The *F* test can be used to test claims of equality of \_\_\_\_\_\_\_\_\_\_\_\_\_\_ means, by a technique called *analysis of variance or ANOVA.* This test investigates means about one variable for three or more \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. The *z* and *t* tests are not used to test claims involving three or more means, but are usually used when testing claims about the equality of two means. The *F* test only indicates whether a \_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_ between three or more means. It does not reveal \_\_\_\_\_\_\_\_\_\_\_ the difference lies. To find where the difference exists, the \_\_\_\_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_ tests are usually used. To test the equality of means of two variables, we use a *\_\_\_\_\_\_\_\_\_\_\_\_ analysis of variance.*

# 12 - 1. One-Way Analysis of Variance

Objective 1. Use The One-way ANOVA Technique to Determine If There Is A Significant Difference Amount Three Or More Means.

When the *F* test is used to test a hypothesis concerning equality of means of three or more populations, the technique is called **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**, or ANOVA.

There is one independent variable, called a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ that distinguishes between the different populations. The *F* test \_\_\_\_\_\_\_\_\_\_\_\_\_\_ the means of the populations simultaneously.

Since we have compared two means using a *t* test, you might think that three or more means could be compared using *t* tests. However, because using the *t* test uses multiple tests, the probability of making a type I error for any given significance level increases. Use of the technique of analysis of variance addresses this problem.

### Characteristics of the *F* Distribution

1. The values of *F* cannot be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, because variances are always \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_;
2. The distribution is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ skewed;
3. The mean value of *F* is approximately equal to \_\_\_\_\_\_\_\_\_\_\_\_\_\_; and
4. The *F* distribution is a family of curves based on \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the variance of the numerator and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the variance of the denominator.

Two different estimates of the population variation are made with the *F* test. One is the estimate \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the groups, the variance of the means of the populations. The second is variance \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ group, the variance using all the data, not affected by the differences between the means. If there is no difference between the means, the \_\_\_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_\_\_\_ variance will be approximately equal to the \_\_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_ variance, so the *F* statistic will be approximately equal to one, and the null hypothesis of equal means will not be rejected. If there is a significant difference between the means, the \_\_\_\_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_\_\_ variance will be larger than the \_\_\_\_\_\_\_\_\_\_\_\_\_-\_\_\_\_\_\_\_\_\_\_ variance, so the *F* statistic will be significantly \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ than one, and the null hypothesis will be rejected. The comparison of variances is called \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ or ANOVA.

### Formula for the *F* Test

where *k* = \_\_\_\_\_\_\_\_\_\_\_ of groups

= sample \_\_\_\_\_\_\_\_

= sample \_\_\_\_\_\_\_\_

the *grand mean*, mean of \_\_\_\_\_\_\_\_ values in all samples

d.f.N.=

where = sample size

variance

d.f.D

The sample sizes are not necessarily \_\_\_\_\_\_\_\_\_\_\_.

The *F* test is always \_\_\_\_\_\_\_\_\_\_-tailed.

### Hypotheses for Test of Difference among Three or More Means

*H*0:

*H1*: At least one mean is \_\_\_\_\_\_\_\_\_\_\_\_\_\_ from the others

### Assumptions for the *F* Test for Comparing Three or More Means

1. The populations from which the samples were obtained must be \_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_ distributed.
2. The samples must be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of one another.
3. The variances of the populations must be \_\_\_\_\_\_\_\_\_\_\_\_\_.
4. The samples must be simple \_\_\_\_\_\_\_\_\_\_\_\_\_\_ samples, one from each of the populations.

### Finding the *F* Test Value for the Analysis of Variance

1. Find the mean and variances of each sample.

(, ), (, ), … , (, )

1. Find the grand mean

1. Find the between-group variance.

1. Find the within-group variance.

1. Find the *F* test value.

The degrees of freedom are

, where *k* is the number of groups, and

, where *N* is the sum of the sample sizes of the groups.

### The Five-Step Hypothesis-Testing Procedure for the Analysis of Variance

**Step 1** State the hypotheses.

**Step 2** Find the critical values. (Use Table H.)

**Step 3** Compute the test value.

**Step 4** Make the decision.

**Step 5** Summarize the results.

### Example 12-1. Miles per Gallon

A researcher wishes to see if there is a difference in the fuel economy for city driving for three different types of automobiles: small automobiles, sedans, and luxury automobiles. Each sample is randomly drawn. The miles per gallon for each is given in the table below. At , test the claim that there is no difference among the means. Assume the requirements for the *F* Test are met.

| **Small** | **Sedans** | **Luxury** |
| --- | --- | --- |
| 36 | 43 | 29 |
| 44 | 35 | 25 |
| 34 | 30 | 24 |
| 35 | 29 |  |
|  | 40 |  |

*Solution*:

**Step 1** State the hypotheses.

*H*0:

*H1*: At least one mean is different from the others

**Step 2** Find the critical values. (Use Table H.)

,

From Table H, with , the critical value is .

**Step 3** Compute the test value.

* 1. Find the mean and variances of each sample.

(, ), (, ), … , (, )

For small cars: and

For the sedans: and

For the luxury cars: and

* 1. Find the grand mean

* 1. Find the between-group variance.

* 1. Find the within-group variance.

* 1. Find the *F* test value.

| **Analysis of Variance Summary Table** | | | | |
| --- | --- | --- | --- | --- |
| **Source** | **Sum of squares** | **d.f.** | **Mean squares** | ***F*** |
| Between | *SSB* = |  | *MSB* = |  |
| Within (error) | *SSW* = |  | *MSW* = |  |
| Total |  |  |  |  |

**Step 4** Make the decision.

The test value is \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, so the decision is to \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the null hypothesis.

**Step 5** Summarize the results.

There \_\_\_\_\_\_\_\_\_\_\_ enough evidence to conclude that at least one mean is different from the others.

### Example 12-2. Calories in Fast-Food Sandwiches

Three popular fast-food restaurant franchises specializing in burgers were surveyed to find out the number of calories in their frequently ordered sandwiches. At the level of significance, can it be concluded that a difference in mean number of calories per burger exists?

| **FF#1** | **FF#2** | **FF#3** |
| --- | --- | --- |
| 970 | 1010 | 740 |
| 880 | 970 | 540 |
| 840 | 920 | 510 |
| 710 | 850 | 510 |
|  | 820 |  |
|  |  |  |

*Solution:*

**Step 1** State the hypotheses.

H0:

*H1*: At least one mean is different from the others

**Step 2** Find the critical values. (Use Table H.)

,

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

From Table H, with , the critical value is \_\_\_\_\_\_\_\_\_\_\_\_.

**Step 3** Compute the test value.

1. Find the mean and variances of each sample.

(, ), (, ), … , (, )

For FF#1: \_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_\_

For FF#2: \_\_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_\_

For FF#3: \_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_\_\_

1. Find the grand mean

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Find the between-group variance.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Find the within-group variance.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Find the *F* test value.

| **Analysis of Variance Summary Table** | | | | |
| --- | --- | --- | --- | --- |
| **Source** | **Sum of squares** | **d.f.** | **Mean squares** | ***F*** |
| Between | *SSB* = |  | *MSB* = |  |
| Within (error) | *SSW* = |  | *MSW* = |  |
| Total |  |  |  |  |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Step 4** Make the decision.

The test value \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, so the decision is to \_\_\_\_\_\_\_\_\_\_\_\_ the null hypothesis.

**Step 5** Summarize the results.

There \_\_\_\_\_\_\_\_\_\_\_ enough evidence to conclude that at least one mean is different from the others.

# 12 – 2. The Scheffé Test and the Tukey Test

## Objective 2. Determine Which Means Differ, Using the Scheffé Or Tukey Test If The Null Hypothesis Is Rejected In The ANOVA.

When the null hypothesis is rejected using the *F* test, the researcher may want to know which means differ. The Scheffé test and the Tukey Test are two methods to determine where significant differences in the means lie.

### **The Scheffé Test**

For the Scheffé test, all the means, two at a time, using \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of means are compared. For instance, if there are three means, the *F* statistic is calculated for with , with , and with .

### Formula for the Scheffé Test

where and are the means of the samples being compared,

and are the respective sample sizes, and

is the within-group variance.

The critical value for the Scheffé test is the \_\_\_\_\_\_\_\_\_\_\_\_\_ of the critical value for the *F* test and . . There is a significant difference between the two means being compared when the *F* test value, , is greater than the critical value, .

### Example 12-3. The Scheffé Test for Calories in Fast Food Sandwiches

Use the Scheffé test to test each pair of means for the fast food sandwiches to find any significant difference exists between each pair of means.

*Solution:*

In Example 12-2, for the samples for the three fast food restaurants, we found

For FF#1: and

For FF#2: and

For FF#3: and

The critical value for Example 12-1 is 4.10. Thus \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. For FF#1 and FF#2

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Since ­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_ , the means of FF#1 and FF#2 \_\_\_\_\_\_\_\_\_\_\_\_\_ significantly different.

1. For FF#1 and FF#3

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Since ­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_, the means of FF#1 and FF#3 \_\_\_\_\_\_\_\_\_ significantly different.

1. For FF#2 and FF#3

­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_

Since ­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_, the means of FF#2 and FF#3 \_\_\_\_\_\_ significantly different.

Thus, the mean calories for sandwiches at Fast Food Restaurant #3 are significantly different from both Fast Food Restaurant #1 and Fast Food Restaurant #2.

### **The Tukey Test**

The Tukey test can be used after the ANOVA to make pairwise comparisons between means when the groups have the \_\_\_\_\_\_\_\_\_\_ sample size.

The symbol for the test value in the Tukey test is *q*.

### Formula for the Tukey Test

where and are the means of the samples being compared,

*n* is the size of the samples, and

is the within-group variance.

When the absolute value of *q* is greater than the critical value for the Tukey test, there is a significant difference between the two means being compared.

The critical value of the Tukey test is found using Table N, where *k* is the number of means in the original problem and *v* is the degrees of freedom for , which is . The value of *k* is across the top row, and *v* is in the left column.

### Example 12-4. Number of Pupils in a Class

Fractures accounted for 2.4% of all U.S. emergency room visits for a total of 389,000 visits for a recent year. A random sample of weekly ER visits is recorded for three hospitals in a large metropolitan area during the summer months.

| **Hospital 1** | **Hospital 2** | **Hospital 3** |
| --- | --- | --- |
| 28  27  40  45 | 30  18  34  28 | 25  20  30  22 |
| 29 | 26 | 18 |
| 25 | 31 | 20 |

At , is there sufficient evidence to conclude a difference in means?

Use the Tukey Test to test each pair of means to find if a specific difference exists.

*Solution:*

Part one is to determine if the means are significantly different.

**Step 1** State the hypotheses.

*H*0:

*H1*: At least one mean is different from the others

**Step 2** Find the critical values. (Use Table H.)

,

From Table H, with , the critical value is .

**Step 3** Compute the test value.

1. Find the mean and variances of each sample.

(, ), (, ), … , (, )

For Hospital 1: and

For Hospital 2: and

For Hospital 3: and

1. Find the grand mean

1. Find the between-group variance.

1. Find the within-group variance.

1. Find the *F* test value.

| **Analysis of Variance Summary Table** | | | | |
| --- | --- | --- | --- | --- |
| **Source** | **Sum of squares** | **d.f.** | **Mean squares** | ***F*** |
| Between | *SSB* = | 2 | *MSB* = | 3.76 |
| Within (error) | *SSW*= | 15 | *MSW* = |  |
| Total | 870.44 | 17 |  |  |

**Step 4** Make the decision.

The test value , so the decision is to reject the null hypothesis.

**Step 5** Summarize the results.

There is enough evidence to conclude that at least one mean is different from the others.

Part two is to use the Tukey test.

, *n* = 6

The critical value of is 3.01 (Table N, *k* = 2, )

1. Hospital 1 and Hospital 2

Since , the means of Hospital 1 and Hospital 2 are not significantly different.

1. Hospital 1 and Hospital 3

Since , the means of Hospital 1 and Hospital 3 are significantly different.

1. Hospital 2 and Hospital 3

Since , the means of Hospital 2 and Hospital 3 are not significantly different.

Thus the mean weekly hospital visits between Hospital 1 and Hospital 3 are significantly different, but neither is significantly different from Hospital 2.

# 12 – 3. Two-Way Analysis of Variance

## Objective 3. Use The Two-way ANOVA Technique To Determine If There Is A Significant Difference In The Main Effects Or Interaction.

When there is one independent variable, we use the one-way analysis of variance technique. However, when the research question involves two independent variables, called \_\_\_\_\_\_\_\_\_\_\_, the two-way analysis of variance, an extension of the one-way ANOVA, is used.

The two-way analysis of variance is complicated, requiring consideration of many aspects of the subject. The researcher is able to test the \_\_\_\_\_\_\_\_\_ of two independent variables on one dependent variable. In addition, the \_\_\_\_\_\_\_\_\_\_\_\_ effect is tested. For instance, consider two different independent variables, A and B collected from the same individual, each with two different treatments. There will be four groups. The groups are called treatment groups. The four groups are

Group 1 Factor *A1*, Factor *B1*

Group 2 Factor *A2*, Factor *B1*

Group 3 Factor *A1*, Factor *B2*

Group 4 Factor *A2*, Factor *B2*

Individuals are assigned to groups \_\_\_\_\_\_\_\_\_\_\_\_. The design is called a (two-by-two) design because each variable has two levels, that is, two \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ treatments.

|  |  | **Variable *B*** | |
| --- | --- | --- | --- |
|  |  | ***B1*** | ***B2*** |
| **Variable *A*** | ***A1*** | Group 1  Factor *A*1, Factor *B1* | Group 1  Factor *A*1, Factor *B2* |
| ***A2*** | Group 1  Factor *A2*, Factor *B1* | Group 1  Factor *A2*, Factor *B*2 |
|  |  | **Two-by-Two ANOVA** | |

There are many different kinds of two-way ANOVA designs, depending on the number of \_\_\_\_\_\_\_\_\_\_\_\_ of each variable. The figures below show a few of these designs, in particular, a) (three-by-two), b) (three-by-three); and c) (four-by-three) designs.

The figure shows three different two-way ANOVA designs:  figure (a) shows a three by two design where variable A has three levels and variable B has two levels; figure (b) shows a three by three design where variable A has three levels and variable B has three levels; figure (c) shows a four by three design where variable A has four levels and variable B has three levels.

The effects of the independent variable on the response variable are called the **\_\_\_\_\_\_\_\_\_\_ effects**. The \_\_\_\_\_\_\_\_\_ effects are

the effect of variable *A* is the change in the response variable resulting from \_\_\_\_\_\_\_\_\_\_\_\_\_\_ the type of *A*;

the effect of variable *B* is the change in the response variable resulting from \_\_\_\_\_\_\_\_\_\_\_\_\_\_ the type of *B*.

Another hypothesis to be tested involves the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the two variables, *A* and *B*, on the response variable. For instance, is there a difference in the response variable using *A1* and *B2* and the response variable using *A2* and *B1*. When a difference of this type happens, the experiment is said to have a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ **interaction effect**. The interaction effect represents a \_\_\_\_\_\_\_\_\_\_\_ effect of the two factors over and above the effects of each factor separately. If there is a significant interaction effect, the effects of the individual factors, A and B, should \_\_\_\_\_\_\_\_\_ be considered \_\_\_\_\_\_\_\_\_\_\_\_\_ also considering the interaction effect.

The two-way ANOVA design has \_\_\_\_\_\_\_\_\_\_ different null hypotheses, one for each independent variable and one for the interaction:

1. The hypotheses regarding the *A-B* interaction effect are

*H0*: There is no interaction effect between Variable A and Variable B on the response variable.

*H1*: There is an interaction effect between Variable A and Variable B on the response variable.

1. The hypotheses regarding Variable *A* are

*H0*: There is no difference in the response variable using different levels of Variable *A*.

*H1*: There is a difference in the response variable using different levels of Variable *A*.

1. The hypotheses regarding Variable *B* are

*H0*: There is no difference in the response variable using different levels of Variable *B*.

*H1*: There is a difference in the response variable using different levels of Variable *B*.

### Assumptions for the Two-Way ANOVA

1. The populations from which the samples are obtained must be \_\_\_\_\_\_\_\_\_\_\_\_\_ or \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ distributed.
2. The samples must be \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.
3. The \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of the populations from which the samples were selected must be equal.
4. The groups must be \_\_\_\_\_\_\_\_\_\_\_\_\_\_ in sample size.

### ANOVA Summary Table

| **ANOVA Summary Table** | | | | |
| --- | --- | --- | --- | --- |
| **Source** | **Sum of squares** | **d.f.** | **Mean square** | ***F*** |
| *A* | *SSA* |  | *MSA* | *FA* |
| *B* | *SSB* |  | *MSB* | *FB* |
| *A* X *B* | *SSAXB* |  | *MSAXB* | *FAXB* |
| Within (error) | *SSW* |  | *MSW* |  |

*A*

*B*

*A*

### Steps for Hypothesis Testing Using Two-Way Analysis of Variance

**Step 1** State the hypotheses.

**Step 2** Find the critical values. (Use Table H.)

**Step 3** Compute the test value.

**Step 4** Make the decision.

**Step 5** Summarize the results.

### Example 12-5. Home-Building Times

A contractor wishes to see whether there is a difference in the time (in days) it takes two subcontractors to build two different types of homes. At , analyze the data shown here, using a two-way ANOVA.

|  | **Home Type 1** | **Home Type 2** | **Home Type 3** |
| --- | --- | --- | --- |
| **Subcontractor 1** | 25, 28, 26, 30 | 30 ,32, 35, 29 | 43, 40, 42, 49 |
| **Subcontractor 2** | 15,18, 22, 21 | 21, 27, 18, 15 | 23, 25, 24, 17 |

Is there a difference in the mean time with respect to contractor or home type? Can it be concluded that there an interaction between subcontractor and home type?

*Solution*:

**Step 1** State the hypotheses.

*These hypotheses for the interaction are*

*H0*: There is no interaction effect between home type and subcontractor.

*H1*: There is an interaction effect between home type and subcontractor.

*The hypotheses for Home Types are*

*H0*: There is no difference between the mean times to build by home type.

*H1*: There is a difference between the mean times to build by home type.

*The hypotheses for Subcontractor are*

*H0*: There is no difference between mean times to build by subcontractor.

*H1*: There is a difference between mean times to build by subcontractor.

**Step 2** Find the critical values. (Use Table H.)

Factor Home Type: d.f.N. = 3 – 1 = 2 (column)

Factor Subcontractor: d.f.N. = 2 – 1 = 1 (row)

Interaction (*A* X *B*): d.f.N = (2)(1) = 2

Within (error): d.f.D. =

Critical value for *FA* is \_\_\_\_\_\_\_\_\_\_\_.

Critical value for *FB* is \_\_\_\_\_\_\_\_\_\_\_.

Critical value for *FAXB* is \_\_\_\_\_\_\_\_\_\_.

**Step 3** Compute the test value.

= 4

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

| **ANOVA Summary Table** | | | | |
| --- | --- | --- | --- | --- |
| **Source** | **Sum of squares** | **d.f.** | **Mean square** | **F** |
| *A* |  |  |  |  |
| *B* |  |  |  |  |
| *A* X *B* |  |  |  |  |
| Within (error) |  |  |  |  |

**Step 4** Make the decision.

\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the null hypothesis.

\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the null hypothesis.

\_\_\_\_\_\_\_\_\_\_\_, \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ the null hypothesis.

**Step 5** Summarize the results.

Since the null hypothesis for the interaction effect (is\is not) statistically significant, (a / no) decision should be made about the times to build homes without further investigation.

Since the null hypothesis for the interaction effect (was\ was not) rejected, it can be concluded that the combination of subcontractor and home type does affect the time to build homes.

In this case the main effects cannot be interpreted independently because there are significant interaction effects.