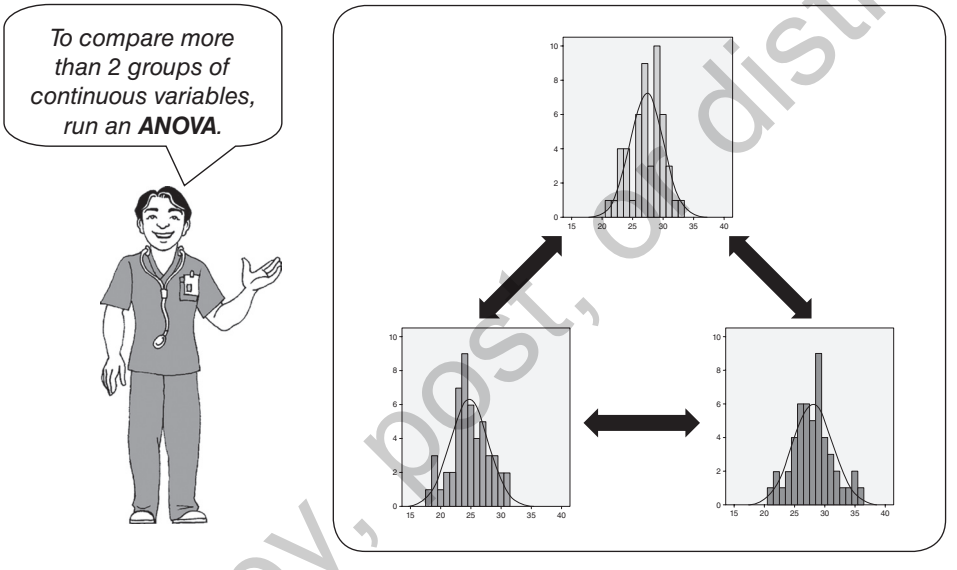
CHAPTER 6

ANOVA and Kruskal-Wallis Test



Three is a magic number.

—Bob Dorough

LEARNING OBJECTIVES

Upon completing this chapter, you will be able to:

- Determine when it is appropriate to run an ANOVA test
- Verify that the data meet the criteria for ANOVA processing: normality, *n,* and homogeneity of variance
- Order an ANOVA test with graphics
- Select an appropriate ANOVA post hoc test: Tukey or Sidak
- Derive results from the descriptives and multiple comparisons tables
- Calculate the unique pairs formula
- Resolve the hypotheses
- Know when and how to run and interpret the Kruskal-Wallis test
- Document the results in plain English

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VIDEO

The videos for this chapter are **Ch 06 – ANOVA.mp4** and **Ch 06 – Kruskal-Wallis Test.mp4.** These videos provide overviews of these tests, instructions for carrying out the pretest checklist, run, and interpreting the results of this each test using the data set: **Ch 06 – Example 01 – ANOVA.sav**

LAYERED LEARNING

The *t* test and ANOVA (analysis of variance) are so similar that this chapter will use the same example and the same 10 exercises used in Chapter 5 (*t* Test); the only difference is that the data sets have been enhanced to include a third or fourth group. If you are proficient with the *t* test, you are already more than halfway there to comprehending ANOVA. The only real differences between the *t* test and ANOVA are in ordering the test run and interpreting the test results; several other minor differences will be pointed out along the way.

That being said, let us go into the expanded example, drawn from Chapter 5, which involved Group 1 (Drug A), Group 2 (Drug B), and now a third group: Group 3 (Drug C). The ANOVA test will reveal which (if any) of these drugs statistically significantly outperforms the others in effectively controlling hypertension.

OVERVIEW—ANOVA

The ANOVA test is similar to the *t* test, except whereas the *t* test compares two groups of continuous variables to each other, the ANOVA test can compare three or more groups to each other.

Example

The nurse manager is interested in identifying the most effective drug for managing patients with moderate hypertension (systolic between 130 mmHg and 140 mmHg).

Research Question

Which is the best drug for lowering moderate hypertension: Drug A, Drug B, or Drug C?

Groups

The nurse manager recruits 90 volunteers who meet the criteria and consent to participate in this study. Each patient's name is written on slips of paper and placed in a hat. The nurse manager randomly draws 30 names from the hat; these patients will receive Drug A, the next 30 names drawn will get Drug B, and the remaining 30 will be given Drug C.

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Procedure

Each participant is brought in to the clinic for a brief visit: Their blood pressure is taken to verify that they meet the criteria (systolic between 130 mmHg and 140 mmHg), and they are given a 30-day supply of the specified medication. After 30 days, each participant will return to the clinic and have his or her blood pressure taken. For purposes of this example, we will presume 100% dosage adherence.

Hypotheses

The null hypothesis (H_0) is phrased to anticipate that the experiment/intervention fails, indicating that *no drug outperformed any of the others*. The alternative hypothesis (H_1) states that *at least one drug did outperform another:*

H_0: There is no statistically significant difference in the performance of the three drugs.

H_1: At least one drug (group) outperformed another.

Admittedly, H_1 is phrased fairly broadly. The Post Hoc Multiple Comparisons table, which is covered in the Results section, will identify which drug(s), if any, outperformed which.

Data Set

Use the following data set: **Ch 06 – Example 01 – ANOVA.sav.**

Notice that this data set has 90 records; the first 60 records (rows) are the same as the *t* test example data set used in Chapter 5 (records 61 through 90 are new):

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = Drug A, 2 = Drug B, 3 = Drug C)
Variable:	SystolicBP
Definition:	Systolic blood pressure (in mmHg)
Type:	Continuous

NOTE: In this data set, records (rows) 1 through 30 are for Group 1 (Drug A), records 31 through 60 are for Group 2 (Drug B), and records 61 through 90 are for Group 3 (Drug C). The data are arranged this way just for visual clarity; the order of the records has no bearing on the statistical results.

If you go to the *Variable View* and open the *Values* menu for the variable *Group,* you will see that the label *Drug C* for the third group has been assigned to the value 3 (Figure 6.1).

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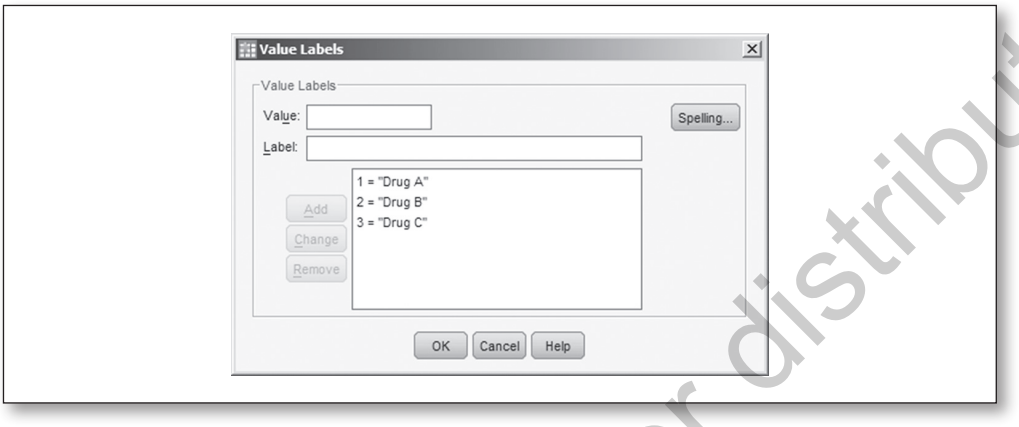
Figure 6.1 Value labels for a three-group ANOVA analysis.



Pretest Checklist

ANOVA Pretest Checklist

☑ 1. Normality*

☑ 2. *n* quota**

☑ 3. Homogeneity of variance**

*Run prior to ANOVA test

**Results produced upon ANOVA test run

The statistical pretest checklist for the ANOVA is similar to the *t* test: **(1) normality, (2) *n*,** and **(3) homogeneity of variance,** except that you will assess the data for more than two groups.

Pretest Checklist Criterion 1—Normality

Check for normality by inspecting the histogram with a normal curve for each of the three groups. Begin by using the *Select Cases* icon to select the records pertaining to the Drug A group (*Group* = 1); the selection criteria would be *Group* = *1*. Next, run a histogram (with normal curve) on the variable *Score*. For more details on this procedure, refer to Chapter 4 ("SPSS—Descriptive Statistics: Continuous Variable (Age) Select by Categorical Variable (Gender)—Females Only"); see the star (★) icon on page **66**.

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Then repeat the process for the Drug B group (*Group* = 2), and finally, repeat the process a third time for the Drug C group (*Group* = 3).

This will produce three histograms with normal curves—one for the scores in the Drug A group, a second for the scores in the Drug B group, and a third for the Drug C group. The histograms should resemble the graphs shown in Figures 6.2, 6.3, and 6.4.

As we read these three histograms, our focus is on the *normality of the curve,* as opposed to the characteristics of the individual bars. Although the height and width of each curve are unique, we see that each is bell shaped and shows good symmetry with no substantial *skewing*. On the basis of the inspection of these three figures, we would conclude that the criteria of *normality* are satisfied for all three groups.

Next, (re)activate all records for further analysis; you can either delete the temporary variable *filter_$* or click on the *Select Cases* icon and select the *All cases* button. For more details on this procedure, please refer to Chapter 4 ("SPSS—(Re)Selecting All Variables"); see the star (★) icon on page **73**.

Pretest Checklist Criterion 2—*n* Quota

Again, as with the *t* test, technically, you can run an ANOVA test with an *n* of any size in each group, but when the *n* is at least 30 in each group, the ANOVA is considered

Figure 6.2 Histogram of score for Group 1: Drug A.

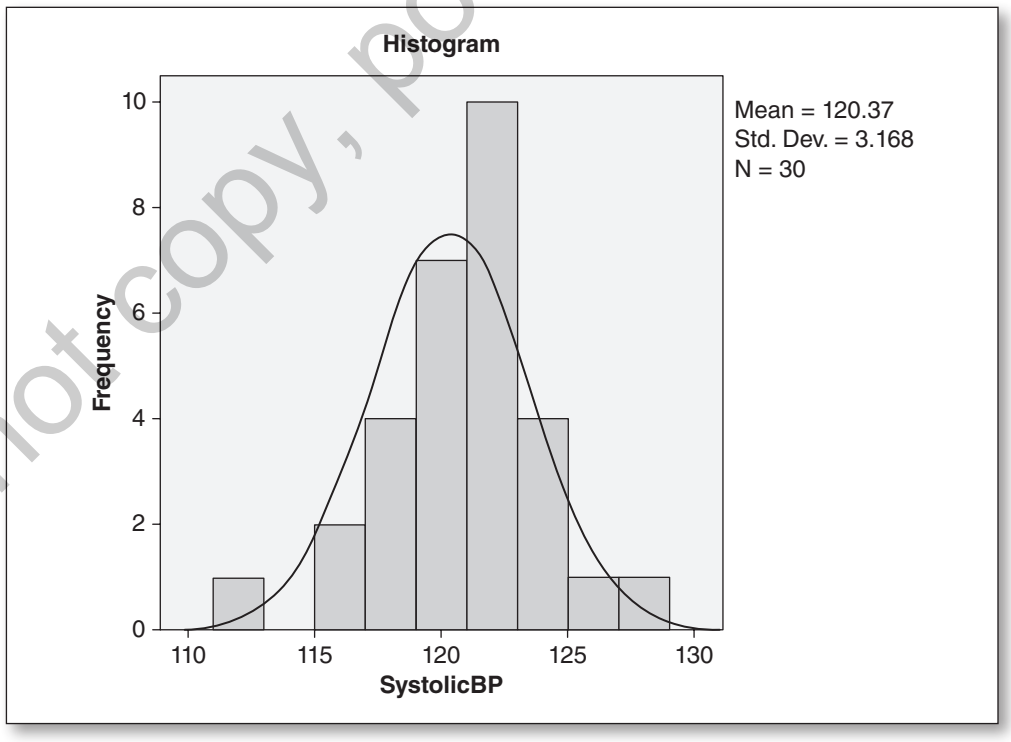

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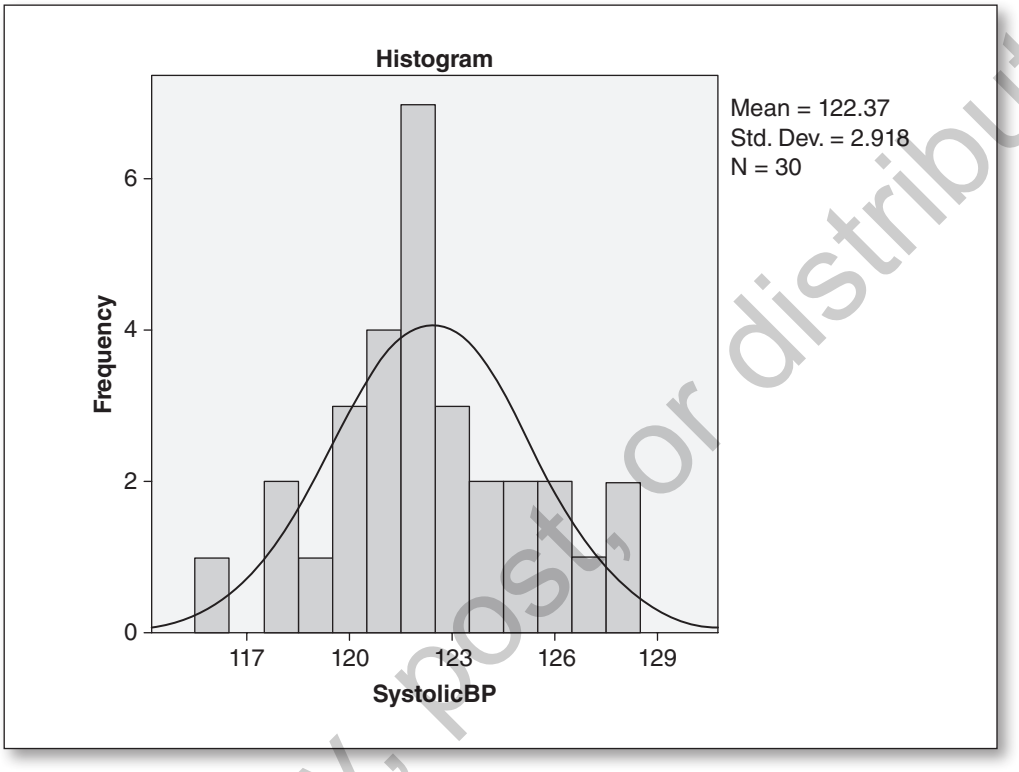
Figure 6.3 Histogram of score for Group 2: Drug B.



more robust. The *n*s will be part of the output produced by the Test Run procedure; we will revisit this criteria in the Results section.

Pretest Checklist Criterion 3—Homogeneity of Variance

Since we process the ANOVA with the same menu as the *t* test, we will select the *homogeneity of variance test* when we order the ANOVA test and read the findings as part of the results. The *homogeneity of variance* rule of thumb for the ANOVA test is just like the *t* test: None of the groups should have a variance (standard deviation^2) that is more than twice the variance of any other group. In other words, if Group 1 had a variance of 20.1, Group 2 had a variance of 24.7, and Group 3 had a variance of 90.6, we would expect the homogeneity of variance criteria to fail since 90.6 is clearly more than twice as large as 20.1 or 24.7.

The remaining two pretest criteria, **(2) *n* quota** and **(3) homogeneity of variance,** are processed during the **Test Run** and finalized in the **Results** section.

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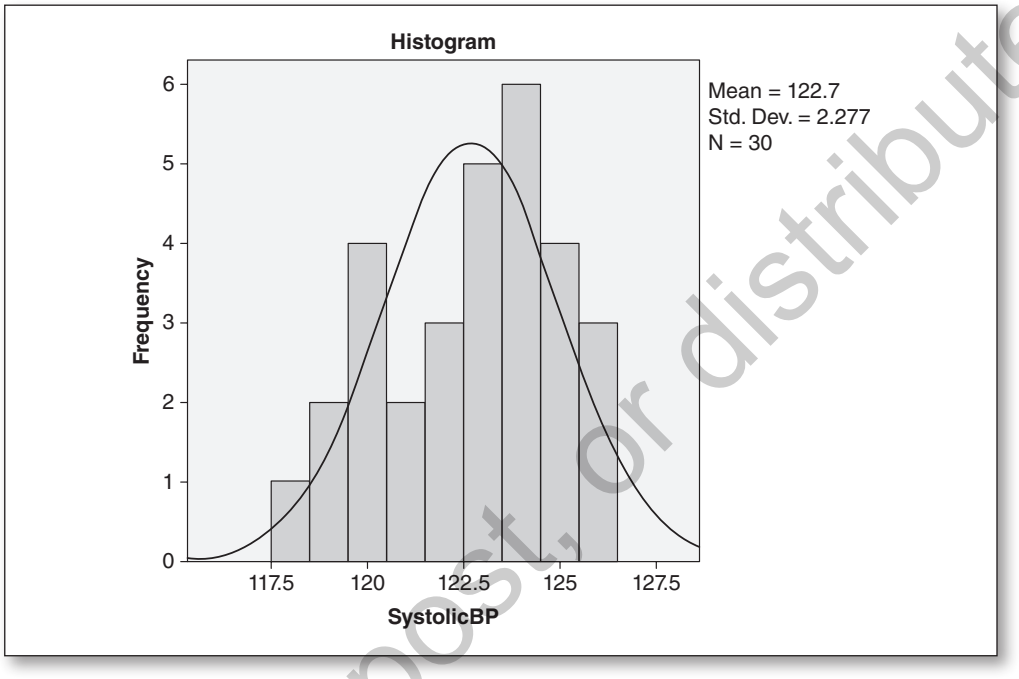
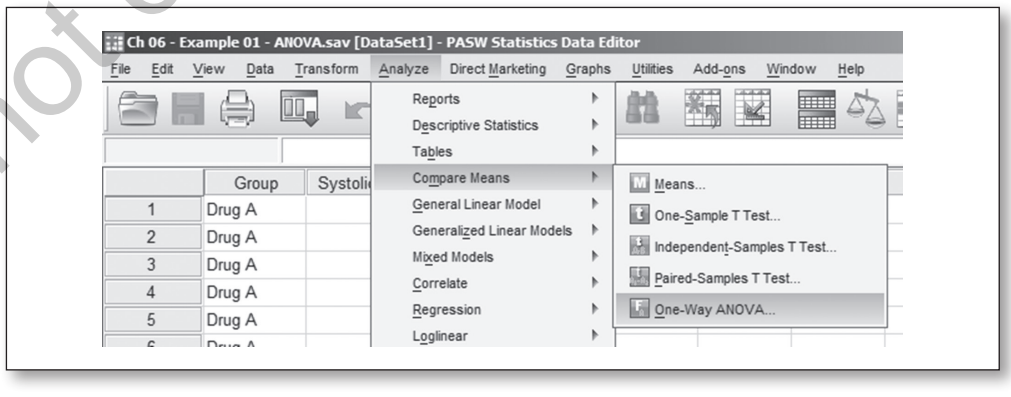
Figure 6.4 Histogram of score for Group 3: Drug C.



Test Run

1. On the main screen, click on *Analyze, Compare Means, One-Way ANOVA* (Figure 6.5).

Figure 6.5 Running an ANOVA test.



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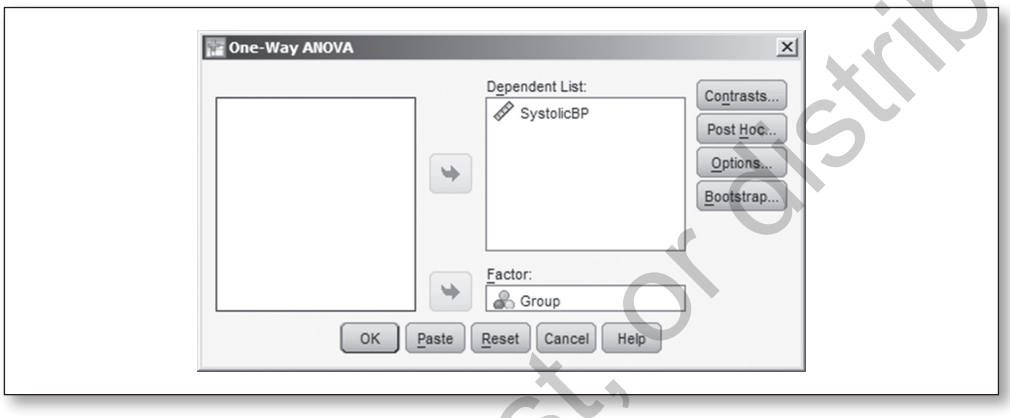
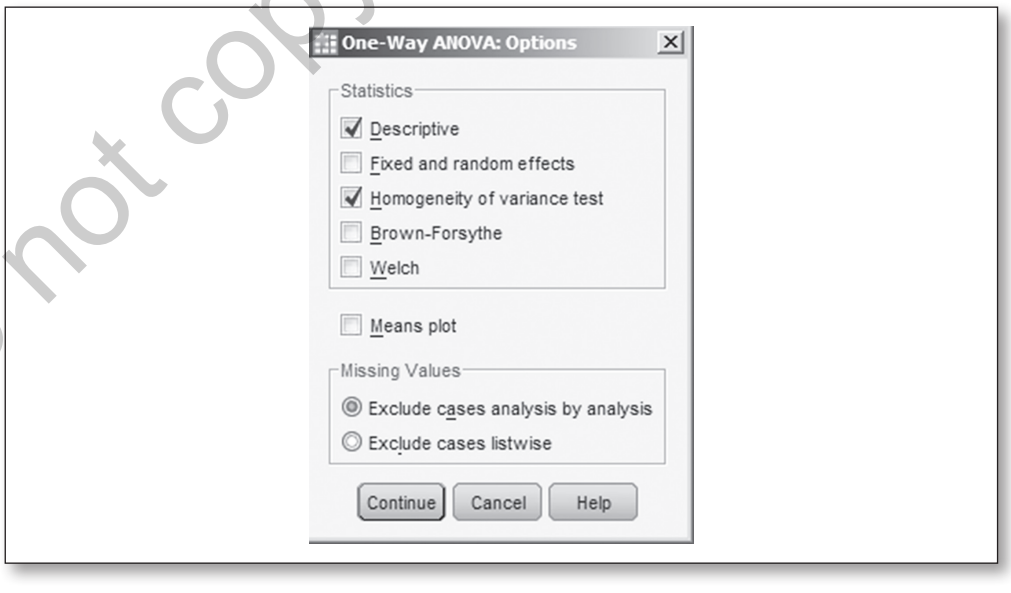
2. On the *One-Way ANOVA* menu, move the continuous variable that you wish to analyze (*SystolicBP*) into the *Dependent List* window, and move the variable that contains the categorical variable that specifies the group (*Group*) into the *Factor* window (Figure 6.6).

Figure 6.6 The one-way ANOVA menu.



3. Click on the *Options* button. On the *One-Way ANOVA: Options* menu, check *Descriptive* and *Homogeneity of variance test,* then click on the *Continue* button (Figure 6.7). This will take you back to the *One-Way ANOVA* menu.

Figure 6.7 The one-way ANOVA: Options menu.



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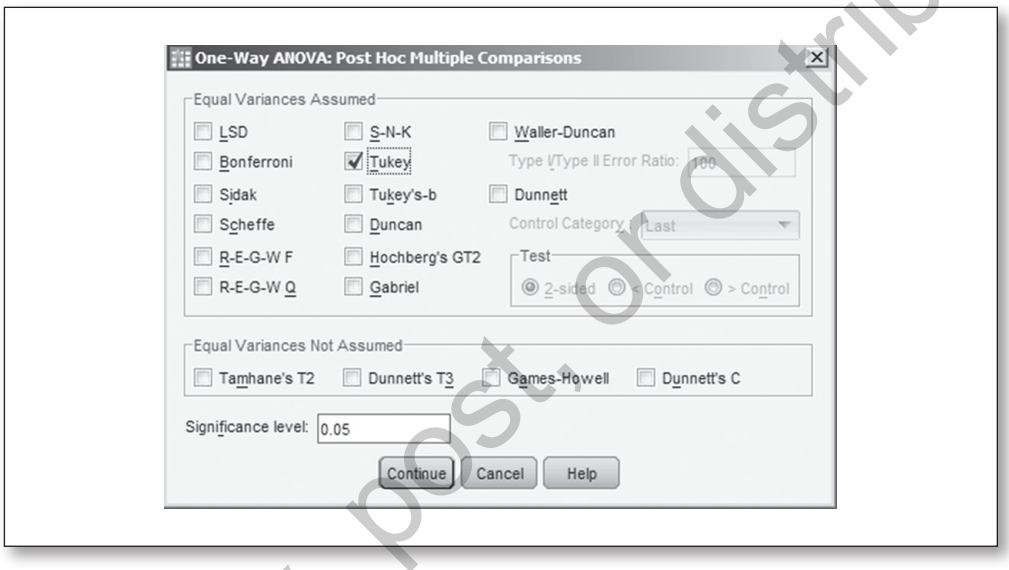
4. Click on the *Post Hoc* button.
5. This will take you to the *One-Way ANOVA: Post Hoc Multiple Comparisons* menu (Figure 6.8).

Figure 6.8 The *One-Way ANOVA: Options* menu.



6. If you were to run the ANOVA test without selecting a post hoc test, then all it would return is a single *p* value; if that *p* is statistically significant, then that would tell you that somewhere among the groups processed, the mean for at least one group is statistically significantly different from the mean of at least one other group, but it would not tell you specifically *which* group is different from *which*. The post hoc test produces a table comparing the mean of each group with the mean of each other group, along with the *p* values for each pair of comparisons. This will become clearer in the *Results* section when we read the post hoc multiple comparisons table.

   As for which post hoc test to select, there are a lot of choices. We will focus on only two options: *Tukey* and *Sidak*. *Tukey* is appropriate when each group has the *same ns*; in this case, each group has an *n* of 30, so check the *Tukey* checkbox, then click on the *Continue* button (this will take you back to the *One-Way ANOVA* menu [Figure 6.6]). If the groups had *different ns* (e.g., *n*(Group 1) = 40, *n*(Group 2) = 55, *n*(Group 3) = 36), then the *Sidak* post hoc test would be appropriate. If you do not know the *ns* for each group in advance, then just select either *Tukey* or *Sidak* and observe the *ns* on the resulting report; if you chose wrong, then go back and rerun the analysis using the appropriate post hoc test.

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ANOVA Post Hoc Summary

- If all groups have the same *n*s, then select *Tukey*.
- If the groups have different *n*s, then select *Sidak*.

7. On the *One-Way ANOVA* menu (Figure 6.6), click on the *OK* button, and the ANOVA test will process.

Results

Pretest Checklist Criterion 2—*n* Quota

Table 6.1 shows that each group has an *n* of 30. This satisfies the *n* assumption, indicating that the ANOVA test becomes more robust when the *n* for each group is at least 30.

Table 6.1 Descriptive Statistics (*n*) of Score for Drug A, Drug B, and Drug C.

Descriptives

SystolicBP

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Drug A	30	120.57	2.800	.511	119.52	121.61	113	128
Drug B	30	122.37	2.918	.533	121.28	123.46	116	128
Drug C	30	122.70	2.277	.416	121.85	123.55	118	126
Total	90	121.88	2.812	.296	121.29	122.47	113	128

Pretest Checklist Criterion 3—Homogeneity of Variance

As for the final item on the pretest checklist, Table 6.2 shows that the homogeneity of variance test produced a significance (*p*) value of .656; since this is greater than the α level of .05, this tells us that there are *no statistically significant differences among the variances of the SystolicBP variable for the three groups analyzed*. In other words, the variances for *SystolicBP* are similar enough among the three groups: Drug A, Drug B, and Drug C that we would conclude that the criteria of the homogeneity of variance has been satisfied.

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Table 6.2 Homogeneity of Variance Test Results.

Test of Homogeneity of Variances

SystolicBP

Levene Statistic	df1	df2	Sig.
.423	2	87	.656

Next, we look at the ANOVA table (Table 6.3) and find a significance (*p*) value of .003; since this is less than the α level of .05, this tells us that there is a statistically significant difference between the (three) group means for *SystolicBP,* but unlike reading the results of the *t* test, we are not done yet.

Table 6.3 ANOVA Test Results Comparing Score of Drug A, Drug B, and Drug C.

ANOVA

SystolicBP

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	95.556	2	47.778	6.040	.003
Within Groups	688.233	87	7.911		
Total	783.789	89			

Remember that in the realm of the *t* test, there are only *two* groups involved, so interpreting the *p* value is fairly straightforward: If *p* is ≤ .05, there is no question as to which group is different from which—clearly, the mean from Group 1 is statistically significantly different from the mean of Group 2, but when there are *three or more groups,* we need more information to determine *which* group is different from which; that is what the post hoc test answers.

Consider this: Suppose you have *two* kids, Aaron and Blake; you are in the living room, and someone calls out from the den, *The kids are fighting again!* Since there are only two kids, you immediately know that the fight is between Aaron and Blake; this is akin to the *t* test, which involves comparing the means of two groups.

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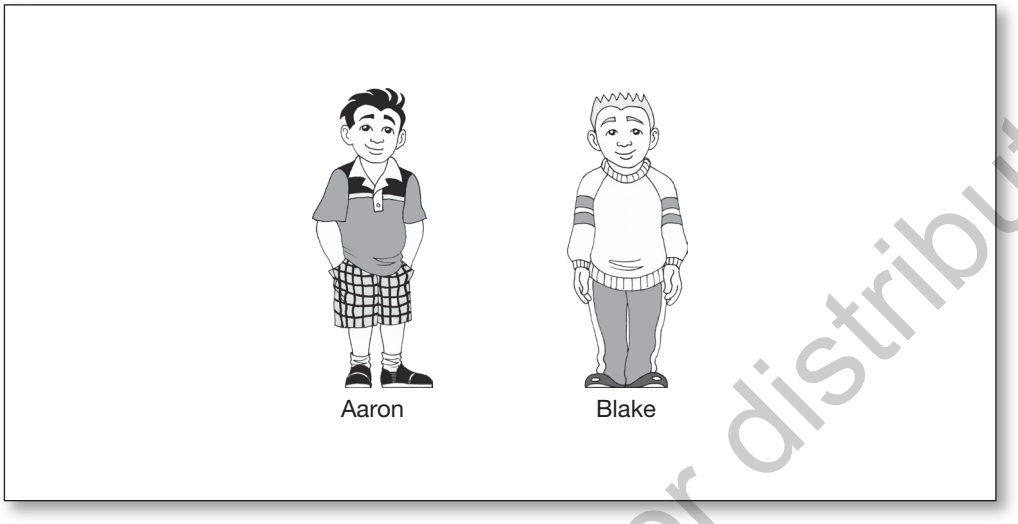
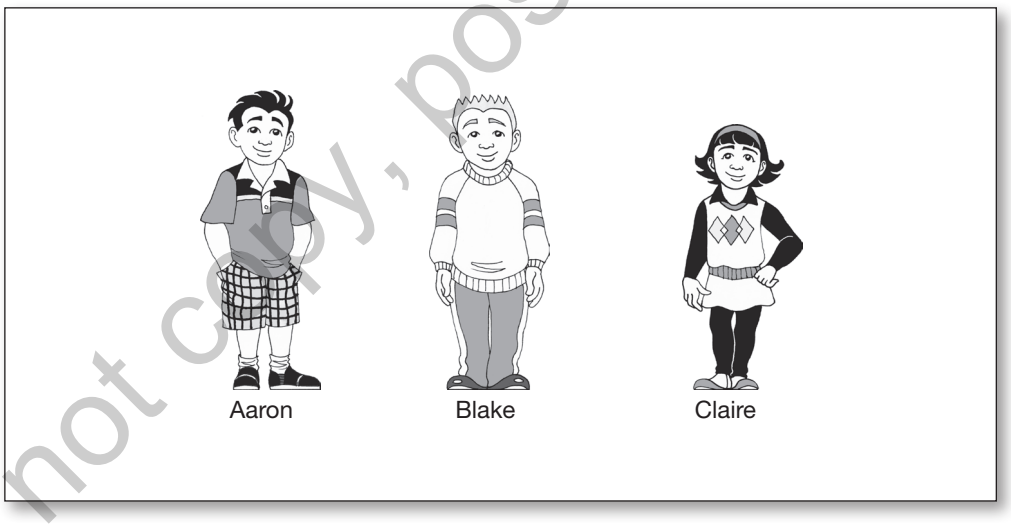


Now suppose you have *three* kids—Aaron, Blake, and Claire:



This time when the voice calls out, *The kids are fighting again!* you can no longer simply know that the fight is between Aaron and Blake; when there are *three* kids, you need more information. Instead of just *one* possibility, there are now *three* possible pairs of fighters:

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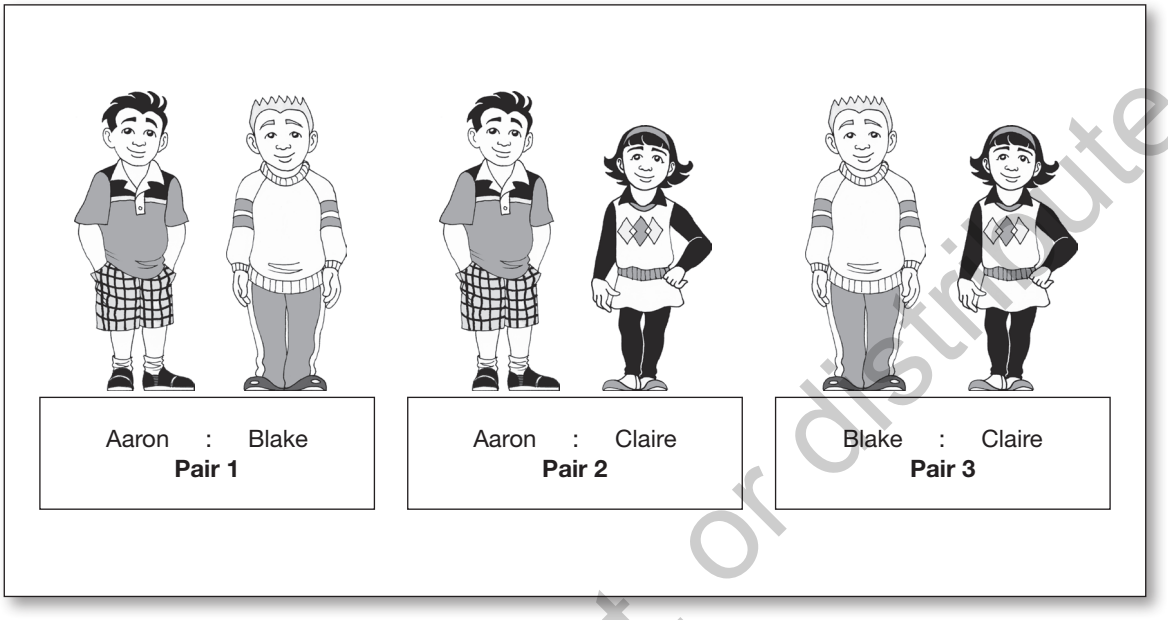

Back to our example: The ANOVA table (Table 6.3) produced a statistically significant *p* value (Sig. = .003), which indicates that there is a statistically significant difference detected somewhere among the three groups (*The kids are fighting!*); the post hoc table will tell us precisely *which pairs* are statistically significantly different from each other (which pair of kids is fighting). Specifically, it will reveal which group(s) outperformed which.

This brings us to the (Tukey post hoc) multiple comparisons table (Table 6.4). As with the three kids fighting, in this three-group design, there are three possible pairs of comparisons that we can assess in terms of (mean) score for the groups.

Drug A	:	Drug B
120.57		122.37
Pair 1		

Drug A	:	Drug C
120.57		122.70
Pair 2		

Drug B	:	Drug C
122.37		122.70
Pair 3		

We will use Table 6.1 (*Descriptives*) and Table 6.4 (*Multiple Comparisons*) to analyze the ANOVA test results. Table 6.1 lists the mean score for each of the three groups: μ(Drug A) = 120.57, μ(Drug B) = 122.37, and μ(Drug C) = 122.70. We will assess each of the three pairwise score comparisons separately.

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Comparison 1—Drug A : Drug B

Table 6.4 first compares the mean score for the Drug A group with the mean score for the Drug B group, which produces a Sig.(nificance) (*p*) of .019. Since the *p* is less than the .05 α level, this tells us that for *SystolicBP,* there is a statistically significant difference between Drug A (μ = 120.57) and Drug B (μ = 122.37).

Table 6.4 ANOVA Post Hoc Multiple Comparisons Table Shows a Statistically Significant Difference Between Drug A and Drug B (*p* = .019).

Multiple Comparisons

SystolicBP
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Drug A	Drug B	-2.000*	.726	.019	-3.73	-.27
	Drug C	-2.333*	.726	.005	-4.06	-.60
Drug B	Drug A	2.000*	.726	.019	.27	3.73
	Drug C	-.333	.726	.891	-2.06	1.40
Drug C	Drug A	2.333*	.726	.005	.60	4.06
	Drug B	.333	.726	.891	-1.40	2.06

*. The mean difference is significant at the 0.05 level.

Comparison 2—Drug A : Drug C

The second comparison in Table 6.5 is between Drug A and Drug C, which produces a Sig.(nificance) (*p*) of .005. Since the *p* is less than the .05 α level, this tells us that for *SystolicBP,* there is a statistically significant difference between Drug A (μ = 120.57) and Drug C (μ = 122.70).

Comparison 3—Drug B : Drug C

The third comparison in Table 6.6 is between Drug B and Drug C, which produces a Sig.(nificance) (*p*) of .891. Since the *p* is greater than the .05 α level, this tells us that for *SystolicBP,* there is no statistically significant difference between Drug B (μ = 122.37) and Drug C (μ = 122.70).

This concludes the analysis of the *Multiple comparisons* (post hoc) table. You have probably noticed that we skipped analyzing half of the rows; this is because there is a double redundancy among the figures in the Sig. column. This is the kind of double redundancy that you would expect to see in a typical two-dimensional table. For example, in a multiplication table, you would see two 32s in the table because 4 × 8 = 32 and 8 × 4 = 32. Similarly, the Sig. column of the *Multiple Comparisons* table contains two *p* values of .005: one comparing Drug A to Drug C and the other comparing Drug C to

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Table 6.5 ANOVA Post Hoc Multiple Comparisons Table Shows a Statistically Significant Difference Between Drug A and Drug C ($p = .005$).

Multiple Comparisons

SystolicBP
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Drug A	Drug B	-2.000*	.726	.019	-3.73	-.27
	Drug C	-2.333*	.726	.005	-4.06	-.60
Drug B	Drug A	2.000*	.726	.019	.27	3.73
	Drug C	-.333	.726	.891	-2.06	1.40
Drug C	Drug A	2.333*	.726	.005	.60	4.06
	Drug B	.333	.726	.891	-1.40	2.06

*. The mean difference is significant at the 0.05 level.

Table 6.6 ANOVA Post Hoc Multiple Comparisons Table Shows No Statistically Significant Difference Between Drug B and Drug C ($p = .891$).

Multiple Comparisons

SystolicBP
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Drug A	Drug B	-2.000*	.726	.019	-3.73	-.27
	Drug C	-2.333*	.726	.005	-4.06	-.60
Drug B	Drug A	2.000*	.726	.019	.27	3.73
	Drug C	-.333	.726	.891	-2.06	1.40
Drug C	Drug A	2.333*	.726	.005	.60	4.06
	Drug B	.333	.726	.891	-1.40	2.06

*. The mean difference is significant at the 0.05 level.

Drug A (Table 6.7). In addition, there are two .019 p values (Drug A : Drug B and Drug B : Drug A) and two .891 p values (Drug B : Drug C and Drug C : Drug B).

The ANOVA test can process any number of groups, provided the pretest criteria are met. As the number of groups increases, the number of (multiple) pairs of comparisons increases as well (see Table 6.8).

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Table 6.7 ANOVA Post Hoc Multiple Comparisons Table Containing Double-Redundant Sig. (p) Values: Drug A : Drug C Produces the Same p Value as Drug C : Drug A ($p = .005$).

Multiple Comparisons

SystolicBP
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Drug A	Drug B	-2.000*	.726	.019	-3.73	-.27
	Drug C	-2.333*	.726	.005	-4.06	-.60
Drug B	Drug A	2.000*	.726	.019	.27	3.73
	Drug C	-.333	.726	.891	-2.06	1.40
Drug C	Drug A	2.333*	.726	.005	.60	4.06
	Drug B	.333	.726	.891	-1.40	2.06

*. The mean difference is significant at the 0.05 level.

Table 6.8 Increasing Groups Substantially Increases ANOVA Post Hoc Multiple Comparisons.

2 Groups Renders 1 Pair	3 Groups Renders 3 Pairs	4 Groups Renders 6 Pairs
G_1:G_2	G_1:G_2 G_2:G_3	G_1:G_2 G_2:G_3 G_3:G_4
	G_1:G_3	G_1:G_3 G_2:G_4
		G_1:G_4

NOTE: G = group.

You can easily calculate the number of (unique) pairwise comparisons the post hoc test will produce:

UNIQUE PAIRS FORMULA

G = Number of groups

Number of ANOVA post hoc unique pairs = $G! \div (2 \times (G - 2)!)$

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The above formula uses the *factorial* function denoted by the exclamation mark (!). If your calculator does not have a factorial (!) button, you can calculate it manually: Simply multiply all of the integers between 1 and the specified number. For example: 3! = 1 × 2 × 3, which equals 6.

Hypothesis Resolution

To clarify the hypothesis resolution process, it is helpful to organize the findings in a table and use an asterisk to flag statistically significant difference(s) (Table 6.9).

NOTE: SPSS does not generate this table (Table 6.9) directly; you can assemble this table by gathering the means from the *Descriptives* table (Table 6.1) and the *p* values from the Sig. column in the *Multiple Comparisons* table (Table 6.4).

With this results table assembled, we can now revisit and resolve our pending hypotheses, which focus on determining the best drug for controlling moderate hypertension. To finalize this process, we will assess each hypothesis per the statistics contained in Table 6.9.

REJECT: H_0: There is no statistically significant difference in the performance of the three drugs.

ACCEPT: H_1: At least one drug (group) outperformed another.

Since we discovered a statistically significant difference among at least one pair of the drugs, we reject H_0 and accept H_1. Specifically, Drug A outperformed Drug B in lowering blood pressure ($p = .019$), and Drug A outperformed Drug C in lowering blood pressure ($p = .005$).

Incidentally, if all of the pairwise comparisons had produced *p* values that were greater than .05, then we would have accepted H_0 and rejected H_1.

Documenting Results

When documenting the results of this study, both Table 6.9 and the following verbose summary would be appropriate to include:

Table 6.9 *Results of ANOVA for SystolicBP.*

Groups	p
μ(Drug A) = 120.57 : μ(Drug B) = 122.37	.019*
μ(Drug A) = 120.57 : μ(Drug C) = 122.70	.005*
μ(Drug B) = 122.37 : μ(Drug C) = 122.70	.891

*Statistically significant difference detected between groups ($p \leq .05$).

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A group of 90 patients with moderate hypertension (systolic between 130 and 140 mmHg) were recruited and randomly assigned to take Drug A, Drug B, or Drug C for 30 days.

After 1 month, patients who took Drug A had a mean systolic blood pressure of 120.57, significantly outperforming Drug B (122.37) and Drug C (122.70) using an α of .05 (see Table).

Groups	p
μ(Drug A) = 120.57 : μ(Drug B) = 122.37	.019*
μ(Drug A) = 120.57 : μ(Drug C) = 122.70	.005*
μ(Drug B) = 122.37 : μ(Drug C) = 122.70	.891

*Statistically significant difference detected between groups ($p \leq .05$).

Occasionally, a p value may be close to .05 (e.g., $p = .066$). In such instances, you may feel compelled to comment that the .066 p level is *approaching* statistical significance. While the optimism may be commendable, this is a common mistake. The term *approaching* wrongly implies that the p value is a dynamic variable—that it is in motion and on its way to crossing the .05 finish line, but this is not at all the case. The .066 p value is a static variable, meaning that it is not in motion—the .066 p value is no more *approaching* .05 than it is *approaching* .07. Think of the .066 p value as *parked;* it is not going anywhere, in the same way that a parked car is neither approaching nor departing from the car parked in front of it, no matter how close those cars are parked to each other. At best, one could state that it (the .066 p value) is *close* to the .05 α level and that it would be interesting to consider monitoring this variable should this experiment be repeated at some future point.

Here is a simpler way to think about this: 2 + 2 = 4, and 4 is not approaching 3 or 5; it is just 4, and it is not drifting in any direction.

OVERVIEW—KRUSKAL-WALLIS TEST

One of the pretest criteria that must be met prior to running an ANOVA states that the data from each group must be normally distributed (Figure 6.9); minor variations in the normal distribution are acceptable. Occasionally, you may encounter data that are substantially skewed (Figure 6.10), bimodal (Figure 6.11), flat (Figure 6.12), or may have some other atypical distribution. In such instances, the Kruskal-Wallis statistic is an appropriate alternative to the ANOVA test.

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Figure 6.9 Normal.

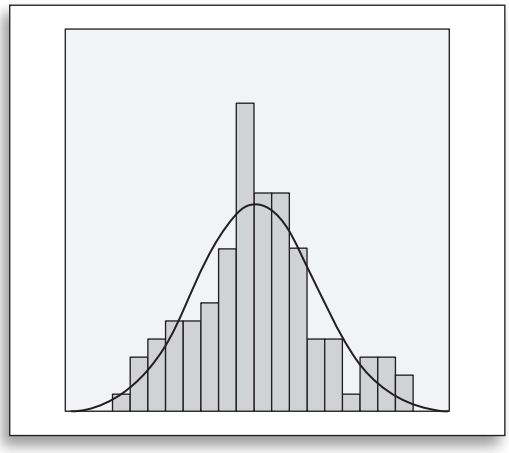


Figure 6.10 Skewed.

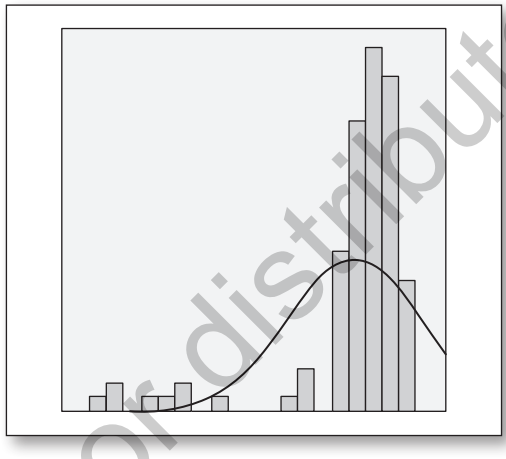


Figure 6.11 Bimodal.

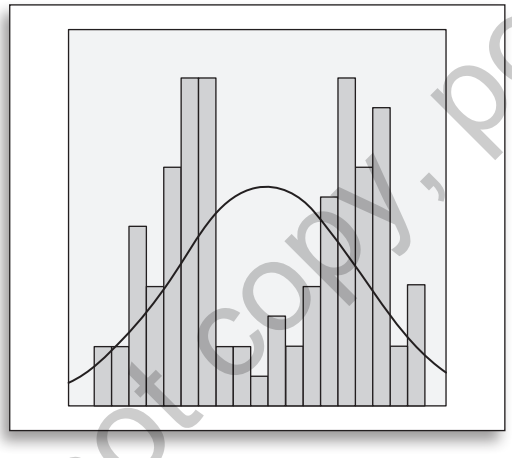
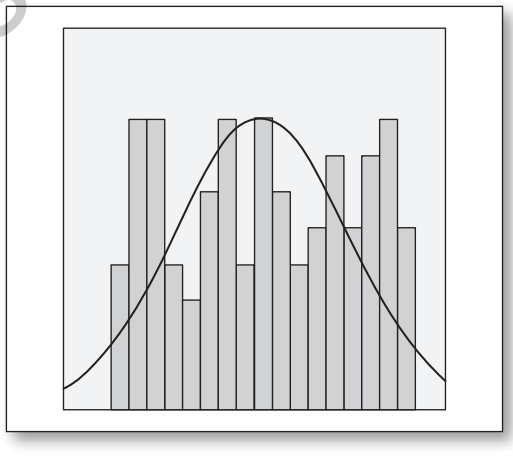


Figure 6.12 Flat.



Test Run

For exemplary purposes, we will run the Kruskal-Wallis test using the same data set (**Ch 06 – Example 01 – ANOVA.sav**) even though the data are normally distributed. This will enable us to compare the results of an ANOVA test to the results produced by the Kruskal-Wallis test.

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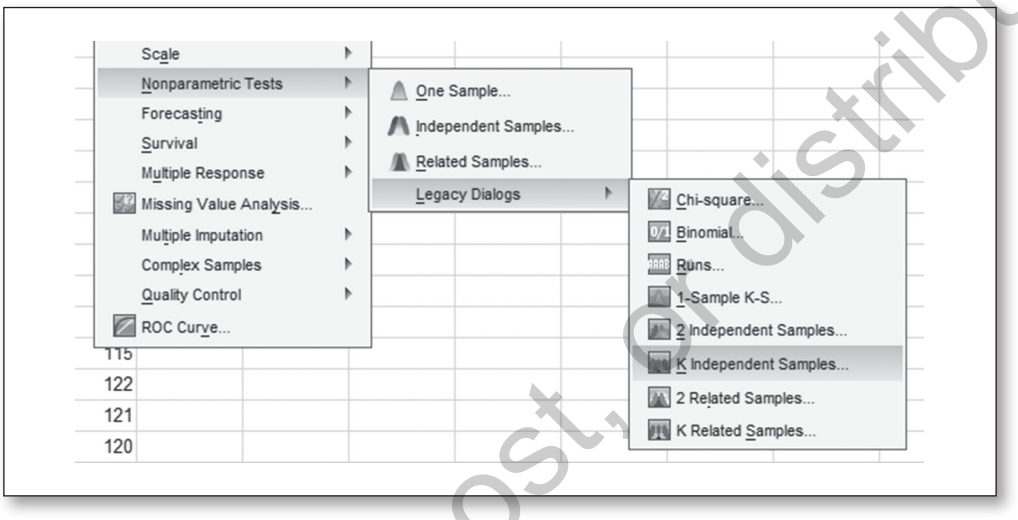
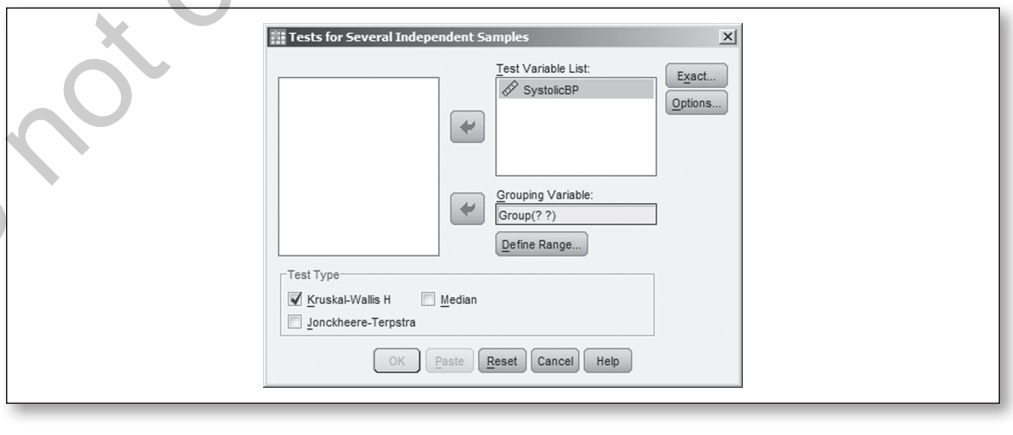
1. On the main screen, click on *Analyze, Nonparametric Tests, Legacy Dialogs, K Independent Samples* (Figure 6.13).

Figure 6.13 Ordering the Kruskal-Wallis test: Click on *Analyze, Nonparametric Tests, Legacy Dialogs, K Independent Samples.*



2. On the *Test for Several Independent Samples* menu, move *SystolicBP* to the *Test Variable List* window.
3. Move *Group* to the *Grouping Variable* box (Figure 6.14).

Figure 6.14 On the *Tests for Several Independent Samples* menu, move *SystolicBP* to *Test Variable List,* and move *Group* to the *Grouping Variable* box.



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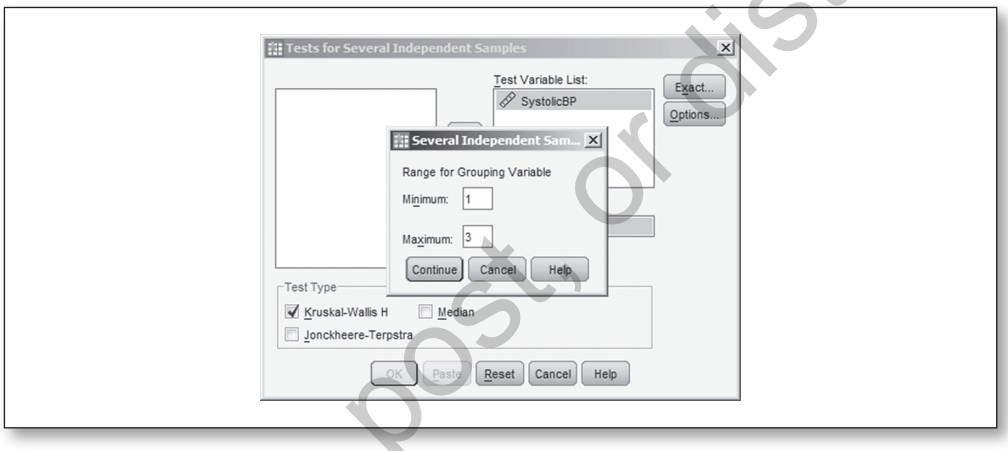
4. Click on *Group(? ?)*, then click on *Define Range*.
5. On the *Several Independent* Samples: Define Range submenu, for *Minimum,* enter *1;* for *Maximum,* enter *3* (since the groups are numbered 1 [for Drug A] through 3 [for Drug C]) (Figure 6.15).
6. Click *Continue;* this will close this submenu.

Figure 6.15 On the *Tests for Several Independent Samples* submenu, for *Minimum,* enter *1;* for *Maximum,* enter *3*.



7. On the *Tests for Several Independent Samples* menu, click on *OK*.

Results

The Kruskal-Wallis result is found in the *Test Statistics* table (Table 6.10); the *Asymp. Sig.* statistic rendered a *p* value of .004; since this is less than α (.05), we would conclude that there is a statistically significant difference (somewhere) among the performances of the three drugs, but we still need to conduct pairwise (post hoc type) analyses to determine which group(s) outperformed which. The ANOVA test provides a variety of post hoc options (e.g., Tukey, Sidak); although the Kruskal-Wallis test does not include a post hoc menu, we can take a few extra steps to

Table 6.10 Kruskal-Wallis *p* Value = .004.

Test Statistics[a,b]

	SystolicBP
Chi-square	10.983
df	2
Asymp. Sig.	.004

a. Kruskal Wallis Test

b. Grouping Variable: Group

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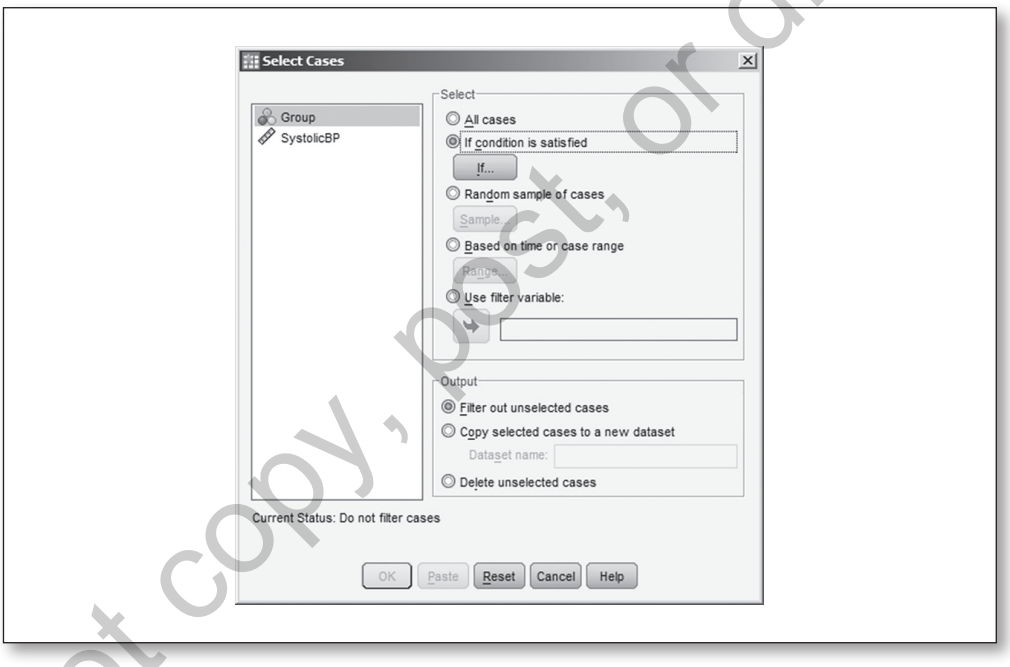
process pairwise comparisons among the groups using the Kruskal-Wallis test. We will accomplish this using the *Select Cases* function to select two groups at a time and run separate Kruskal-Wallis tests for each pair. First, we will select and process Drug A : Drug B, then Drug A : Drug C, and finally Drug B : Drug C.

8. Click on the *Select Cases* icon.

On the *Select Cases* menu, click on ⊙ *If condition is satisfied* (Figure 6.16).

Figure 6.16 On the Select Cases menu, click on ⊙ *If condition is satisfied,* then click on *If*.



9. Click on *If*.
10. On the *Select Cases: If* menu, specify the pair of groups that you want selected (Figure 6.17):
    a. *On the first pass* through this process, enter *Group = 1 OR Group = 2*
    b. *On the second pass,* enter *Group = 1 OR Group = 3*
    c. *On the third pass,* enter *Group = 2 OR Group = 3*

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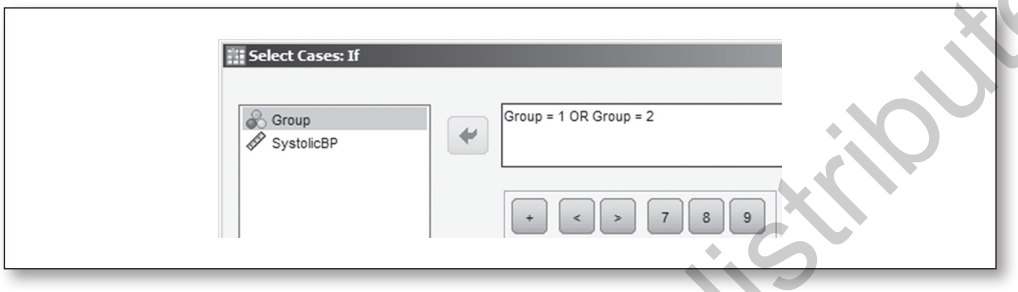
Figure 6.17 On the *Select Cases* menu, click on ⊙ *If condition is satisfied,* then click on *If*.



11. Click *Continue*.
12. Click *OK*.
13. Now that only two groups are selected, run the Kruskal-Wallis procedure from Step 1 and record the *p* value produced by each run; upon gathering these figures, you will be able to assemble a Kruskal-Wallis post hoc table (Table 6.11). NOTE: You can keep using the parameters specified from the previous run(s).

To finalize this discussion, consider Table 6.12, which shows the *p* values produced by the ANOVA Tukey post hoc test compared alongside the *p* values produced by the Kruskal-Wallis test.

In addition to noting the differences in the pairwise *p* values (Table 6.12), remember that the ANOVA test produced an initial *p* value of .003 (which we read before the paired post hoc tests), whereas the Kruskal-Wallis produced an initial (overall) *p* value of .004. The differences in these *p* values are due to the internal transformations that the Kruskal-Wallis test conducts on the data. If one or more substantial violations are detected when running the pretest checklist for the ANOVA, then the Kruskal-Wallis test is considered a viable alternative.

Table 6.11 Pairwise *p* Values for the Kruskal-Wallis Test (Manually Assembled).

Groups	p
Drug A : Drug B	.011*
Drug A : Drug C	.002*
Drug B : Drug C	.494

*Statistically significant difference detected between groups ($p \leq .05$).

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Table 6.12 *Pairwise p Values for Kruskal-Wallis and ANOVA Post Hoc Table (Manually Assembled).*

Groups	Kruskal-Wallis *p*	ANOVA *p*
Drug A : Drug B	.011*	.019*
Drug A : Drug C	.002*	.005*
Drug B : Drug C	.494	.891

*Statistically significant difference detected between groups ($p \leq .05$).

GOOD COMMON SENSE

When carrying the results of an ANOVA test into the real world, there are some practical considerations to take into account. Using this example, suppose the goal for this study was to identify a drug that would effectively reduce moderate hypertension to a systolic level of under 125 mmHg. While the findings of the ANOVA may be interesting, clearly, all three of the drugs would be considered suitable as they all met the specified criteria of reducing the systolic pressure to under 125 mmHg, and hence the *p* values of this test become less relevant.

Considering that the range of the three means (minimum = 120.57, maximum = 122.70) is (only) 2.13, it is plausible to dismiss this relatively minor difference in light of other real-world factors when it comes to selecting among these three drugs, such as dosage protocol (one pill a day vs. multiple dosages per day), side effects, adverse interaction(s), cost, availability, covered/not covered by insurance, and so on.

Another issue involves the capacity of the ANOVA model. Table 6.8 and the combinations formula (**Unique pairs = G! ÷ (2 × (G − 2)!)**) reveal that as more groups are included, the number of ANOVA post hoc paired comparisons increases substantially. A 5-group design would render 10 unique comparisons, 6 groups would render 15, and a 10-group design would render 45 unique comparisons along with their corresponding *p* values. While SPSS or any statistical software would have no problem processing these figures, there would be some real-world challenges to address: Consider the pretest criteria—in order for the results of an ANOVA test to be considered robust, there should be a minimum *n* of 30 per group. Hence, for a design involving 10 groups, this would require an overall *n* of at least 300. Furthermore, a 10-group study would render 45 unique pairwise comparisons in the ANOVA post hoc table, which, depending on the nature of the data, may be a bit unwieldy when it comes to interpretation, documentation, and overall comprehension of the results.

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Key Concepts

- ANOVA
- Pretest checklist
  - Normality
  - Homogeneity of variance
  - *n*
- Post hoc tests
  - Tukey
  - Sidak
- Hypothesis resolution
- Documenting results
- Kruskal-Wallis test
- Good common sense

Practice Exercises

NOTE: These practice exercises and data sets are the same as those in **Chapter 5 – *t* Test** except instead of the two-group designs, a third group has been included to enable ANOVA processing, except for Exercises 9 and 10, which now involve four groups.

Exercise 6.1

You want to determine if meditation can reduce resting pulse rate. Participants were recruited and randomly assigned to one of three groups: Members of Group 1 (the control group) will not meditate; members of Group 2 (the first treatment group) will meditate for 30 minutes per day on Mondays, Wednesdays, and Fridays over the course of 2 weeks; and members of Group 3 (the second treatment group) will meditate for 30 minutes a day 6 days a week, Monday through Saturday. At the end, you gathered the resting pulse rates for each participant.

Data set: **Ch 06 – Exercise 01A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = No meditation, 2 = Meditates 3 days, 3 = Meditates 6 days)
Variable:	Pulse
Definition:	Pulse rate (beats per minute)
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

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d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using data set: **Ch 06 – Exercise 01B.sav.**

Exercise 6.2

You want to determine the optimal preceptor-to-nurse ratio. Nurses will be randomly assigned to one of three groups: Group 1 will involve each preceptor working with only one nurse; in Group 2, each preceptor will work with two nurses; and in Group 3, each preceptor will work with five nurses. At the end of each shift, patients will be asked to complete the Acme Nursing Satisfaction Survey, which renders a score from 0 to 100.

Data set: **Ch 06 – Exercise 02A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = One-to-one, 2 = Two-to-one, 3 = Five-to-one)
Variable:	ANSS
Definition:	Acme Nursing Satisfaction Survey score (0–100)
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 02B.sav.**

Exercise 6.3

Clinicians at a nursing home facility want to see if giving residents a plant to tend to will help lower depression. To test this idea, the residents are randomly assigned to one of three groups: Those assigned to Group 1 will serve as the control group and will not be given a plant. Members of Group 2 will be given a small bamboo plant along with a card detailing care instructions. Members of Group 3 will be given a small cactus along with a card detailing care instructions. After 90 days, all participants will complete the Acme Depression Scale, which renders a score between 1 and 100 (1 = Low depression . . . 100 = High depression).

Data set: **Ch 06 – Exercise 03A.sav**

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Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = No plant, 2 = Bamboo, 3 = Cactus)
Variable:	Depress
Definition:	Acme Depression Scale (1 = Low depression . . . 100 = High depression)
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 03B.sav.**

Exercise 6.4

You want to determine if chocolate enhances mood. Subjects will be recruited and randomly assigned to one of three groups: Those in Group 1 will be the control group and will eat their regular diet. Those in Group 2 will eat their usual meals and have a piece of chocolate at breakfast, lunch, and dinner over the course of a week. Those in Group 3 will eat their meals as usual and have two pieces of chocolate at breakfast, lunch, and dinner over the course of a week. At the end of the week, all participants will complete the Acme Mood Scale (1 = Extremely bad mood . . . 100 = Extremely good mood).

Data set: **Ch 06 – Exercise 04A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = No chocolate, 2 = Chocolate [1 per meal], 3 = Chocolate [2 per meal])
Variable:	Mood
Definition:	Acme Mood Scale score (1–100)
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

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c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 04B.sav.**

Exercise 6.5

During flu season, the administrators at a walk-in health clinic want to determine if providing patients with a pamphlet or a video will increase their receptivity to flu shots. Each patient will be given a ticket at the check-in desk with a 1, 2, or 3 on it; the tickets will be issued in (repeating) sequence (e.g., 1, 2, 3, 1, 2, 3, etc.). Once escorted to the exam room, patients with a number 1 ticket will serve as control participants and will not be offered any flu shot informational material. Patients with a number 2 ticket will be given a flu shot information pamphlet describing the rationale for the flu shot and flu prevention practices, emphasizing effective hand hygiene. Patients with a number 3 ticket will be shown a brief video covering the same information as contained in the pamphlet. At the end of the day, the charts were reviewed and three entries were made in the database: total number of flu shots given to patients in Group 1, total number of flu shots given to patients in Group 2, and the total number of flu shots given to patients in Group 3.

Data set: **Ch 06 – Exercise 05A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = Nothing, 2 = Flu shot pamphlet, 3 = Flu shot video)
Variable:	Shots
Definition:	Number of flu shots given in a day for each group
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 05B.sav.**

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Exercise 6.6

You want to determine if introducing a video in the waiting area will help relax patients. This study will take place over 3 days: On the first day, Group 1 (the control group) will experience the waiting room as is—with the monitor off; on the second day, Group 2 will have a classic movie playing; and on the third day, Group 3 will have a scenic video playing (e.g., waterfalls, vistas, wildlife). For patients who consent to participating in this research, the nurse will anonymously copy their pulse rate to a journal along with the day number (Group).

Data set: **Ch 06 – Exercise 06A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = Control, 2 = Classic movie, 3 = Scenic video)
Variable:	Pulse
Definition:	Pulse rate (gathered by a pulse oximeter)
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 06B.sav.**

Exercise 6.7

In an effort to determine the effectiveness of light therapy to alleviate depression, you recruit a group of subjects who have been diagnosed with depression. The subjects are randomly assigned to one of three groups: Group 1 will be the control group—members of this group will receive no light therapy. Members of Group 2 will get light therapy for 1 hour on even-numbered days over the course of 1 month. Members of Group 3 will get light therapy every day for 1 hour over the course of 1 month. After 1 month, all participants will complete the Acme Mood Scale, consisting of 10 questions; this instrument renders a score between 1 and 100 (1 = Extremely bad mood . . . 100 = Extremely good mood).

Data set: **Ch 06 – Exercise 07A.sav**

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Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = No light therapy, 2 = Light therapy: even days, 3 = Light therapy: every day)
Variable:	Mood
Definition:	Acme Mood Scale (1 = Extremely bad mood . . . 100 = Extremely good mood)
Type:	Continuous

a. Write the hypotheses.

b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.

c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).

d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 07B.sav.**

Exercise 6.8

It is thought that exercising early in the morning will provide better energy throughout the day. To test this idea, subjects are recruited and randomly assigned to one of three groups: Members of Group 1 will constitute the control group and not be assigned any walking. Members of Group 2 will walk from 7:00 to 7:30 a.m., Monday through Friday, over the course of 30 days. Members of Group 3 will walk from 7:00 to 8:00 a.m., Monday through Friday, over the course of 30 days. At the conclusion of the study, each participant will answer the 10 questions on the Acme End-of-the-Day Energy Scale. This instrument produces a score between 1 and 100 (1 = Extremely low energy . . . 100 = Extremely high energy).

Data set: **Ch 06 – Exercise 08A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = No walking, 2 = Walking: 30 Minutes, 3 = Walking: 60 minutes)
Variable:	Mood
Definition:	Acme End-of-the-Day Energy Scale (1 = Extremely low energy . . . 100 = Extremely high energy)
Type:	Continuous

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a. Write the hypotheses.
b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.
c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).
d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 08B.sav.**

NOTE: Exercises 9 and 10 involve four groups each.

Exercise 6.9

In order to determine the best method for facilitating smoking cessation, patients who smoke two packs per day (40 cigarettes) are recruited and randomly assigned to one of four psychoeducational peer support groups with a qualified facilitator: Group 1 will meet once a week in an in-person setting, Group 2 will meet once a week via Internet videoconferencing, Group 3 will meet twice a week in-person, and Group 4 will meet twice a week via videoconferences. After 10 weeks, each participant will be asked how many cigarettes he or she smokes per day.

Data set: **Ch 06 – Exercise 09A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = 1 meeting in-person, 2 = 1 meeting videoconference, 3 = 2 meetings in-person, 4 = 2 meetings videoconference)
Variable:	Smoking
Definition:	Number of cigarettes each participant smokes per day after 10 weeks
Type:	Continuous

a. Write the hypotheses.
b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.
c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).
d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 09B.sav.**

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Exercise 6.10

Due to numerous complications involving missed medication dosages, you implement a study to determine the best strategy for enhancing medication adherence. Patients who are on a daily medication regime will be recruited, receive a complimentary 1-month dosage of their regular medication(s), and randomly be assigned to one of four groups: Group 1 will serve as the control group (no treatment); Group 2 will participate in a 1-hour in-person nurse-administered medication adherence workshop; Group 3 will receive text message reminders (e.g., "It's time to take one tablet of Drug A"); Group 4 will attend the medication adherence workshop and also receive text messages. At the end of 1 month, participants will present their prescription bottle(s); the nurse will count the remaining pills and calculate the dosage adherence percentage (e.g., 0 pills remaining = 100% adherence).

Data set: **Ch 06 – Exercise 10A.sav**

Codebook

Variable:	Group
Definition:	Group number
Type:	Categorical (1 = Control, 2 = Rx workshop, 3 = Texts, 4 = Rx workshop and texts)
Variable:	RxAdhere
Definition:	Percentage of medication adherence (0–100)
Type:	Continuous

a. Write the hypotheses.
b. Run each criterion of the pretest checklist (normality, homogeneity of variance, and *n*) and discuss your findings.
c. Run the ANOVA test and document your findings (*n*s, means, and Sig. [*p* value], hypotheses resolution).
d. Write an abstract under 200 words detailing a summary of the study, the ANOVA test results, hypothesis resolution, and implications of your findings.

Repeat this exercise using **Ch 06 – Exercise 10B.sav.**

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