Chapter 11
One-way ANOVA:
Differences Between Multiple Independent Group Means

11.1 Introduction to One-way ANOVA

In the previous two chapters we distinguished between two distinct applications of the *t*-test - the independent samples *t*-test and the correlated samples *t*-test. This same distinction applies to the new procedure introduced in this chapter, **One-way ANOVA**. The present chapter will introduce this procedure for independent samples, and the ANOVA procedure for correlated samples will be presented in Chapter 12.

As with the *t*-test, ANOVA also tests for significant differences between groups. But while the *t*-test is limited to the comparison of only *two* groups, one-way ANOVA can be used to test differences in **three or more groups**. Several hypotheses worth investigating in our project involve the comparison of more than two groups. For example, EZ execs would certainly be interested in any differences in leader performance in relation to employees' **sex role type** or **leadership style**. However, as you will see, there are four levels of both of these quasi-independent variables (and so four groups to compare). Since the *t*-test only permits comparison of two groups, it is necessary to use analysis of variance (ANOVA) procedures for these comparisons.

The ANOVA procedure produces an *F* statistic, a value whose probability enables the researcher to reject or retain the null hypothesis, i.e., to conclude whether or not the differences in the scores on the dependent variable are statistically significant or due to chance. As with the *t*-test test, ANOVA is appropriate when the data are interval or ratio level, when the groups show similar variances, and when the data are normally distributed.

ANOVA is based upon a comparison of variance attributable to the independent variable (variability **between** groups or conditions) relative to the variance **within** groups resulting from random chance. In fact, the formula for computing the *F* statistic involves dividing the between-group variance estimate by the within-group variance estimate.

While different procedures are used to compute the ANOVA for independent vs. correlated samples designs, each procedure yields an *F* statistic which is evaluated in essentially the same way. Thus, regardless of which design is employed, the end result is an *F*-value, and when the probability of occurrence of the *F* value is less than .05, we conclude that there are significant differences groups, i.e., variation which cannot be attributed to chance.

11.1a The Need for Individual Comparisons

When three or more groups are being analyzed in the ANOVA, there frequently arises the need to carry out more specific two-group comparisons in order to determine where the major treatment effect is occurring. A significant F-value only indicates that there is a significant difference *somewhere* between the groups - it does not indicate *which* groups are different. To determine this, secondary comparisons among all group means are needed subsequent to the ANOVA.

These two-group comparisons are commonly referred to as individual comparisons, follow-up tests, or *post-hoc* tests. Let's assume, for example, that you are a clinical psychologist who has designed an experiment to assess the effectiveness of different types of therapy on the treatment of phobias in a sample of eighty men and women. You assign each participant to one of four groups (either a control group or one of three different types of therapy). After an adequate treatment period, you rate the amount of improvement each subject has shown (higher score = more improvement). The mean improvement scores (hypothetical, of course!) for the four groups are as follows:

- Group 1 Control: $M = 12$
- Group 2 Psychoanalytic: $M = 18$
- Group 3 Client-centered: $M = 23$
- Group 4 Cognitive-behavioral: $M = 41$

You perform an ANOVA on the four groups, and find that there is significant overall variation (or differences) between the treatment groups. From this analysis, you can conclude that the independent variable (therapy) is having a significant effect, but you are unable to state where the effect is occurring. Is psychoanalytic therapy more effective than receiving no treatment at all? Is cognitive-behavioral therapy more effective than either psychoanalytic or client-centered therapies? Might there also be a significant difference between psychoanalytic and client-centered approaches? These questions require that we carry out more specific individual comparisons between the pairs of groups in which we're interested.

There are a number of guidelines for performing these two-group comparisons. For example, most researchers agree that it is appropriate to perform individual comparisons only if the result of the overall ANOVA is significant. Furthermore, one must decide at some point in the experimental process whether these comparisons are to be *a priori* (planned before the data are collected), or *post hoc* (decided upon after collecting and studying the data). Last, one must decide which specific *a priori* or *post hoc* technique (since there are many) best suits the situation (or researcher). While we are not able to review all the relevant guidelines for performing individual comparisons within this text, suffice it to say that these comparisons are generally considered an important and necessary part of the analysis of an experimental design in which there are three groups or more.

11.2 Sex Role Type and Leader Performance

For this chapter's example we will examine differences in **leader performance** (the dependent variable) in relation to EZ employees' **sex role type** (the independent variable). Recall from Chapter 5 that we referred to sex role type in the context of creating new variables using the SPSS **Transform** procedure, but we did not describe the specific rules that we used for creating this new variable. Essentially, we used a combination of scores on two categorical variables, **masc** and **fem**, to create the four levels of this new variable. That is, employees were classified into one of four sex-role identities based on their scores on **masc** and **fem**: **Sex-role diffuse**, **Masculine sex-typed**, **Feminine sex-typed** and **Androgynous**.

Specifically, employees were assigned a score between **1** and **4** on this new **sex role type** variable based on the *particular combination* of **masc** and **fem** scores each participant received. Thus, for any given participant, the combination of his/her scores on these two variables yields one of four possible categories into which s/he can be classified:

- low masculinity-low femininity (i.e., the employee scored 1 on both **masc** and **fem**)
- high masculinity-low femininity (the employee scored 2 on **masc** and 1 on **fem**)
- low masculinity-high femininity (the employee scored 1 on **masc** and 2 on **fem**)
- high masculinity-high femininity (the employee scored 2 on **masc** and 2 on **fem**)

To create these four groups, the SPSS **Transform, Into a Different Variable...** option was selected, then the following four conditional **IF** statements were used to create the new **sex role type** variable:

- If **masc** = 1 *and* **fem** = 1, then **sex role type** = **1** (Sex Role Diffuse Identity)
- If **masc** = 2 *and* **fem** = 1, then **sex role type** = **2** (Masculine Sex-typed Identity)
- If **masc** = 1 *and* **fem** = 2, then **sex role type** = **3** (Feminine Sex-typed Identity)
- If **masc** = 2 *and* **fem** = 2, then **sex role type** = **4** (Androgynous Sex Role Identity)

SPSS processed these conditional statements by examining each participant's **masc** and **fem** scores. Employees who received a score of **1** on *both* **masc** and **fem** (i.e., employees who were *both* low-masculine *and* low-feminine) were assigned the number **1** on the new **sex role type** variable (recall that this category of sex-role orientation is referred to as **Sex role diffuse**, indicating that persons in this group rate themselves as *neither* strongly masculine nor strongly feminine).

Employees who scored 2 on **masc** (high-masculine) *and* 1 on **fem** (low-feminine) were assigned the number **2** on **sex role type** (this represents the sex-role category, **Masculine sex-typed**, indicating that these people rate themselves as high-masculine and low-feminine). Next, employees who scored **1** on **masc** (low-masculine) *and* **2** on **fem** (high-feminine) were assigned the number **3** on **sex role**

type (this is the **Feminine sex-typed** sex-role category, consisting of people who rate themselves as low-masculine and high-feminine).

Finally, employees who received a score of **2** on *both* **masc** and **fem** (i.e., persons who scored high on both masculinity and femininity) were assigned the number **4** on **sex role type**(recall that this sex-role category is referred to as **Androgynous**, indicating that these people rate themselves as *both* strongly masculine and strongly feminine).

To see this new variable and the labels we assigned, open your **ezdata.sav** file and click the **Variable View** tab at the bottom of the window. Scroll to the bottom and you will see that we named this variable **sextype** in the data file. Go across that row and click on the cell in the **Values** column and you will see the labels we provided four the scores between 1 and 4 on this variable. In fact, you will also see another new variable, **leaderstyle**, and its labels - a variable we created using the same procedures. This will be the independent variable in the exercise at the end of this chapter, so we will describe it then.

This new variable may seem confusing to you because of the complexity of the variable transformation procedure to create this new variable. In fact, that is why we chose not to include the description of this process in Chapter 5, and created the new variable for you! Also, the conceptual underpinnings of **sex role type** can be difficult to understand given that one must think of two variables simultaneously (**masc** and **fem**) to describe a person's sex role identity. But SPSS has already created the four groups for you, so just focus on the meaning of the four categories:

- **Sex role diffuse** persons see themselves as *neither* strongly masculine nor strongly feminine. They do not have a clearly developed identity regarding masculinity and femininity.
- **Masculine sex-typed** persons see themselves as primarily masculine in their identity. They emphasize masculinity and reject femininity in their self-concept.
- **Feminine sex-typed** persons see themselves as primarily feminine in their identity. The emphasize femininity and reject masculinity in their self-concept.
- **Androgynous** persons have integrated masculinity and femininity in their identity, seeing themselves as *both* strongly feminine *and* strongly masculine.

Given these four different types of sex role identity, our goal is to examine differences in our dependent variable, **leader performance**, in relation to this independent variable using the **One-way ANOVA** procedure. You might try to anticipate the results before we run the procedure. For example, one might expect that the sex role diffuse employees will have the lowest performance scores, while androgynous individuals will have the highest performance scores.

11.3 Running One-way ANOVA

Open your **ezdata.sav** file and select **Analyze, Compare Means, One-Way ANOVA...** from the menu (Figure 11.1).
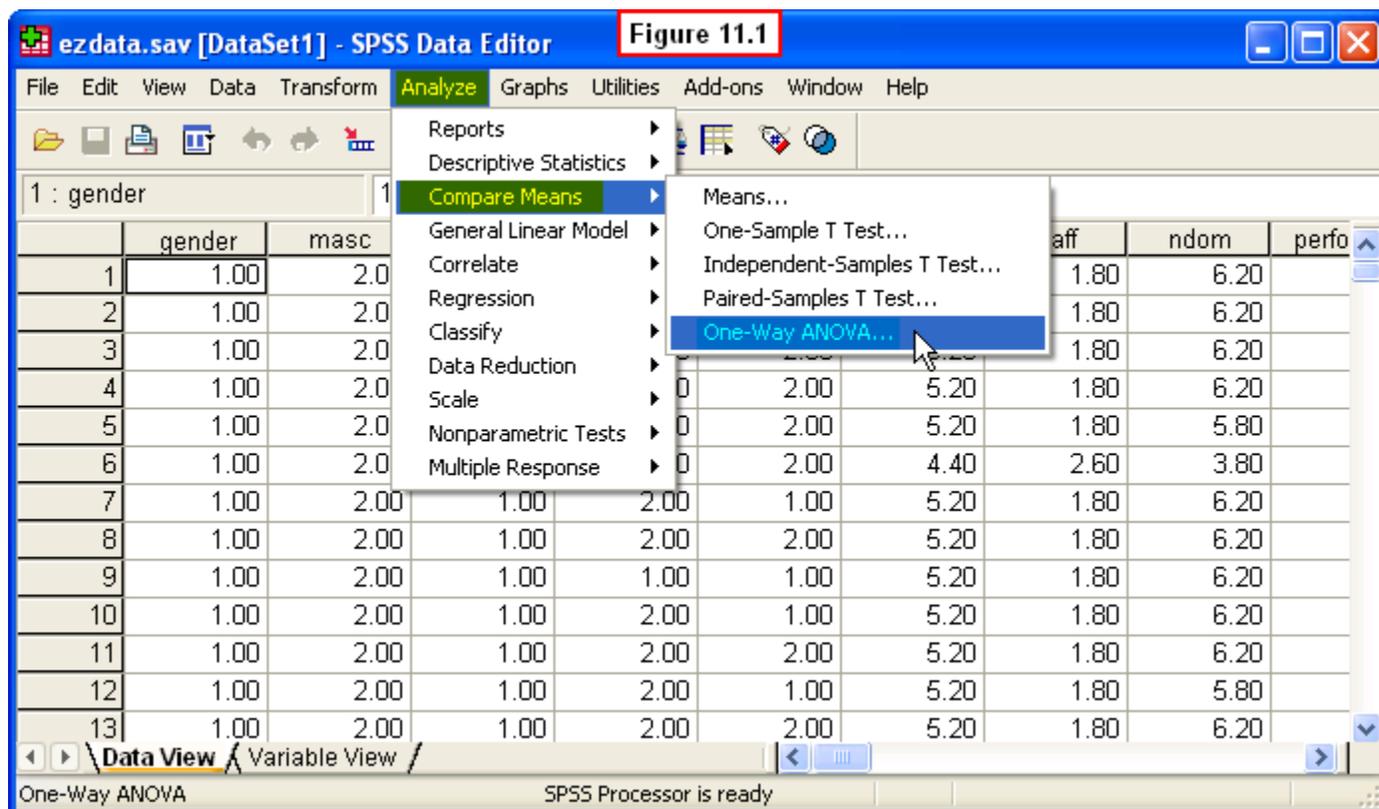

A One-Way ANOVA dialog window will appear. Select **Leader Performance 1 (perform1)** on the left and move it to the **Dependent List:** pane on the right. Next scroll all the way down on the left, select **Sex Role Type (sextype)** and move it to the **Factor:** pane on the lower right. Note that SPSS uses the term, **Factor**, to refer to the independent variable, so these terms are synonymous. This will generate the ANOVA table when we run the analysis. But recall that we need to specify the multiple comparisons of group means first, so to do this click the **Post Hoc...** button at the bottom.
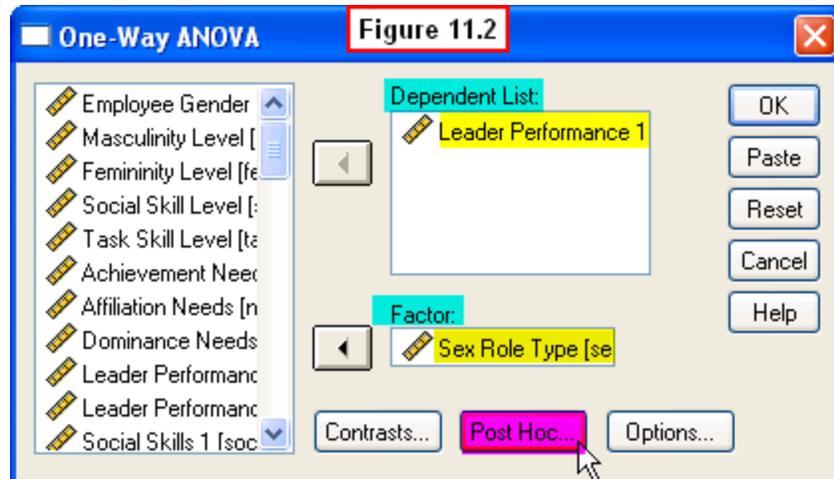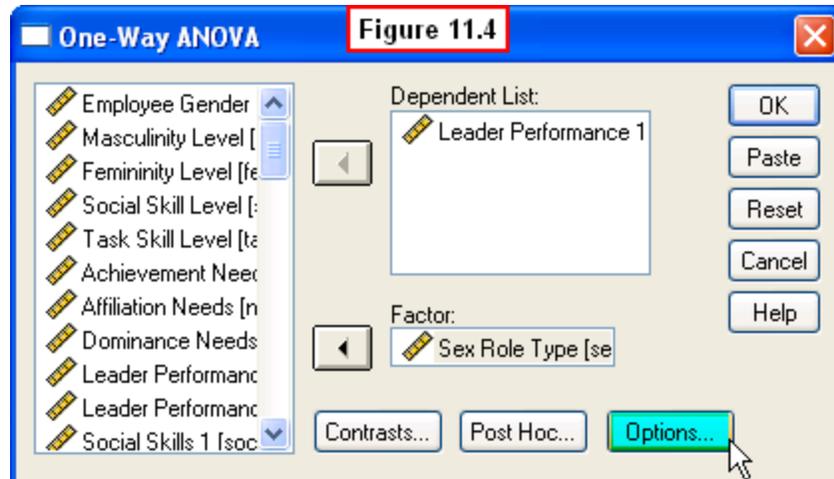
Figure 11.2

A **One-Way ANOVA: Post Hoc Multiple Comparisons** window will appear (Figure 11.3). There are numerous statistical procedures one can choose from to perform these comparisons, but a discussion of these is beyond the scope of this chapter. For our purposes, select the **LSD** box. LSD stands for Least Significant Difference.

Briefly, a value is computed which is how much two means must differ to justify rejecting Ho and concluding they are significantly different. The differences between all possible pairs of means are computed by subtraction. These mean differences are compared to the Least Significant Difference value. Any two means that differ at least by this amount will be judged to be significantly different at the .05 level.

Figure 11.3
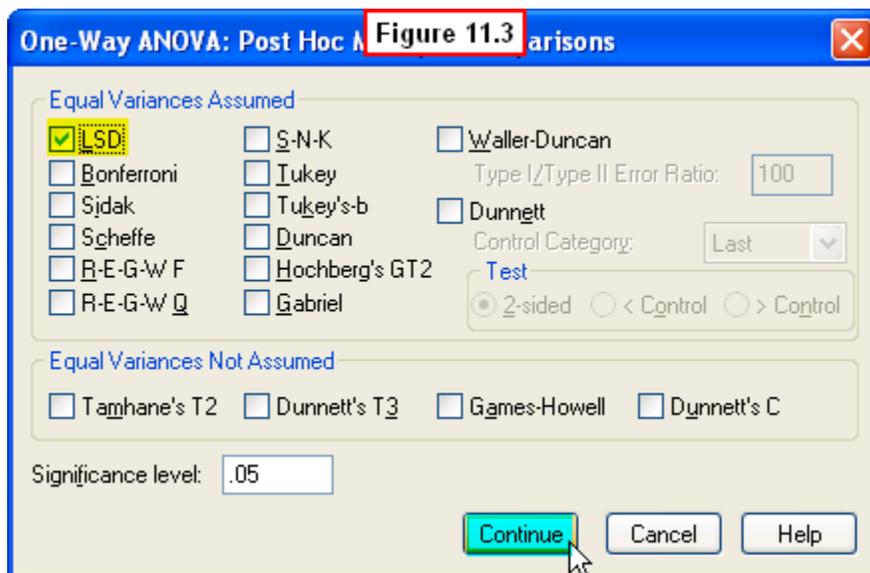
Click the **Continue** button at the bottom of this window and SPSS will return to the original **One-Way ANOVA** dialog window. Next we need to specify what other statistics besides the *F*-value that we want to compute. To do this, click the **Options...** button at the bottom of this window (Figure 11.4).

Figure 11.4

A **One-Way ANOVA: Options** dialog window will appear (Figure 11.5). Researchers typically want to examine descriptive statistics, so check the **Descriptive** box. Researchers also typically select the Homogeneity of variance test as well to determine whether or not this condition of ANOVA has been met. However, to simplify this example, we will not perform this test here. Last, recall that a visual depiction of results can greatly facilitate interpretation, so check the **Means plot** box. Then click the **Continue** button.
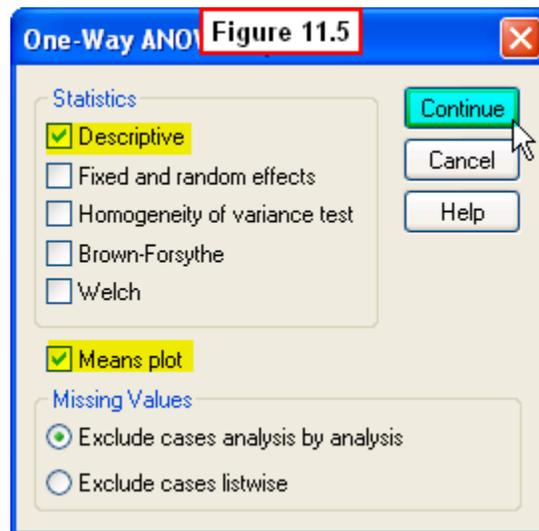
Figure 11.5

This will return you to the main dialog window. To run the ANOVA, click the **OK** button in the upper right corner.

11.4 Interpreting the Output

Several statistics are presented in the first table, **Descriptives** (Figure 11.6). The most relevant for our purposes are the four group means reflecting leader performance

scores. Examination of these means suggests that the average leadership performance was lowest among the sex role diffuse group and highest for the androgynous group. But before we can interpret these means, we must first examine the results of the F-test and the multiple comparisons of means.

Figure 11.6

Descriptives

Leader Performance 1

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maxim
Sex Role Diffuse	37	3.4054	1.67431	.27525	2.8472	3.9636	1.00	
Masc Sex-Typed	59	6.3898	2.31946	.30197	5.7854	6.9943	1.00	
Fem Sex-Typed	51	5.0588	1.85916	.26033	4.5359	5.5817	2.00	
Androgynous	81	7.2716	1.78194	.19799	6.8776	7.6656	2.00	
Total	228	5.9211	2.36772	.15681	5.6121	6.2300	1.00	

The ANOVA table is shown in Figure 11.7. The Mean Square values are computed by dividing the Between and Within Groups Sum of Squares by their respective degrees of freedom (df), where df = 3 and 224, respectively. The F-value (38.48) is computed by dividing the Mean Square Between Groups by the Mean Square Within Groups. As with the t-test, the most important part of this table the **Sig.** value, since this is the probability that the differences between groups is due to chance. Recall that if p (Sig.) is less than or equal to .05, we reject Ho. Since in this case, the Sig. is less than .001, we can reject the null hypothesis of no differences. If we were to write these results according to APA guidelines, we would state the following:

A one-way ANOVA revealed that there were significant differences in leadership performance between the four groups, $F(3,224) = 38.48$, $p < .001$.

Figure 11.7

ANOVA

Leader Performance 1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	432.778	3	144.259	38.478	.000
Within Groups	839.801	224	3.749		
Total	1272.579	227			

Before we can state where the significant differences occur, we must examine the results of the LSD multiple comparisons (Figure 11.8). This table presents the results of all possible comparisons between means, so some of the information in the table is redundant. We will not discuss the section labeled **95% Confidence Interval**, since our main interest in this table lies with the results of the multiple comparisons.

Figure 11.8

Multiple Comparisons

Dependent Variable: Leader Performance 1

LSD

(I) Sex Role Type	(J) Sex Role Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Sex Role Diffuse	Masc Sex-Typed	-2.98443*	.40604	.000	-3.7846	-2.1843
	Fem Sex-Typed	-1.65342*	.41814	.000	-2.4774	-.8294
	Androgynous	-3.86620*	.38420	.000	-4.6233	-3.1091
Masc Sex-Typed	Sex Role Diffuse	2.98443*	.40604	.000	2.1843	3.7846
	Fem Sex-Typed	1.33101*	.37021	.000	.6015	2.0605
	Androgynous	-.88177*	.33141	.008	-1.5348	-.2287
Fem Sex-Typed	Sex Role Diffuse	1.65342*	.41814	.000	.8294	2.4774
	Masc Sex-Typed	-1.33101*	.37021	.000	-2.0605	-.6015
	Androgynous	-2.21278*	.34612	.000	-2.8948	-1.5307
Androgynous	Sex Role Diffuse	3.86620*	.38420	.000	3.1091	4.6233
	Masc Sex-Typed	.88177*	.33141	.008	.2287	1.5348
	Fem Sex-Typed	2.21278*	.34612	.000	1.5307	2.8948

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

This table is divided into four main sections, with four rows within each section. For example, the first main section lists the Sex Role Diffuse group in the first column. The mean performance score for this group will be compared to that of the other three groups listed in the second column. In each main section, (**I**) refers to the mean for the group in the first column (e.g., Sex Role Diffuse), and (**J**) refers to the means for the other three groups listed in the second column (e.g., Masculine, Feminine, and Androgynous) which are being compared to the (**I**) mean.

The Mean Difference (**I - J**) column reports the difference between each pair of means. Look back at Figure 11.6 to see the group means. Thus, in the first row of this section, we can see that SPSS subtracted the Masculine sex-typed mean (**J** = 6.39) from the Sex role diffuse mean (**I** = 3.41), to yield (**I - J**) = (3.41 - 6.39) = -2.98 for the mean difference between these two groups. An asterisk next to the Mean Difference flags the pair of group means as significantly different at the .05 level (note that wherever an asterisk appears, the probability is less than .05 in the **Sig.** column for that particular comparison of two means). Below is the interpretation of these analyses as it would be written in a research report.

LSD comparisons revealed that all four means were significantly different from each other. Androgynous employees had significantly higher mean leadership performance ratings (*M* = 7.27) than did the masculine sex-typed (*M* = 6.39), feminine sex-typed (*M* = 4.88), and sex role diffuse employees (*M* = 3.41). Masculine sex-typed employees received significantly higher performance ratings than did the feminine sex-typed and

sex role diffuse employees. Feminine sex-typed employees received higher performance ratings than did sex role diffuse employees.

These differences can be clearly seen in the graph depicting the mean performance scores of each of the four groups (Figure 11.9).

Figure 11.9
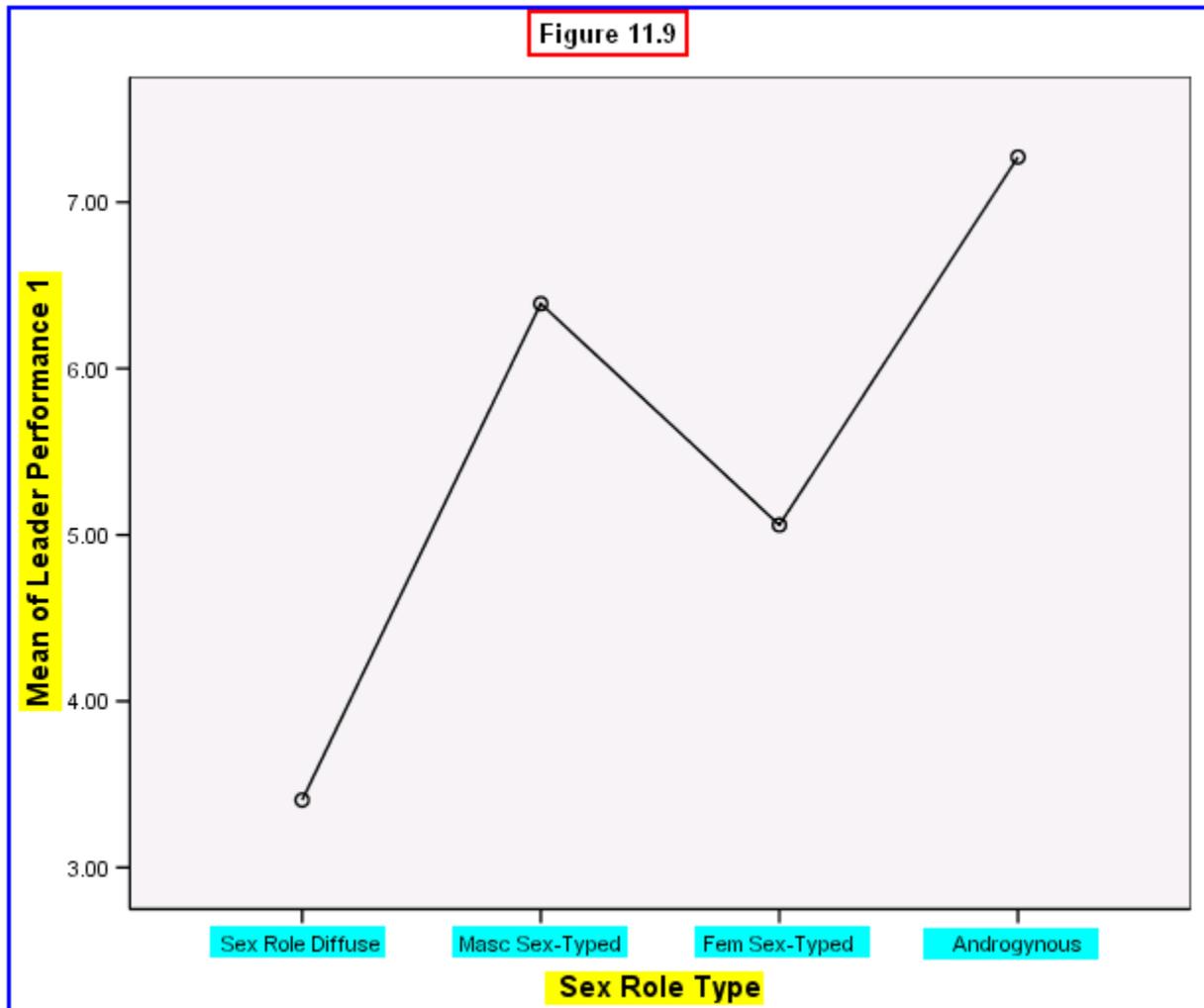
The one-way ANOVA procedure we performed yielded interesting results that you would want to report to upper-level management at EZ Manufacturing. Androgynous individuals (who integrate masculinity and femininity in their identity) appear to have the greatest leadership potential. Masculine sex-typed individuals did have higher performance scores than did feminine sex-typed employees. Perhaps this was due to a masculinity bias, reflecting stereotypes that associate masculinity, but not femininity, with leadership.

However, femininity was not viewed as a liability *per se*. Feminine sex-typed employees had higher performance scores than did the sex role diffuse group. Further, high-femininity, when paired with high-masculinity (i.e., androgyny) was associated with the

best leader performance. These results demonstrate the importance of high masculinity in this organization, but also suggest that high-femininity does not necessarily detract from leader performance.

11.5 Chapter Review Video

Review Me!

11.6 Try It! Exercises

1. Using One-Way ANOVA: Leadership Style and Leader Performance

We have created another new variable, **Leadership Style**, in the **ezdata.sav** file using the same procedure we described in Section 11.2 to create the sex role typing variable. The leader style variable was created using the categorical variables, **task1** (where 1 = low task skills; 2 = high task skills), and **soc1** (where 1 = low social skills; 2 = high social skills).

Specifically, employees were assigned a score between **1** and **4** on this new **leaderstyle** variable based on the *particular combination* of **task1** and **soc1** scores each participant received. Thus, for any given participant, the combination of his/her scores on these two variables yields one of four possible categories into which s/he can be classified:

- low task skills-low social skills (i.e., the employee scored 1 on both **task1** and **soc1**)
- high task skills-low social skills (the employee scored 2 on **task1** and 1 on **soc1**)
- low task skills-high social skills (the employee scored 1 on **task1** and 2 on **soc1**)
- high task skills-high social skills (the employee scored 2 on **task1** and 2 on **soc1**)

To create these four groups, the SPSS **Transform, Into a Different Variable...** option was selected, then the following four conditional **IF** statements were used to create the new **leaderstyle** variable:

- If **task1** = 1 *and* **soc1** = 1, then **leaderstyle** = **1** (Low Task & Social Skills)
- If **task1** = 2 *and* **soc1** = 1, then **leaderstyle** = **2** (High Task/Low Social Skills)
- If **task1** = 1 *and* **soc1** = 2, then **leaderstyle** = **3** (Low Task/High Social Skills)
- If **task1** = 2 *and* **soc1** = 2, then **leaderstyle** = **4** (High Task & Social Skills)

Thus, Group 1 consists of employees aren't oriented to either task or social issues in leadership style. Group 2 consists of people who are primarily task-oriented in their leadership style. Group 3 includes persons who are primarily relationship-oriented in their leadership style. Last, Group 4 consists of individuals who are oriented strongly

towards both task and social issues in leadership style. You might try to anticipate the pattern of results regarding performance before you run this analysis.

Open your **ezdata.sav** file and you will see that this new variable is the last one listed in the data file. Use the procedures described in Section 11.3 to conduct a one-way ANOVA using **Leadership Style (leader style)** as the independent variable (factor) and **Leadership Performance (perform1)** as the dependent variable to determine whether or not there are significant differences in performance in relation to employee leadership style.

- **Print** your output file to submit to your instructor.
- Answer the following questions:
    - What is the value of the *F*-statistic?
    - What is the significance level?
    - Should you reject or fail to reject the null hypothesis of no differences in performance between the leader style groups?
    - Write a statement about the *F*-value as shown in Section 11.4
    - Conduct LSD Multiple Comparisons in your analysis. Based on the results of the post hoc tests, which groups differ from each other?
    - For those means that are significantly different, state what the differences are (i.e., which group had the higher performance score?)
- **Write an interpretation of the results** along with your answers to the above questions to submit to your instructor. Follow the example in Section 11.4.