

Chapter 14

Mixed-Model Factorial ANOVA: Combining Independent and Correlated Group Factors

14.1 Introduction to Mixed-Model Factorial ANOVA

In Chapters 9 and 10 we distinguished between two distinct applications of the t-test: the independent samples t-test and the correlated samples t-test. Similarly, in Chapters 11 and 12 we distinguished between independent and correlated samples one-way ANOVA's. Recall that when a **between-subjects design** is used, the appropriate statistical test to use assumes **independent-samples**, whereas **within-subjects designs** require statistical tests assuming **correlated samples**.

In Chapter 13 we introduced two-way factorial ANOVA involving independent samples designs for both independent variables. However, it is possible to have experimental designs involving two independent variables that are both within-subjects. So the same distinctions we made between the two types of t-tests and one-way ANOVA's can be applied to two-way factorial ANOVA.

The researcher must know his/her experimental design in order to run the appropriate statistical test. In this chapter we introduce a two-way ANOVA which combines one independent samples factor and one correlated groups factor. These types of designs are called **mixed-model ANOVA's**, since they involve a mixture of one between-groups factor and one within-subjects factor.

Recall from the past several chapters that we analyzed changes in leader performance, task skills, and social skills before and after attending a leadership training workshop. Since repeated measures were obtained from the sample participants on these variables, they are correlated samples (within-subjects) variables. We saw from these analyses that there were significant improvements from time 1 to time 2 on all of these variables.

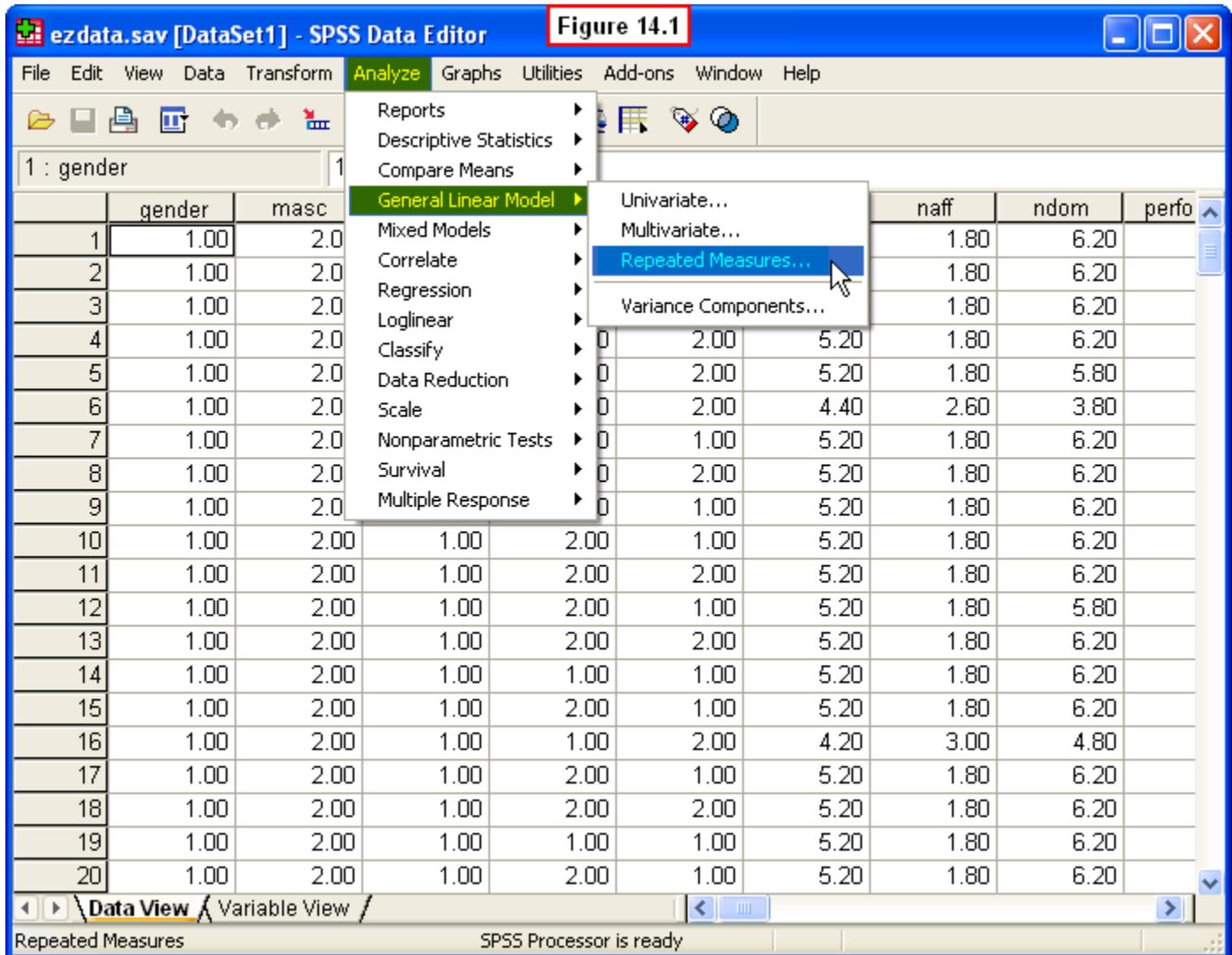
Given the focus on gender and gender role stereotypes in this project, an interesting question that could be asked is whether or not the gains on these variables were the same for male employees compared to female employees. For example, it may be that men benefit more from training in social skills than do women, given that women are already relatively strong in this aspect of leadership given their socialization. Further, women may benefit more than men from training in task skills, given the socialization of task skills in men.

The answer to these questions can be obtained by conducting a mixed-model factorial ANOVA on the social skills and task skills of employees. The example in this chapter will examine the effects of the workshop on task skills in men and women, while the

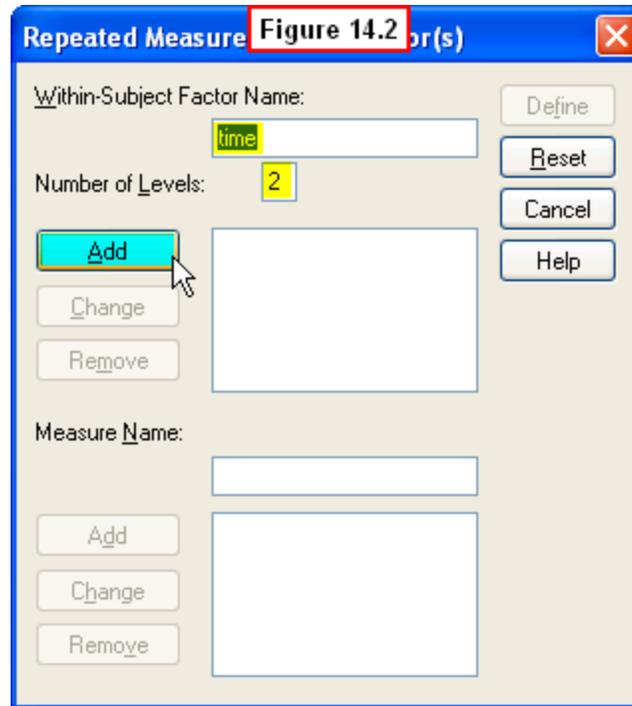
end-of-chapter exercise will ask you to do the same analysis for the effects of the workshop on social skill scores.

14.2 Running Mixed-Model ANOVA

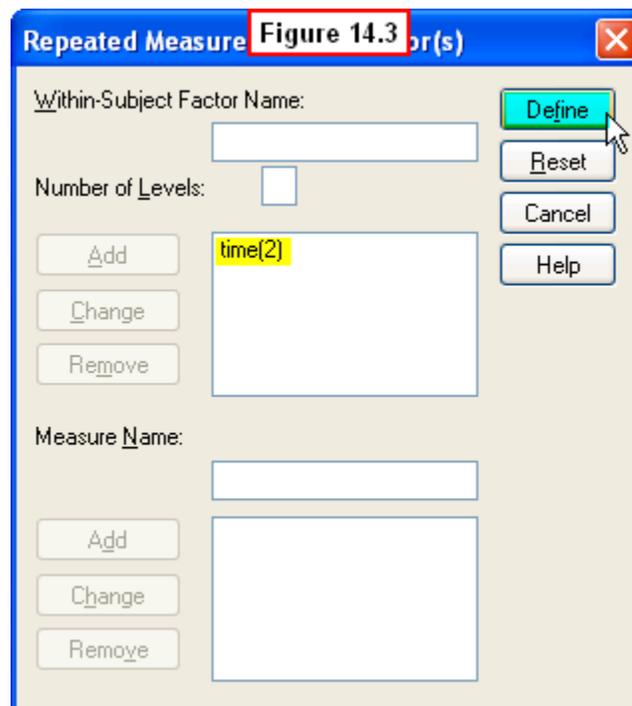
Open your **ezdata.sav** file and select **Analyze, General Linear Model, Repeated Measures...** from the menu (Figure 14.1).



A **Repeated Measures Define Factor(s)** dialog window will appear. As we did in Chapter 12, we need to define the **Within-Subject Factor Name** (i.e., the **Task Skills** repeated measures variable, consisting of the before-after measures, **task1**, and **task2**), and enter the number of levels of this factor. To do this, type **time** in the box below **Within-Subject Factor Name**, and enter a **2** in the box next to **Number of levels**. Then click the **Add** button.



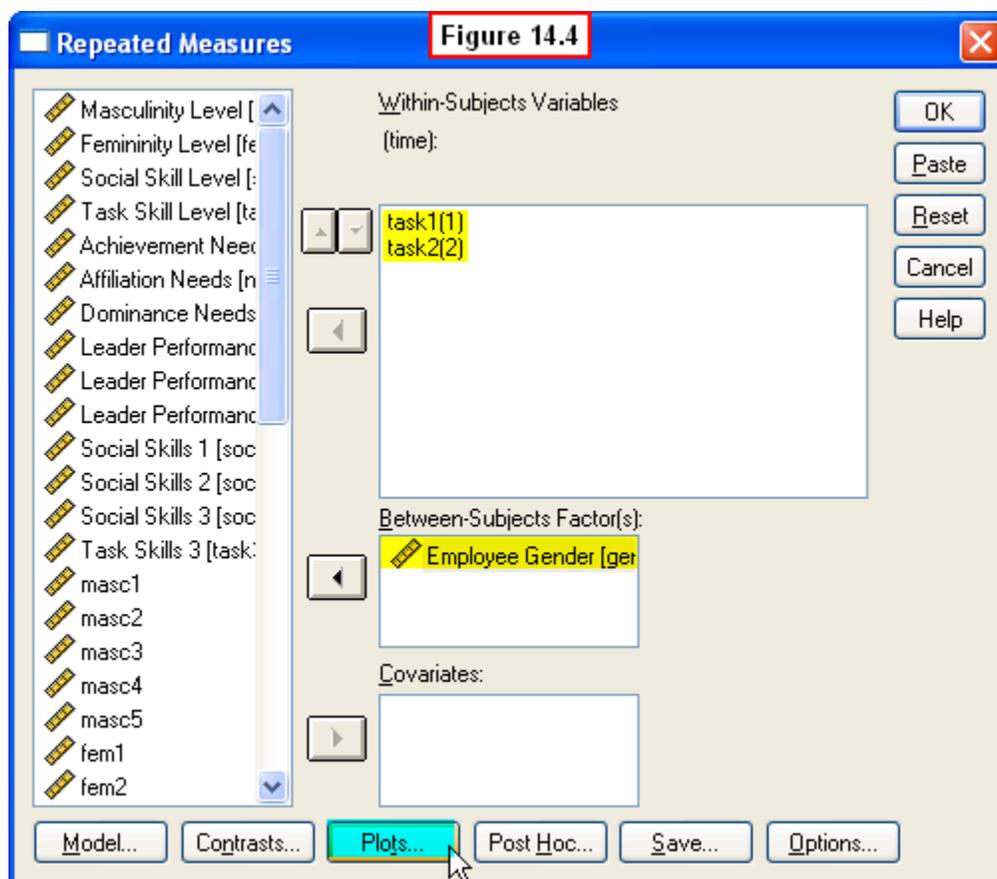
After you have done this, your window should look like that shown in Figure 14.3. Note that SPSS will now name this variable **time**, and it shows that there are three levels: **time (2)**. Now SPSS needs us to define what the two levels of **time** are. To do this, click the **Define** button in the upper right corner.



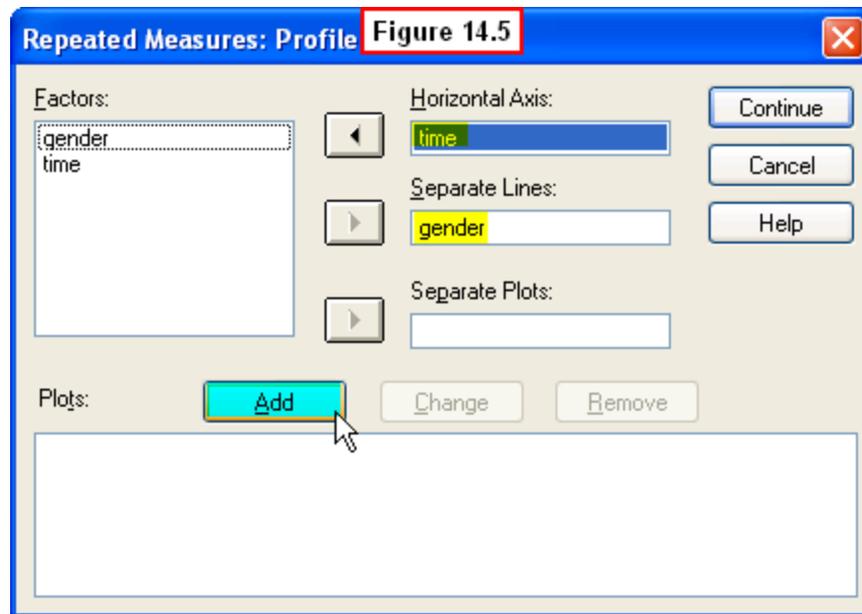
A **Repeated Measures** dialog window will appear (Figure 14.4). To specify the levels, scroll down the variable list on the left, then highlight the first two levels of the **Task Skills** variables (**task1** and **task2**). Click the right-arrow button in the middle, and these variables will be moved to the appropriate places in the **Within-Subjects Variables (time)** variable definition box.

Next we need to specify our **Between-Subjects Factor (Employee Gender)**. Highlight this variable on the left, then click the right-arrow key in the middle to move this to the **Between-Subjects Factor(s):** box on the right.

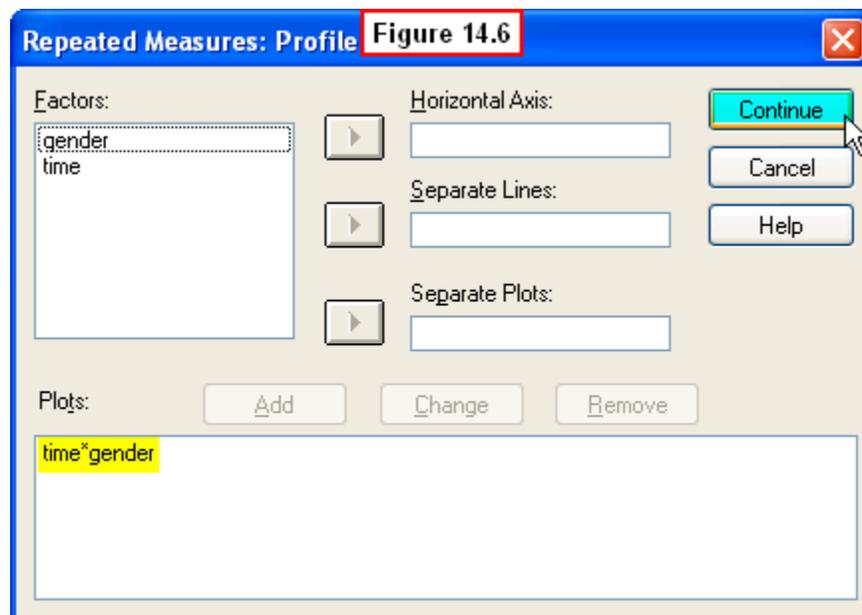
As we saw in Chapter 13, in the event that the **Time x Gender** interaction effect is significant, it will be helpful to generate a graph depicting the interaction. To do this, click the **Plots...** button at the bottom of this window.



A **Repeated Measures: Profile Plots** dialog window will appear (Figure 14.5). Select the **time** variable on the left, then click the right-arrow button in the middle to move this to the **Horizontal Axis** box on the right. Then select **gender** on the left and use the right-arrow key to move it to the **Separate Lines:** box on the right. Last, click the **Add** button at the bottom of this dialog window.

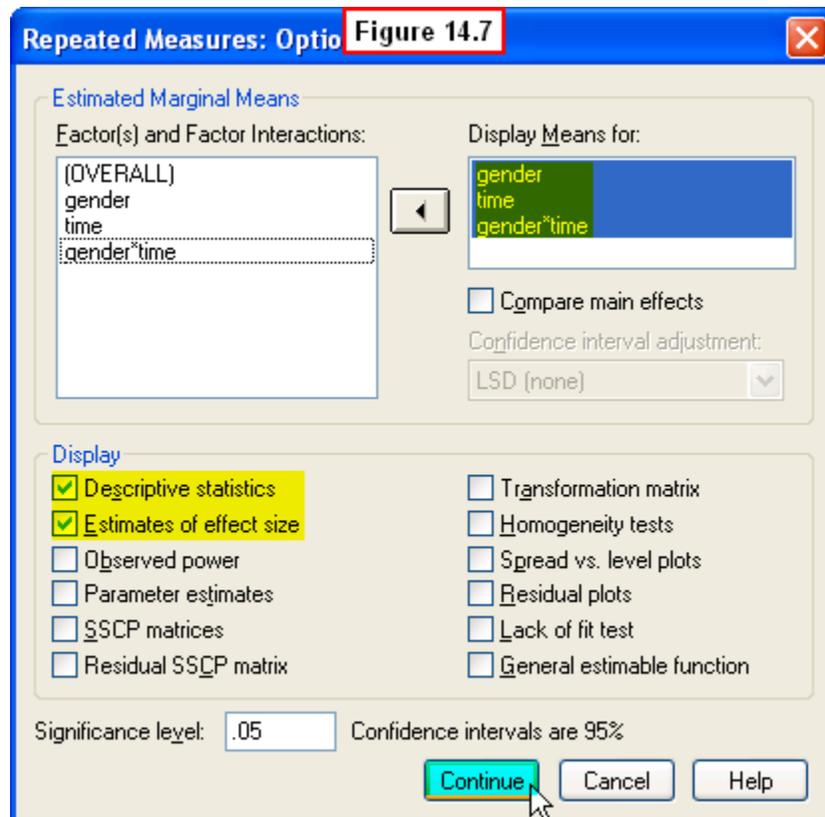


Your window should now look like the one shown in Figure 14.6.



This will cause SPSS to create a figure displaying the mean Task Skills on the Y-axis (vertical) and the two times of measurement on the X-axis (horizontal). SPSS will also generate two separate lines for the mean Task Skills scores before and after the workshop. The first line will graph these two means for men, and the second will depict these means for women. Click the **Continue** button in the upper-right corner, and this will close this window and return you to the main **Repeated Measures** dialog window (Figure 14.4).

Click the **Options...** button in the lower right corner of this dialog window, and a new **Repeated Measures: Options** dialog window will appear (Figure 14.7). To display the marginal means for the two main effects and the cell means for the interaction effect, highlight these in the **Factor(s) and Factor Interactions:** box on the left, and use the right-arrow key in the middle to move them to the **Display Means for:** box on the right (see Chapter 13 for a review of main effects and interaction effects). To generate descriptive statistics and estimates of effect size, check these two boxes in the lower left corner of this window. Last, click the **Continue** button at the bottom of this window.



This window will close and return you to the main **Repeated Measures** dialog window. To run our analysis, click the **OK** button in the upper right corner of this window. The results of this analysis will then be displayed in an output viewer window.

14.3 Interpreting the Output

The first two tables simply list the two levels of the **time** variable and the sample size for male and female employees. Several statistics are presented in the next table, **Descriptives** (Figure 14.8). The most relevant for our purposes are the two marginal means for Task Skills (highlighted in blue) and the four cell means

representing the before-after task skills scores of men and women. We will return to a discussion of these means in discussing the interpretation of our ANOVA results.

Figure 14.8

Descriptive Statistics

	Employee Gender	Mean	Std. Deviation	N
Task Skills 1	Male	5.4091	2.01961	110
	Female	4.8559	1.74569	118
	Total	5.1228	1.89895	228
Task Skills 2	Male	5.4545	2.22016	110
	Female	5.5424	1.64677	118
	Total	5.5000	1.94075	228

You can skip over the next two tables of the output (**Multivariate Tests** and **Mauchly's Test of Sphericity**), since they are beyond the scope of this chapter. The next table, **Tests of Within-Subjects Effects**, presents the ANOVA results for the main effect of our within-groups factor, **time**, and the **time x gender** interaction effect (Figure 14.9).

Figure 14.9

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
time	Sphericity Assumed	15.248	1	15.248	7.394	.007	.032
	Greenhouse-Geisser	15.248	1.000	15.248	7.394	.007	.032
	Huynh-Feldt	15.248	1.000	15.248	7.394	.007	.032
	Lower-bound	15.248	1.000	15.248	7.394	.007	.032
time * gender	Sphericity Assumed	11.695	1	11.695	5.671	.018	.024
	Greenhouse-Geisser	11.695	1.000	11.695	5.671	.018	.024
	Huynh-Feldt	11.695	1.000	11.695	5.671	.018	.024
	Lower-bound	11.695	1.000	11.695	5.671	.018	.024
Error(time)	Sphericity Assumed	466.086	226	2.062			
	Greenhouse-Geisser	466.086	226.000	2.062			
	Huynh-Feldt	466.086	226.000	2.062			
	Lower-bound	466.086	226.000	2.062			

The most relevant portions of this table are the F-values, significance levels and effect sizes. The **Sig** column reveals probabilities for both the **time** main effect (.007) and the **time x gender** interaction (.018) are both less than .05, so we can conclude that these are both significant effects (although the Partial Eta Squared values indicate that both are weak effects).

Also skip over the next table on the output (**Tests of Within-Subjects Contrasts**), since it is not relevant to our purposes. The next table, **Tests of Between-Subjects Effects**, presents the ANOVA results for our between-groups variable, **gender** (Figure 14.10). Since the probability in the **Sig.** column (.28) is greater than .05, we can conclude that the main effect for gender is not significant.

Figure 14.10

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	12868.137	1	12868.137	2444.651	.000	.915
gender	6.164	1	6.164	1.171	.280	.005
Error	1189.617	226	5.264			

The next section of the output, **Estimated Marginal Means**, presents information which is partially redundant with the means displayed in Figure 14.8. This section organizes the means into three tables, one for the marginal means of each of the two main effects and a third table which displays the cell means for the interaction effect. The marginal means for the main effect of gender are shown in Figure 14.11.

Figure 14.11

1. Employee Gender

Measure: MEASURE_1

Employee Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	5.432	.155	5.127	5.737
Female	5.199	.149	4.905	5.493

Recall that the main effect of gender was not significant ($p > .05$). So even though the mean task skills score for men (5.432) appears to be greater than that for women (5.199), this is not a statistically significant difference. Thus, the appropriate interpretation is that there was not a significant difference in overall task skills between men and women. The marginal means for the main effect of time are shown in Figure 14.12.

Figure 14.12

2. time

Measure: MEASURE_1

time	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	5.133	.125	4.887	5.378
2	5.498	.129	5.245	5.752

Recall that the main effect for time was significant ($p < .05$), so it is appropriate to conclude that the mean task skill score after the leadership training workshop was significantly higher (5.498) than the mean task skill score before the workshop (5.133). Thus, as we saw in previous chapters, this analysis also suggests that the workshop was effective in increasing leader task skills.

However, recall that the Time x Gender interaction was also significant. As we saw in Chapter 13, an interaction effect suggests that the effects of one variable depend on the level of the second variable. To interpret the interaction, we need to examine the four cell means (Figure 14.13).

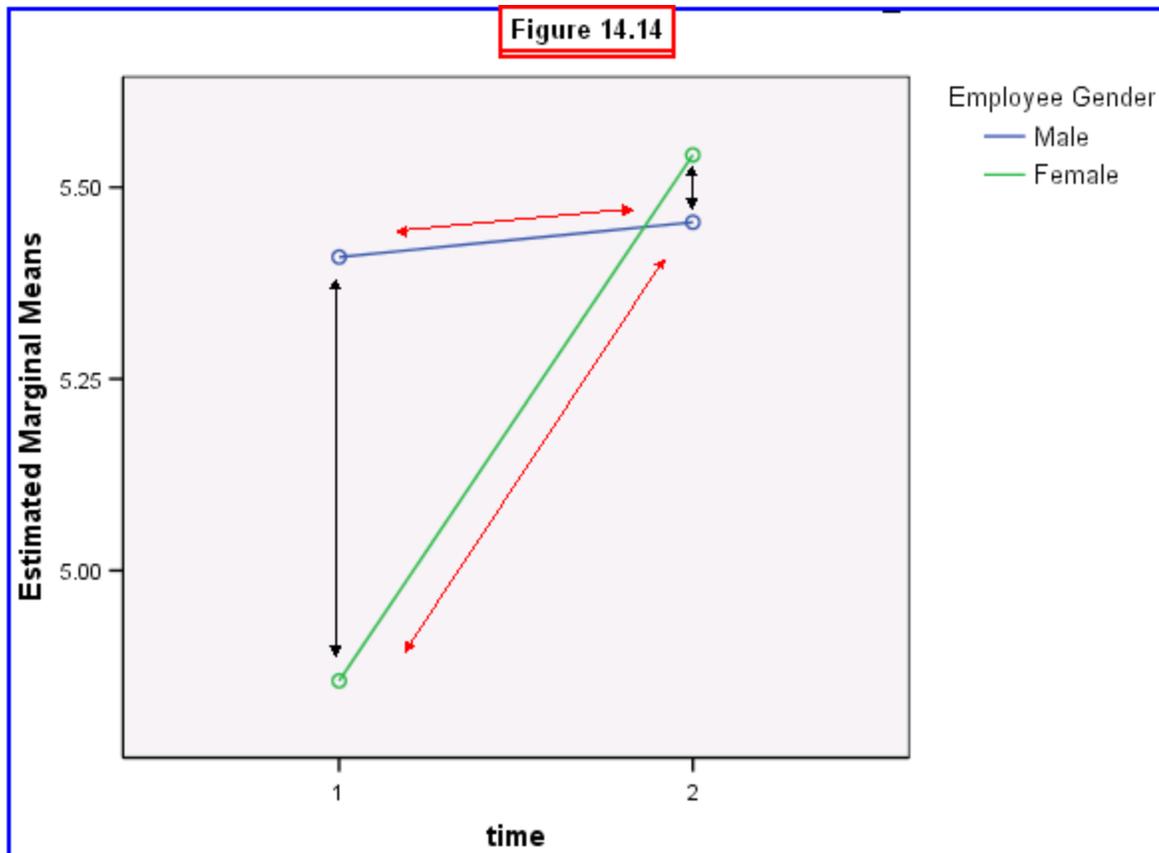
Figure 14.13

3. Employee Gender * time

Measure: MEASURE_1

Employee Gender	time	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Male	1	5.409	.180	5.055	5.763
	2	5.455	.185	5.089	5.820
Female	1	4.856	.173	4.514	5.197
	2	5.542	.179	5.190	5.895

Recall from Chapter 13 that interpretation of an interaction is facilitated by graphing the four cell means. These are depicted in Figure 14.14.



It can be seen in this figure that the effect of the workshop (represented by the Time variable) depended on the gender of the employees. Looking at the two lines, we see that although there was a dramatic increase in task skill scores for female employees from Time 1 to Time 2, the workshop didn't produce much of a change in the task skill scores of male employees.

Further, looking between the lines (i.e., comparing genders at the two times), shows that gender differences in task skills depended on the time of measurement. While men had much higher task scores than did women before the workshop, there wasn't much of a difference between task scores of men and women after the workshop.

In light of gender stereotypes, these results make sense. Men generally are socialized to have high task skills, so they started out at a high level. Thus, the workshop didn't affect their already high level of task skills. Women are socialized to have relatively low task skills, so they started out at a lower level. The workshop was most successful at increasing the task skills of women. In fact, what started out as a big gender difference before the workshop ended up being a trivial difference after the workshop. Below is an illustration of how these results would formally be reported in APA format:

A 2 (Time) x 2 (Gender) mixed-model ANOVA revealed that the main effect for Gender was not significant $F(1,226) = 1.17, p > .05, \text{Eta-squared} = .01$. Thus, there was no overall difference in the task scores of men ($M = 5.43$) compared to women ($M = 5.20$).

A significant main effect for Time was obtained, $F(1,226) = 7.39, p < .05$, though this was a weak effect (Eta-squared = .03). Task scores after the workshop ($M = 5.50$) were significantly higher than before the workshop ($M = 5.50$).

However, a significant Time x Gender was also obtained, $F(1,226) = 5.67, p < .05$, though this was a weak effect (Eta-squared = .02). Examination of the cell means indicated that although there was a large increase in task skill scores for female employees from Time 1 ($M = 4.86$) to Time 2 ($M = 5.54$), the workshop didn't produce much of a change in the task skill scores of male employees from Time 1 ($M = 5.41$) to Time 2 ($M = 5.46$). Before the workshop men had much higher task scores ($M = 5.41$) than did women ($M = 4.86$). But after the workshop, there was not much of a difference in task scores between men ($M = 5.46$) and women ($M = 5.54$).

Technically, we would have had to compute multiple comparisons among the four cell means to justify the above interpretation of the interaction, but that is beyond the scope of this chapter. Our main goal was to provide you with another example of how to interpret an interaction, rather than to also explain the multiple comparison procedures (which would support these conclusions anyway).

As we saw in Chapter 13, factorial ANOVA can yield much more useful information than simpler types of experimental designs. Based on the present analysis, you could report to EZ execs that the leadership training program benefited female employees much more than male employees, resulting in task skill scores equivalent to those of men after the workshop. Before you recommend only sending female employees to the leadership training workshop, let's see what the effects of the workshop are for social skills scores between men and women. That will be the exercise at the end of this chapter.

14.4 Chapter Review Video

[Review Me!](#)

14.5 Try It! Exercises

1. Using Two-Way Mixed-Model ANOVA: Effects of Leader Training Workshop on Social Skills Scores of Men and Women

Use the procedures described in Section 14.2 to compute a 2 (Time) x 2 (Gender) mixed-model ANOVA to examine differences in social skills before the workshop (i.e., **soc1**) and after the workshop (i.e., **soc2**) in relation to EZ employees' sex (**GENDER**).

After you have completed this two-way ANOVA:

- **Print** your output file to submit to your instructor.
- Answer the following questions:
 - Is the main effect of time significant, and how large is the difference?
 - Is the main effect of gender significant, and how large is the difference?
 - Is the Time x Gender interaction significant, and what does this mean?
 -
- **Write an interpretation of the results** along with your answers to the above questions to submit to your instructor.
 - Follow the example of APA write-up in Section 14.3 to write your interpretations of the two main effects.
 - Assume you conducted multiple comparisons of the four cell means relevant to the interaction effect. Write an interpretation of the interaction graph following the example in Section 14.3.