Comparing Means in SPSS (*t*-Tests)

This section covers procedures for testing the differences between two means using the SPSS **Compare Means** analyses. Specifically, we demonstrate procedures for running Dependent-Sample (or One-Sample) *t*-tests, Independent-Sample *t*-tests, Difference-Sample (or Matched- or Paired-Sample) *t*-tests. Unfortunately, SPSS does not provide procedures for running *Z*-tests.

For the following examples, we have created a data set based on cartoon 9.1 (Cow Poetry). To obtain our data, we have randomly drawn a sample of 30 cows from the population of cows owned by Farmer Perry. With the measurements we take from this sample we are going to ask three research questions. First, we are interested in the number of times each cow in our sample touches the electric fence and whether this sample differs from the larger population of Farmer Perry's cows. We will test this hypothesis using a Dependent-Sample (One-Sample) *t*-test. Second, we are interested in whether different types of cows (Holstein vs. Jersey) in our sample differ in their fence touching behavior. We will test this hypothesis using an Independent-Sample *t*-test. Third, we are interested finding out whether our cow's fence touching behavior is affected by completing Cow School. In this case we will ask two specific questions: a) does the sample of cows differ from the population of cows afer the sample completes school. We will test this hypothesis using a Dependent-Sample (One-Sample) *t*-test. b) Does the post cow school fence touching behavior of our sample of cows differ from the pre cow school fence touching behavior. We will test this hypothesis using the Difference-Sample (or Paired-Sample) *t*-test.

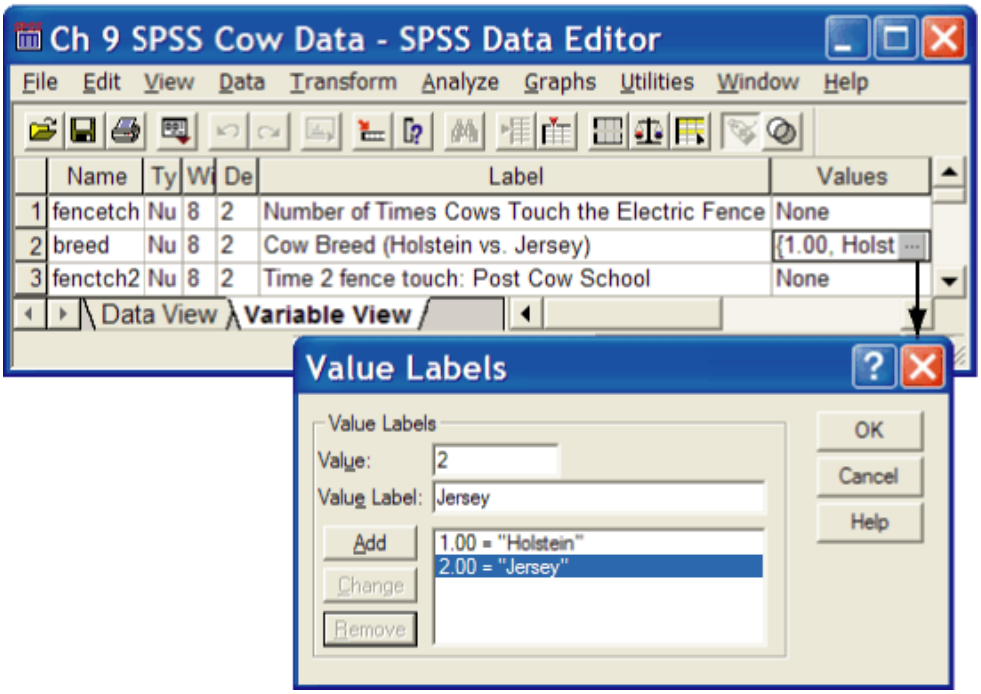
Setting Up the Data

Figure 9.2 presents the variable view of the SPSS data editor where we have defined three new variables (two continuous and one discrete). The first variable (continuous) represents the frequency with

which the cows in our sample touch the electric fence. We have given it the variable name **fencetch** and given it the variable label "Number of Times Cows Touch the Electric Fence."

The second variable (discrete) represents the breed of cow for each of our subjects: Holstein vs. Jersey. We have given it the variable name **breed** and the variable label "Cow Breed (Holstein vs. Jersey)." Also, we provided value labels for the two breeds. The value of 1 was assigned to the Holstein label, and the value of 2 was assigned to the Jersey label.

Figure 9.2 SPSS: Variable View for Cow Data



The third variable (continuous) represents the frequency with which the cows in our sample touch the electric fence, which is assessed in the same way **fencetch** was measured. However, for this variable the measurements were made after the sample had completed 3 weeks of Cow School. We have given it the variable name **fenctch2** and the variable label "Time 2 Fence Touch: Post Cow School."

Figure 9.03 SPSS: Data View for Cow Data

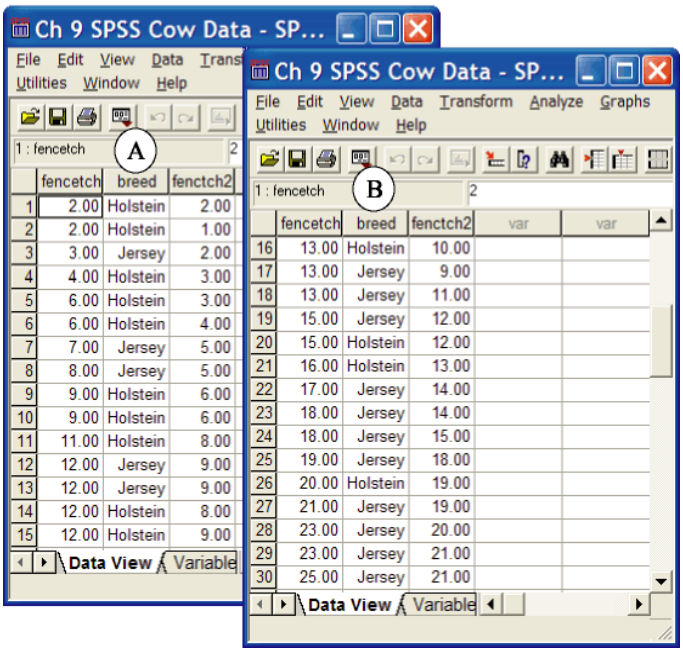


Figure 9.3 presents the data view of the SPSS data editor. Here, we have entered the 30 cow's data for our three variables. Note that there are two

windows presented in the figure. The lefthand window (labeled A) presents the data for the first half of the sample (cows 1 to 15). Window B represents the same SPSS window, where we have scrolled down to show the data for the remaining cows (subjects 16 to 30). Remember that the columns represent each of the different variables and the rows represent each observation, which in this case is each cow. For example, the first cow touched the fence 2 times before attending cow school, is a Holstein, and touched the fence 2 times after attending cow school. Similarly, the 30th cow touched the fence 25 times before attending cow school, is a Jersey, and touched the fence 21 times after attending cow school.

Dependent-Sample (One-Sample) *t*-test

The Dependent-Sample *t*-test allows us to test whether a sample Mean (0) is significantly different from a population mean (∶) when only the sample Standard Deviation (*s*) is known. In terms of knowing when to use the Dependent *t*-test, you should consider using this test when you have continuous data collected from a group that you want to compare that group's average score to some known criterion value (probably a population mean).

Running the Analyses

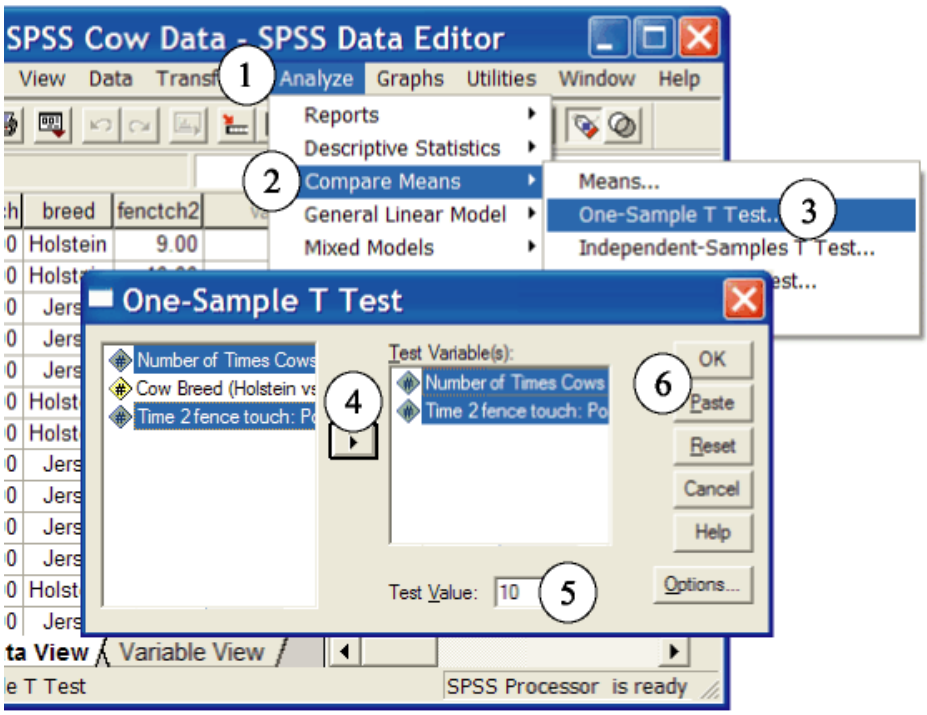
In this example we present the steps for using **One-Sample T Test...** data analysis procedure to determine whether a sample mean is significantly different from a criterion value (in this case the population mean). Before you can run this type of analysis you will need to know the value that you want to compare with your sample mean. In this case our test (comparison) value is 10 and was obtained by finding the average number of times every one of Farmer Perry's cows touched the electric fence (i.e., the population mean for fence touching).

In the procedure presented bellow, we are going to perform two tests at the same time. The first test will compare the mean of **fencetch** (frequency of touching the electric fence prior to attending cow school)

with the population average for touching the electric fence. The second test will compare mean of **fenctch2** (frequency of touching the electric fence after attending cow school) with the population average for touching the electric fence.

One-Sample T Test Steps (See Figure 9.4): From the **Analyze** (1) pull down menu, select **Compare Means** (2), then select **One-Sample T Test...** (3) from the side menu. In the **One-Sample T Test** dialogue box, enter the variables **fencetch** and **fenctch2** in the **Test Variable(s)** field by either double-left-clicking on each variable or selecting the variables and left-clicking on the boxed arrow pointing to the right (4). To request the descriptive statistics, left-click the **Statistics...** (5) button. Next, enter the population mean in the **Test Value:** field. In this case, our test value is 10. Finally, double check your variables and the test value and either select **OK** (6) to run, or **Paste** to create syntax to run at a later time.

Figure 9.4 **SPSS: Running One-Sample T Test for Cow Data**



If you selected the paste option from the procedure above, you should have generated the following syntax:

```
T-TEST
  /TESTVAL=10
  /MISSING=ANALYSIS
  /VARIABLES=fencetch fenctch2
```

```
/CRITERIA=CIN (.95) .
```

To run the analyses using the syntax, while in the Syntax Editor, select **All** from the **Run** pull-down menu.

Reading the One-Sample T Test Output

The One-Sample T Test Output is presented in Figure 9.5. This output consists of two parts: One-Sample Statistics and One-Sample Tests. The One-Sample Statistics output presents the sample size (N), mean, standard deviation, and the standard-error-of-the-mean (the standard deviation divided by the square route of N) for each variable being tested.

Figure 9.5 SPSS: Output for One-Sample T Test

T-Test

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Number of Times Cows Touch the Electric Fence	30	12.8000	6.42409	1.17287
Time 2 fence touch: Post Cow School	30	10.2667	6.09654	1.11307

One-Sample Test

	Test Value = 10					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Number of Times Cows Touch the Electric Fence	2.387	29	.024	2.8000	.4012	5.1988
Time 2 fence touch: Post Cow School	.240	29	.812	.2667	-2.0098	2.5432

The One-Sample Tests output reports the t obtained, the degrees of freedom (df = n-1), the two tailed alpha level or level of significance (Sig.), and the difference between the sample mean and the population mean (Mean Difference: Sample Mean - Population Mean). This part of the output also reports a confidence interval for the mean difference. Like the confidence intervals covered in Chapter 8, this confidence interval is the range of scores for which we are 95 % confident that it contains the true mean difference found in the population.

With respect to the first hypothesis regarding the fence touching behavior of our sample prior to attending cow school, we have a *t* obtained of 2.387, which with 29 degrees of freedom is significant at the .024 level. Unlike the table of critical values we use to evaluate our hand calculated statistics, SPSS reports

the exact level of significance. From these results we can conclude that the average number of times the cows in our sample touch the electric fence is significantly different from the average number of times all of Farmer Perry's cows touch the electric fence. Looking at the Mean Difference statistic, we can be more specific and say that our sample of cows touched the electric fence an average of 2.8 more times than the general population of cows did.

With respect to the second hypothesis regarding the fence touching behavior of our sample after attending cow school, we have a *t* obtained of .24, which is not significant. The alpha level associated with this *t* value for 29 degrees of freedom is .812, which indicates that there is an 81.2% chance that a difference between the sample mean and population mean this large would occur by chance alone and is likely due to sampling error. Further, because this value is larger than the .05 alpha level, we must reject the alternative hypothesis and conclude that after attending cow school our sample no longer significantly differs from the entire population Farmer Perry's cows.

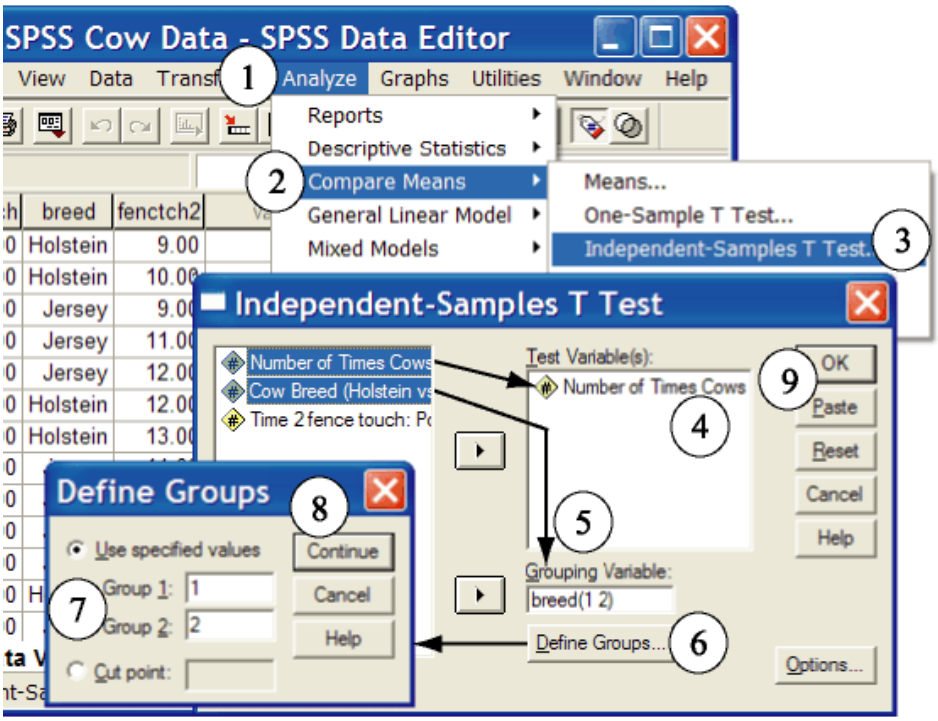
Independent-Sample T Test

The Independent-Sample *t*-test allows us to test whether a two sample means are significantly different from each other. In terms of knowing when to use the Independent-sample *t*-test, you should consider using this test when you have two variables; one discrete variable consisting of two groups and on continuous variable consisting of a continuum of scores. In our current example, our discrete variable, **breed**, consists of the Holstein and Jersey groups. Also, we will use the continuous variable **fencetch**, which represents the frequency of touching the electric fence prior to attending cow school. With this data we can test the hypothesis that the average number of times that unschooled Holsteins touch the electric fence significantly differs from the average number of times that unschooled Jerseys touch the electric fence.

Running the Independent-Sample T Test

Independent-Sample T Test Steps (See Figure 9.6): From the **Analyze** (1) pull down menu, select **Compare Means** (2), then select **Independent-Sample T Test...** (3) from the side menu. In the **Independent-Sample T Test** dialogue box, enter the continuous variable **fencetch** in the **Test Variable(s)** field (4) by left-clicking the variable and left-clicking on the boxed arrow pointing to the **Test Variable(s)** field. Next, enter the discrete variable **breed** in the **Grouping Variabel:** field (5). To tell SPSS what values have been paired with each group, left-click the **Define Groups...** button (6). In the **Define Groups** dialogue box, enter the numerical values that have been used to represent the groups of interest into the **Group 1:** and **Group 2:** fields (7). In this case we have used the numerical values of 1 and 2 and have entered them in the **Group 1:** and **Group 2:** fields, respectively. Next, left-click **Continue** (8). Finally, double check your variables and either select **OK** (9) to run, or **Paste** to create syntax to run at a later time.

Figure 9.6 **SPSS: Running Independent-Samples T Test**



If you selected the paste option from the procedure above, you should have generated the following syntax:

```
T-TEST
  GROUPS=breed(1 2)
```

```
/MISSING=ANALYSIS

/VARIABLES=fencetch

/CRITERIA=CIN(.95) .
```

To run the analyses using the syntax, while in the Syntax Editor, select **All** from the **Run** pull-down menu.

Figure 9.7 **SPSS: Output for Independent Samples T Test**

T-Test

Group Statistics

	Cow Breed (Holstein vs. Jersey)	N	Mean	Std. Deviation	Std. Error Mean
Number of Times Cows Touch the Electric Fence	Holstein	14	9.7857	5.38057	1.43802
	Jersey	16	15.4375	6.22863	1.55716

Independent Samples Test

		Levene's Test for Equality of Variances	
		F	Sig.
Number of Times Cows Touch the Electric Fence	Equal variances assumed	.368	.549
	Equal variances not assumed		

Independent Samples Test

		t-test for Equality of Means			
		t	df	Sig. (2-tailed)	Mean Difference
Number of Times Cows Touch the Electric Fence	Equal variances assumed	-2.640	28	.013	-5.6518
	Equal variances not assumed	-2.666	27.998	.013	-5.6518

Independent Samples Test

		t-test for Equality of Means		
		Std. Error Difference	95% Confidence Interval of the Difference	
			Lower	Upper
Number of Times Cows Touch the Electric Fence	Equal variances assumed	2.14095	-10.03733	-1.26624
	Equal variances not assumed	2.11958	-9.99357	-1.31000

Reading the Independen

t-Sample T Test Output

Figure 9.7 presents the output for the Independent-Sample T Test. This output consists of two major parts: Group Statistics and Independent Samples Test. The Group Statistics output provides the sample sizes (N), means, standard deviations, and the standard error of the mean (the standard deviation divided by the square root of n) for the continuous variable, separate for each group. With respect to our current example, there were 14 Holsteins in our sample, and they touched the electric fence an average of 9.7857, with a standard deviation and standard error of the mean of 5.38057 and 1.43802, respectively. Similarly, there were 16 Jerseys, and they touched the electric fence an average of 15.4375, with a standard deviation and standard error of the mean of 6.22863 and 1.55716, respectively.

The Independent-Samples Test output presented in Figures 9.7 is further split into three parts. However, depending on your printer settings the format of your printed output may differ somewhat from what we have presented, but all the parts will be same. The first part of this output (which we have labeled A), tests one of the assumptions that must be met in order to properly use independent sample *t* tests. That is, the group standard deviations should be equal. If they are equal then we can use the standard *t* test procedures covered in this chapter. However, if the variability within the two groups is not equivalent (equal) then we need to used a test that corrects for this. Both the standard *t* test and the modified *t* test results are presented in the output box we have labeled as "B" and are presented in the rows labeled "Equal variances assumed" and "Equal variances not assumed," respectively. To decide which *t* test results to use, we must look at the significance level (Sig.) of Levene's Test for Equality of Variances, which we have encircled in figure 9.7. If the significance level is greater than .05, then we can assume that group variances are equal and need to use the first row of *t* test results. If the significance level is .05 or less, then we should assume that the group variances are not equal and need to use the second row of *t* test results. In this case the significance level is .549 (larger than .05), so we can use the first row of *t* test results, which we have encircled in bock B of figure 9.7. (Note: the *t* and *df* presented in the "Equal variances assumed" row will be

most consistent with your hand calculations).

Part B of the Independent Samples Test output provides us with the *t* obtained, degrees of freedom (df), the two tailed level of significance (Sig.), and the mean difference (Group 1 mean - Group 2 mean). In our current example, we see that we have a *t* obtained of -2.64 and, with 28 degrees of freedom (*df* = n-2), it is significant at the .013 level. Thus, we can conclude that Holstein and Jersey cows are significantly different with respect to the frequency that they touch the electric fence. More specifically, by examining the group means and the mean difference (Group 1 mean - Group 2 mean) we can see that Holsteins touch the electric fence an average of 5.6518 fewer time than did the Jersey cows.

Part C of the Independent Samples Test output, provides us with confidence intervals for the difference between the group means. This interval allows us to estimate the actual difference found in the population between the groups of interest. In this case we can be 95% confident that actual difference in fence touching frequency found between all Holsteins in the population and all Jersey cows in the population is somewhere between (1.26624 and 10.03733).

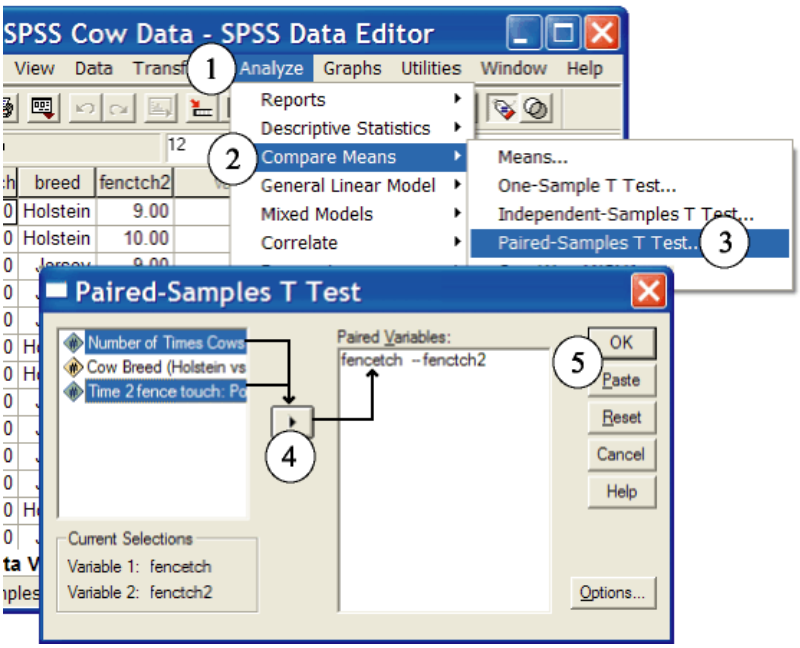
Difference-Sample (Paired-Sample) T Test

The Difference-Sample *t*-test allows us to test whether a two sample means, collected from the same group on two separate occasions, are significantly different from each other. In terms of knowing when to use the Difference-Sample *t*-test, you should consider using this test when you have two continuous variables that represent the same variable measured on two separate occasions. In our current example, we have measured fence touching behavior twice; once before our cows attended cow school (**fencetch**) and once after attending cow school (**fenctch2)**. With this data we can test the hypothesis that the average number of times that unschooled cows touch the electric fence significantly differs from the average number of times that the same cows touch the electric fence after attending three weeks of cow school.

Running the Dependent-Sample (Paired-Sample) T Test

Paired-Sample T Test Steps (See Figure 9.8): From the **Analyze** (1) pull down menu, select **Compare Means** (2), then select **Paired-Sample T Test...** (3) from the side menu. In the **Paired-Sample T Test** dialogue box, left-click the continuous variable **fencetch** and then left-click the continuous variable **fenctch2**. Next enter the analysis pair in the **Paired Variable(s)** field by left-clicking on the boxed arrow (4) pointing to the **Paired Variable(s)** field. Finally, double check your variables and either select **OK** (5) to run, or **Paste** to create syntax to run at a later time.

Figure 9.8 SPSS: Running the Paired-Sample T Test



If you selected the paste option from the procedure above, you should have generated the following syntax:

```
T-TEST
  PAIRS= fencetch  WITH fenctch2 (PAIRED)
  /CRITERIA=CIN(.95)
  /MISSING=ANALYSIS.
```

To run the analyses using the syntax, while in the Syntax Editor, select **All** from the **Run** pull-down menu.

Reading the Paired-Sample Output

[Figure 9.9 near here]

T-Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Number of Times Cows Touch the Electric Fence	12.8000	30	6.42409	1.17287
	Time 2 fence touch: Post Cow School	10.2667	30	6.09654	1.11307

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Number of Times Cows Touch the Electric Fence & Time 2 fence touch: Post Cow School	30	.988	.000

Paired Samples Test

		Paired Differences				
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper
Pair 1	Number of Times Cows Touch the Electric Fence - Time 2 fence touch: Post Cow School	2.5333	1.04166	.19018	2.1444	2.9223

A

Paired Samples Test

		t	df	Sig. (2-tailed)
Pair 1	Number of Times Cows Touch the Electric Fence - Time 2 fence touch: Post Cow School	13.321	29	.000

B

Figure 9.9 presents the output for the Paired-Sample T Test. This output consists of three major parts: Paired Samples Statistics, Paired Samples Correlations, and Paired Samples Test. The Paired Samples Statistics output provides the mean, sample sizes (N), standard deviations, and the standard error of the mean (the standard deviation divided by the square root of n) for each continuous variable. The Paired Samples Correlations output presents a hypothesis testing statistic that will be covered in next chapter on Correlation and Regression. Essentially this statistics tells us how strongly related our two variables are. The closer correlation value gets to 1 (or -1) the more related our two variables are.

In figure 9.9, the Paired Sample Test output is split into two parts, which we have labeled A and B. Again, depending on your printer settings, the format of your printed output may be little different from what we present. Part A presents the basic parts of the Difference *t* formula presented earlier in this chapter. First, we are given the mean difference (the column labeled Mean). The mean diffrence is the numerator of the difference *t* formula and is obtained by subtracting the mean for the first measurement from the mean for the second measurement. In this case we are subtracting the mean for the post-cow-school fence touching

variable (10.2667) from the mean for the pre-cow-school fence touching variable (12.8000), which gives us a value of 2.5333. The second column, labeled "Std. Deviation", reports the standard deviation of the difference, which is part of the denominator of the Difference *t* formula. The third column, labeled "Std. Error Mean," reports the standard error of the mean difference, which is obtained by dividing the standard deviation of the difference by the square root of *n*. The standard error of the mean difference is the complete numerator of the Difference *t* formula. The last two columns of this *output* block present the boundaries of the 95% confidence interval within which the true mean difference for the population is expected to fall.

Part B of the Paired Sample Test output presents the *t* obtained, degrees of freedom, and the two tailed level of significance. In this case, the *t* obtained is 13.321, and, with 29 degrees of freedom (df = *n* - 1), it is significant at least at the .001 alpha level. Though SPSS reports a significance level of .000, it is generally inappropriate to report it as such, and reporting .001 is the preferred method.

With respect to our current example's hypotheses, we can conclude that the pre-cow-school fence touching behavior for our sample of cows differed from their post-cow-school fence touching behavior. More specifically, by examining the difference between our pre- and post-cow-school fence touching behavior means, we can conclude that on average our sample of cows touched the electric fence an average of 2.5333 time more often before attending cow school, compared to their post-cow-school fence touching frequency.