of Between-Subjects Effects

Dependent Variable: Difference in Days with Colds

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	205.400[a]	2	102.700	4.836	.016	.264
Intercept	1.200	1	1.200	.057	.814	.002
group	205.400	2	102.700	4.836	.016	.264
Error	573.400	27	21.237			
Total	780.000	30				
Corrected Total	778.800	29				

a. R Squared = .264 (Adjusted R Squared = .209)

Figure 152. **The results of a one-way analysis of variance.**

Because the overall F test was significant, follow-up tests were conducted to evaluate pairwise differences among the means. A decision has to be made whether to use a post hoc procedure that assumes equal variances (Tukey or R-E-G-W-Q) or one that does not assume equal variances (Dunnett's C) to control for Type I error across the multiple pairwise comparisons. In our example, the standard deviations range from 4.07 to 5.48 and the variances (the standard deviations squared) range from 16.54 to 30.00, indicating that the variances are somewhat, but not

drastically, different from each other. The test of homogeneity of variance was nonsignificant, $p = .28$. Because there may be a lack of power associated with the test due to the small sample size, the result of the homogeneity test does not necessarily imply that there are no differences in the population variances. Therefore, the prudent choice for these data would be to ignore the results of the Tukey and R-E-G-W-Q tests and to use the results of the Dunnett's *C* test, a multiple comparison procedure that does not require the population variances to be equal.

Selected SPSS Output for Post Hoc Comparisons

The results of the post hoc comparisons are shown in Figure 153. Using the Dunnett's *C* test, groups 1 and 2 differed significantly from one another. In the table labeled Multiple Comparisons, the stars (*) in the Mean Difference column indicate which pairwise comparisons are significant.

Post Hoc Tests

Vitamin C Treatment

Multiple Comparisons

Dependent Variable: Difference in Days with Colds

	(I) Vitamin C Treatment	(J) Vitamin C Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Placebo	Low Vitamin C Dose	5.60*	2.061	.030	.49	10.71
		High Vitamin C Dose	5.50*	2.061	.033	.39	10.61
	Low Vitamin C Dose	Placebo	-5.60*	2.061	.030	-10.71	-.49
		High Vitamin C Dose	-.10	2.061	.999	-5.21	5.01
	High Vitamin C Dose	Placebo	-5.50*	2.061	.033	-10.61	-.39
		Low Vitamin C Dose	.10	2.061	.999	-5.01	5.21
Dunnett C	Placebo	Low Vitamin C Dose	5.60*	1.836		.47	10.73
		High Vitamin C Dose	5.50	2.172		-.56	11.56
	Low Vitamin C Dose	Placebo	-5.60*	1.836		-10.73	-.47
		High Vitamin C Dose	-.10	2.157		-6.12	5.92
	High Vitamin C Dose	Placebo	-5.50	2.172		-11.56	.56
		Low Vitamin C Dose	.10	2.157		-5.92	6.12

Based on observed means.

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

Homogeneous Subsets

Difference in Days with Colds

	Vitamin C Treatment	N	Subset 1	Subset 2
Tukey HSD[a,b]	Low Vitamin C Dose	10	-2.10	
	High Vitamin C Dose	10	-2.00	
	Placebo	10		3.50
	Sig.		.999	1.000
Ryan-Einot-Gabriel-Welsch Range[b]	Low Vitamin C Dose	10	-2.10	
	High Vitamin C Dose	10	-2.00	
	Placebo	10		3.50
	Sig.		.962	1.000

Means for groups in homogeneous subsets are displayed.

Based on Type III Sum of Squares

The error term is Mean Square(Error) = 21.237.

a. Uses Harmonic Mean Sample Size = 10.000.

b. Alpha = .05.

Figure 153. **The results of post hoc pairwise comparisons.**

Using SPSS Graphs to Display the Results

The same graphical methods that were presented for the independent-samples *t* test (Lesson 24) can be used for one-way ANOVA as well. ANOVA results may be depicted using boxplots to show the distributions of the dependent variable across the groups.

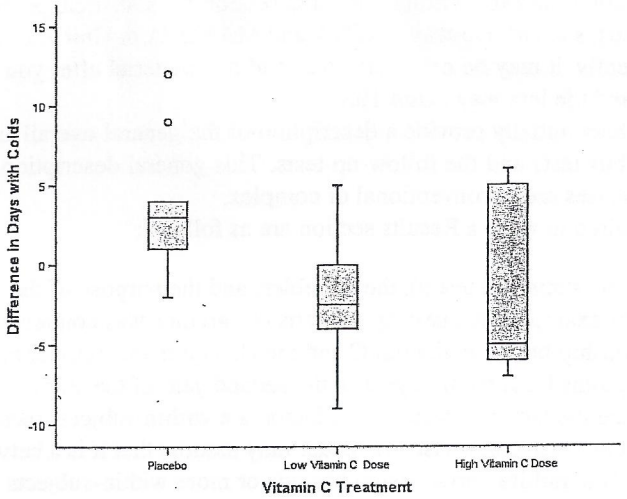

Figure 154. **Changes in number of days with cold symptoms for placebo, low-dose, and high-dose vitamin C treatment groups.**

We created a boxplot to show the distributions of the changes in number of days with cold symptoms for the three vitamin C treatment groups. Figure 154 shows the distributions of the three groups.

An APA Results Section

A one-way analysis of variance was conducted to evaluate the relationship between vitamin C and the change in the number of days with cold symptoms from the first year to the second year of the study. The independent variable, the vitamin C factor, included three levels: placebo, low doses of vitamin C, and high doses of vitamin C. The dependent variable was the change in the number of days of cold symptoms from the first year to the second year. The ANOVA was significant, $F(2, 27) = 4.84$, $p = .02$. The strength of relationship between the vitamin C treatment and the change in the number of days with cold symptoms, as assessed by η^2, was strong, with the vitamin C factor accounting for 26% of the variance of the dependent variable.

Follow-up tests were conducted to evaluate pairwise differences among the means. Because the variances among the three groups ranged from 16.54 to 30.00, we chose not to assume that the variances were homogeneous and conducted post hoc comparisons with the use of the Dunnett's *C* test, a test that does not assume equal variances among the three groups. There was a significant difference in the means between the group that received a low dose of vitamin C and the placebo group, but no significant differences between the two vitamin C groups and between the high dose and placebo groups. The group that received a low dose of vitamin C showed a greater decrease in number of days with cold symptoms in comparison to the placebo group. The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three vitamin C groups, are reported in Table 19.

Table 19

95% Confidence Intervals of Pairwise Differences in Mean Changes in Number of Days of Cold Symptoms

Vitamin C group	*M*	*SD*	Placebo	Low dose
Placebo	3.50	4.14		
Low dose	−2.10	4.07	.47 to 10.73*	
High dose	−2.00	5.48	−.56 to 11.56	−6.12 to 5.92

Note: An asterisk indicates that the 95% confidence interval does not contain zero, and therefore the difference in means is significant at the .05 significance using Dunnett's *C* procedure.

Writing an APA Results Section

We present some guidelines for writing a Results section for statistical procedures that may require follow-up tests, such as one-way ANOVA and MANOVA in Unit 7, or the Friedman test in Unit 10. Consequently, it may be necessary to reread this material after you have read the other lessons in Unit 7 and the lessons in Unit 10.

Some researchers initially provide a description of the general overall analytic strategy that includes the omnibus tests and the follow-up tests. This general description is necessary to the degree that the analyses are unconventional or complex.

The steps required to write a Results section are as follows:

1. Describe the statistical test(s), the variables, and the purpose of the statistical test(s). For example, "A one-way analysis of variance was conducted to evaluate the relationship between vitamin C and the change in the number of days with cold symptoms from the first year to the second year of the study."
   - Describe the factor or factors. If a factor is a within-subjects factor, be sure to label it as such. Otherwise the reader may assume that it is a between-subjects factor. If a multifactorial design has one or more within-subjects factors, describe each factor as a between-subjects or a within-subjects factor.
   - Indicate the number of levels of each factor. It may also be informative to the reader to have a description of each level if the levels are different treatments. However, it is not necessary to report the number of levels and what the levels are for factors with obvious levels such as gender.
   - Describe what the dependent variable(s) are.
2. Report the results of the overall test(s).
   - Describe any decisions about which test was chosen based on assumptions. For example, for a one-way within-subjects ANOVA, justify the choice of using a traditional univariate test instead of a multivariate test.
   - Report the test value and significance level (for the one-way ANOVA, $F(2, 27) = 4.84$, $p = .02$). For p values of .000, report them as $p < .01$. For multifactor designs, report the statistic for each of the main and interaction effects. Tell the reader whether the test(s) are significant or not.
   - Report statistics that allow the reader to make a judgment about the magnitude of the effect for each overall test (e.g., for the one-way ANOVA, $\eta^2 = .45$).
   - Italicize all non-Greek symbols except subscripts and superscripts.
3. Report the descriptive statistics. Refer the reader to a table or figure that presents the relevant descriptive statistics (e.g., means and standard deviations for ANOVA designs). A table or figure may not be necessary for simpler designs, such as a one-way ANOVA with three groups. For these simple designs, the descriptive statistics may be presented in the text.
4. Describe and summarize the general conclusions of the analysis. For example, "The results of the one-way ANOVA supported the hypothesis that different types of vitamin C treatment had a differential effect on the reduction of cold symptoms in individuals."
5. Report the results of the follow-up tests.
   - Describe the procedures used to conduct the follow-up tests. Explain any decisions you made about choice of tests based on their assumptions.
   - Report the method used to control for Type I error across the multiple tests.
   - Summarize the results of the follow-up procedures. It may be useful to present the results of the significance tests among pairwise comparisons with a table of means and standard deviations. When possible, report confidence intervals for pairwise comparisons.