

## One-Way ANOVA using SPSS 11.0

This section covers steps for testing the difference between three or more group means using the SPSS **ANOVA** procedures found in the **Compare Means** analyses. Specifically, we demonstrate procedures for running a One-Way Anova, obtaining the LSD post hoc test, and producing a chart that plots the group means. These analyses will allow us to determine which group means are significantly different from one or more other group means.

For the following examples, we have recreated the data set based on The Far Side Cartoon presented in Class (Liquids off of a duck's back) found in Table 12.1. Again, the Independent variable is the type of liquid applied to the duck's back. In our example, one group of ducks had acid applied to their backs, one group had vinegar applied, and one group served as a control group and received no treatment. The dependent variable is the number of feathers lost or gained during the 24 hours following the application of the liquid.

### Setting Up the Data

Figure 12.1 presents the variable view of the SPSS data editor where we have defined two variables; one discrete and one continuous. The first variable represents the three different groups that received the three different liquid application treatments. We have given it the variable name **group** and given it the variable label "Experiment Group." The second variable represents the number of feathers lost or gained. We have given it the variable name **feathers** and the variable label "Number of Feathers Lost (-) or Gained (+)."

Since the **groups** variable represents discrete groups, we need to assign numerical values to each group and provide value labels for each of the groups. Again, this is done by clicking on the cell in the

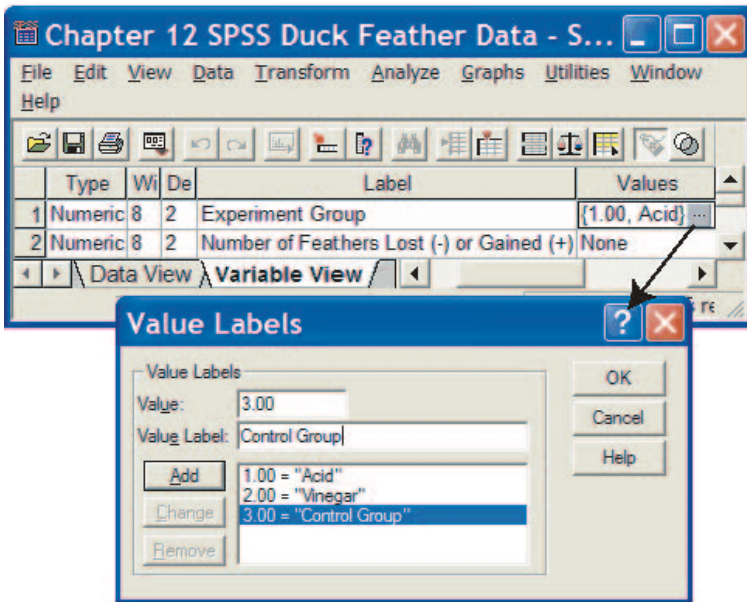
Table 12.1 Liquids off a Duck’s Back Data

*One-way Analysis of Variance for Feathers Lost (or Gained)*

Group 1			Group 2			Group 3		
s #	X.1	X.1 <sup>2</sup>	s #	X.2	X.2 <sup>2</sup>	s #	X.3	X.3 <sup>2</sup>
X11	-8		X12	+2		X13	-3	
X21	-9		X22	-6		X23	+2	
X31	-10		X32	-4		X33	-3	
X41	-8		X42	-1		X43	+2	
X51	-11		X52	-1		X53	+4	
X61	-15		X62	+4		X63	-1	
X71	-16		X72	-3		X73	-3	
X81	-7		X82	-2		X83	-2	
X91	-12		X92	-4		X93	+2	
X101	-14		X102	-5		X103	-3	
GX.1			GX.2			GX.3		
GX.1 <sup>2</sup>			GX.2 <sup>2</sup>			GX.3 <sup>2</sup>		
( $n_1=10$ )			( $n_2=10$ )			( $n_3=10$ )		

Group 1 = One ounce of acid poured “off” a duck’s back.  
 Group 2 = One ounce of vinegar poured “off” a duck’s back.  
 Group 3 = Control group; no treatment given

Figure 12.1 SPSS: Variable View for Duck Feather Data



variable row desired (in this case row 1) in the **Values** column and then clicking on the little gray box that appears, which will open the **Value Labels** dialogue box. In this dialogue box you can pair numerical values with labels for each of your groups. For this example we have paired 1 with the label “Acid”, 2 with the label “Vinegar”, and 3 with the label “Control Group.”

Figure 12.2 SPSS: Data View for Duck Feather Data

Figure 12.2 consists of two overlapping screenshots of the SPSS Data View window. The top window, labeled 'A', shows the first 15 rows of data. The bottom window, labeled 'B', shows the last 15 rows of data (rows 16-30). Both windows show columns for 'group' and 'feathers'.

Row	group	feathers
1	Acid	-8.00
2	Acid	-9.00
3	Acid	-10.00
4	Acid	-8.00
5	Acid	-11.00
6	Acid	-15.00
7	Acid	-16.00
8	Acid	-7.00
9	Acid	-12.00
10	Acid	-14.00
11	Vinegar	2.00
12	Vinegar	-6.00
13	Vinegar	-4.00
14	Vinegar	-1.00
15	Vinegar	-1.00
16	Vinegar	4.00
17	Vinegar	-3.00
18	Vinegar	-2.00
19	Vinegar	-4.00
20	Vinegar	-5.00
21	Control Gro	-3.00
22	Control Gro	2.00
23	Control Gro	-3.00
24	Control Gro	2.00
25	Control Gro	4.00
26	Control Gro	-1.00
27	Control Gro	-3.00
28	Control Gro	-2.00
29	Control Gro	2.00
30	Control Gro	-3.00

Figure 12.2 presents the

data view of the SPSS data editor. Here, we have entered the duck feather data for the 30 ducks in our sample.

Remember that the columns represent each of the different variables and the rows represent each observation, which in this case is each duck. For example, the first duck (found in part A of the figure) had acid poured down its back and lost 8 feathers. Similarly,

the 30<sup>th</sup> duck (found in part B of the figure) was in the control group and lost 3 feathers.

Figure 12.3 SPSS: Running the ANOVA

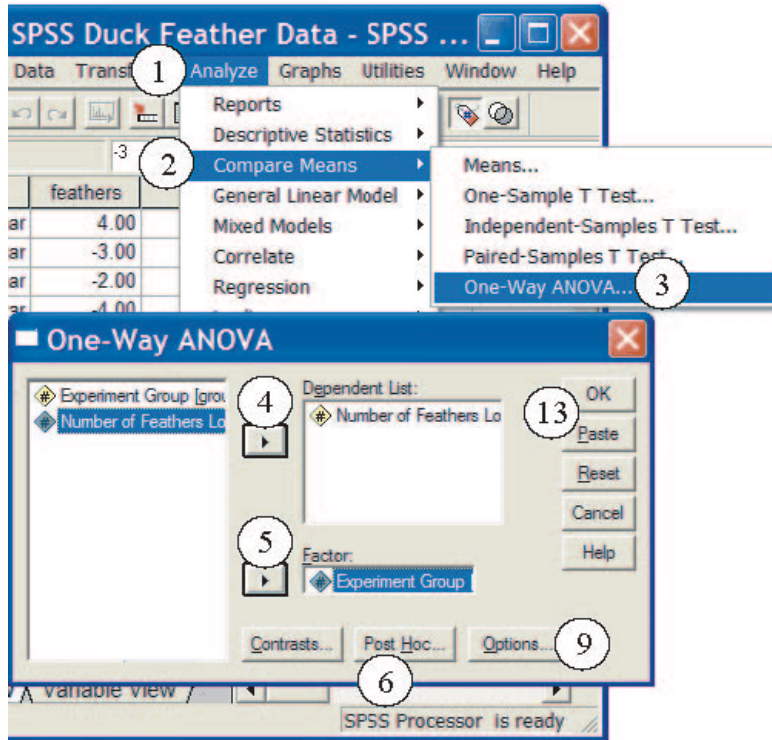
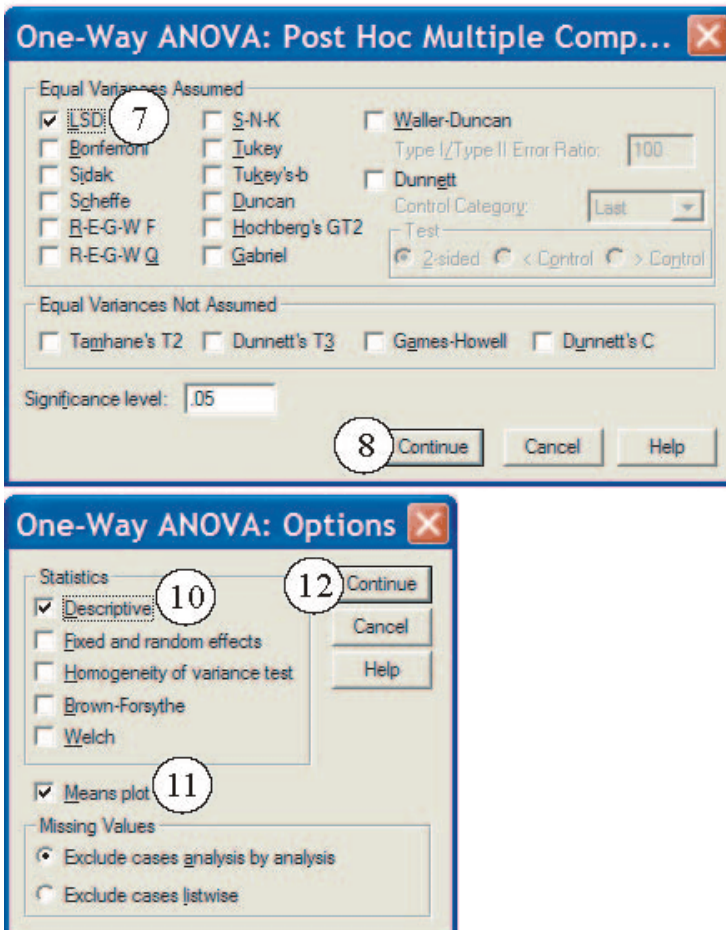


Figure 12.4 SPSS: Running the Anova Continued



## Running the Analyses

One-Way Anova (See Figure 12.3): From the **Analyze** (1) pull down menu select **Compare Means** (2), then select **One-Way Anova...** (3) from the side menu. In the **One-Way Anova** dialogue box, enter the variable **feathers** in the **Dependent List:** field by left-clicking on the variable and left-clicking on the boxed arrow (4) pointing to the **Dependent List:** field.

Next, enter the variable **group** in the

**Factor:** field by left-clicking on the variable and left-clicking on the boxed arrow (5) pointing to the **Factor:** field. Next, request the LSD *t*-tests by left click the **Post Hoc...** (6) button.

Figure 12.4 presents the **One-Way Anova: Post Hoc Multiple Comparisons** dialogue box. Here, select the **LSD** (7) option under the **Equal Variances Assumed** options. Click **Continue** (8) to return to the **One-Way Anova** dialogue box. Next, to request the descriptive statistics for each of the groups and to request a line chart that will plot the

group means, left click the **Options...** button (9; found in Figure 12.3). In the **One-Way Anova: Options** dialogue box (found in Figure 12.4), select the **Descriptive** option (10) under Statistics. This will provide you with the sample size, mean, standard deviation, standard error of the mean, and range for each group. Also, select the **Means Plot** option (11). This will provide you with a line chart that graphs the group means. Left click **Continue** (12) to return to the **One-Way Anova** dialogue box. Finally, double check your variables and options and either select **OK** (13) to run, or **Paste** to create syntax to run at a later time.

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

```
ONEWAY  
feathers BY group  
/STATISTICS DESCRIPTIVES  
/PLOT MEANS  
/MISSING ANALYSIS  
/POSTHOC = LSD ALPHA(.05).
```

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

## Reading the One-Way Anova Output

The One-Way Anova Output is presented in Figures 12.5, 12. 6, and 12.7. This output consists of four major parts: Descriptives (in Figure 12.5), ANOVA (in Figure 12. 5), Multiple Comparison (in Figure 12.6), and the Means Plots (in Figure 12.7).

Figure 12.5 SPSS: Anova Output for Duck Feather Data

### Oneway

#### Descriptives

Number of Feathers Lost (-) or Gained (+)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
Acid	10	-11.0000	3.16228	1.00000	-13.2622	-8.7378
Vinegar	10	-2.0000	3.12694	.98883	-4.2369	.2369
Control Group	10	-.5000	2.71825	.85959	-2.4445	1.4445
Total	30	-4.5000	5.53827	1.01114	-6.5680	-2.4320

#### Descriptives

Number of Feathers Lost (-) or Gained (+)

	Minimum	Maximum
Acid	-16.00	-7.00
Vinegar	-6.00	4.00
Control Group	-3.00	4.00
Total	-16.00	4.00

#### ANOVA

Number of Feathers Lost (-) or Gained (+)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	645.000	2	322.500	35.613	.000
Within Groups	244.500	27	9.056		
Total	889.500	29			

### *Reading the Descriptives Output*

The descriptives output provides each group's sample size ( $N$ ), mean, standard deviation, the standard error of the mean (the standard deviation divided by the square root of  $N$ , which estimates the potential for sampling error), and the minimum and maximum scores. Also, this part of the output presents the confidence interval within which we are 95% confident that the true population mean for this group would fall. Like the confidence intervals presented in Chapter 8, this interval is found by adding and subtracting from the mean the 95% confidence limit, which is obtained by multiplying the standard error of the mean by the  $t_{\text{critical}}$  associated with  $n-1$  degrees of freedom, at the .05 alpha level. For the most part, we will usually only need to concern ourselves with the means and standard deviations for each of our groups. In this case the means and standard deviations (presented in parentheses) for the acid group, the vinegar group and the control group are -11.00 (3.16228), -2.00 (3.12694), and -.5 (2.71825), respectively. Thus, eyeballing our data, we can begin to suspect that the acid group lost significantly more feathers than the other two groups.

### *Reading the ANOVA Output*

Like most ANOVA Summary Tables, the three rows present the Between Group, Within Groups, and Total sample Anova information, respectively. The first column provides us with the between, within, and total sums of squares. In this case we have  $SS_{\text{between}} = 645.00$ ,  $SS_{\text{within}} = 244.50$ , and  $SS_{\text{total}} = 889.50$ .

The second column presents the degrees of freedom between groups ( $\#$  of groups - 1), degrees of freedom within groups ( $n - \#$  of groups), and total degrees of freedom ( $n - 1$ ). In this case the  $df_{\text{between}}$  is 2 ( $\#$  of groups - 1), because we have 3 groups;  $df_{\text{within}}$  is 27 ( $n - \#$  of groups), because we have 30 subjects and 3 groups; and the  $df_{\text{total}}$  is 29 ( $n-1$ ), because we have 30 ducks in our sample.

The third column presents the Mean Square (MS) between and within, respectively. Again,

$MS_{\text{between}}$  is obtained by dividing the  $SS_{\text{between}}$  by the  $df_{\text{between}}$ . In this case  $MS_{\text{between}} = 322.50$ . Similarly,  $MS_{\text{within}}$  is obtained by dividing the  $SS_{\text{within}}$  by the  $df_{\text{within}}$ . In this case  $MS_{\text{within}} = 9.056$ .

The fourth and fifth columns present the final  $F$  statistic and its associated level of significance, respectively. The  $F$  is obtained by dividing the  $MS_{\text{between}}$  by  $MS_{\text{within}}$ . In this case we have an  $F_{\text{obtained}}$  of 35.613. Though this is slightly different from the  $F$  we obtained with our hand calculations, this can be attributed to differences in the rounding rules that we use. Looking at the exact significance level that SPSS gives us for the  $F_{\text{obtained}}$ , the  $F_{\text{obtained}}$  is significant at an alpha level less than .01, which is consistent with our hand calculations. More specifically, the  $F_{\text{obtained}}$  is significant at least at the alpha level less than .001, as indicated by the significance level of .000 reported in the last column of the SPSS table, which falls well below the required .05 alpha level. Thus, we can conclude that the differences found between our groups are significant and there is less than 1 in a 1000 chance that the differences we found are the result of sampling error. However, even though we know that at least one of our group means is significantly different from at least one other group mean, we are not sure which groups are different and which are not. To obtain this information, we must turn to the Multiple Comparisons output presented in Figure 12.6

### *Reading the Multiple Comparisons Output*

The Multiple Comparisons output presents the results of the LSD  $t$ -tests that we requested when running the Anova analyses. In Figure 12.6 we present this part of the output as two blocks. To simplify things we will only discuss the first block of this output. In our example the first block consists of three major rows; labeled Acid, Vinegar, and Control Group, respectively. Within each major row the remaining two variables comprise minor rows of their own. For example, major row 1 (Acid) contain the minor rows labeled Vinegar and Control Group, respectively. Each of these minor rows represents an LSD  $t$ -test where the major row variable is the first mean in the equation and the minor row variable



is the second variable. In major row 1: minor row 1, we are assessing whether the LSD  $t$  obtained by subtracting the mean of the Vinegar group (-2.00) from the mean of the Acid group (-11.00) is significant.

The first column of data, labeled Mean Difference (I-J), presents the result of subtracting the minor row variable mean from the major row mean, which is the numerator of the LSD  $t$ -test. For major

Figure 12.6 SPSS: Anova Output for Duck Feather Data Continued

## Post Hoc Tests

### Multiple Comparisons

Dependent Variable: Number of Feathers Lost (-) or Gained (+)

LSD

(I) Experiment Group	(J) Experiment Group	Mean Difference (I-J)	Std. Error	Sig.
Acid	Vinegar	-9.0000*	1.34578	.000
	Control Group	-10.5000*	1.34578	.000
Vinegar	Acid	9.0000*	1.34578	.000
	Control Group	-1.5000	1.34578	.275
Control Group	Acid	10.5000*	1.34578	.000
	Vinegar	1.5000	1.34578	.275

### Multiple Comparisons

Dependent Variable: Number of Feathers Lost (-) or Gained (+)

LSD

(I) Experiment Group	(J) Experiment Group	95% Confidence Interval	
		Lower Bound	Upper Bound
Acid	Vinegar	-11.7613	-6.2387
	Control Group	-13.2613	-7.7387
Vinegar	Acid	6.2387	11.7613
	Control Group	-4.2613	1.2613
Control Group	Acid	7.7387	13.2613
	Vinegar	-1.2613	4.2613

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

row 1: minor row 1, the mean difference is  $(-11.00) - (-2.00) = -9.00$ . The second column of data, labeled Stand. Error, presents the denominator of the LSD  $t$ -test. For the Acid - Vinegar group comparison the Standard Error is 1.34578. SPSS does not display the resulting LSD  $t$  value, but dividing the mean difference (column 1) by the standard error (column 2) will provide you with an LSD  $t$  value comparable to the values you obtain in your hand calculations. The third column of data (and the last one we are really concerned with) presents the exact level of significance associated with the obtained LSD  $t$  value. In this case the difference between the Acid group and Vinegar group means is significant at least at the .001 alpha level. That is 1 time in a 1,000 two groups that were really the same would have means this different. This falls well below the required .05 alpha level. We can conclude that the ducks exposed to Acid lost significantly more feather than did the duck that had been exposed to Vinegar.

In the second row of the Acid major row we are subtracting the Control Group mean (-.5000) from the Acid group mean (-11.00). In this case we have a mean difference, standard error, and significance level of -10.50, 1.34578, and .000 respectively. Thus, we can conclude that the Acid group lost significantly more feathers than did the ducks that were not exposed to any liquids, and this difference is significant at least at the .001 alpha level.

In the second major row comparisons are being made between the mean for the Vinegar group and the Acid group (minor row 1) and the Vinegar group mean and the Control Group mean (minor row 2). The first comparison (Vinegar - Acid) is redundant with the comparison made between Acid and Vinegar present in the Acid major row. You may notice that the mean difference of Vinegar - Acid has a different sign than the Acid - Vinegar mean difference (+ 9 instead of -9). Regardless, this comparison answers the same question we asked previously: Are the acid and vinegar means significantly different? Looking at the exact significance level for the Vinegar - Acid comparison, we see that the significance level is the same as we obtained for the Acid - Vinegar comparison.

Conversely, the Vinegar - Control Group comparison has not yet been evaluated. Here, we are

subtracting the Control Group mean (-.5000) from the Vinegar group mean (-2.00). The mean difference, standard error, and significance level are -1.5, 1.34578, and .257, respectively. Since the significance level is much larger than the required .05 alpha level, we must conclude that difference in feathers lost or gained for the Vinegar group and Control Group is not significant.

The final major row in this output (labeled Control Group) presents the Control Group - Acid and Control Group - Vinegar comparisons. These comparisons are redundant with the Acid - Control Group and the Vinegar - Control Group comparisons presented above. There is no need to interpret these results.

In summary, in our current example the LSD multiple comparison indicates that the ducks who had acid poured on their back lost more feathers than did ducks who had either vinegar or nothing poured on their back. Further, ducks who had vinegar poured on their backs did not lose any more or gain any more feathers than did ducks that did not have any liquid poured on them.

### *Reading the Means Plots*

Figure 12.7 graphically displays the means for the three treatment groups. The X axis (abscissa) represents the three different treatment group (Acid, Vinegar, and Control Group). The Y axis (ordinate) represents the number of feathers lost or gained. Because we are working with negative numbers, the top of the Y axis represents 0, and the further you go down the Y axis the more feathers are lost by our groups of ducks. In this case, the Acid group lost the most feathers (-11.00) compared to the Vinegar group (-2.00) and Control Group (-.50).

Figure 12.7 SPSS: Anova Output for Duck Feather Data Continued

**Means Plots**