SPSS for Windows

Versions 20.0 for (Windows 7)
A Survival Guide
For EPRS 8530 and EPRS 8540

Edition 5 ***(Version 1.0)***

December 2014

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Foreword

The purpose of this guidebook is to help you achieve the course objectives for either Quantitative Methods I and/or Quantitative Methods II: (1) to gain understanding of the various statistical techniques for analysis with descriptive statistics, (2) to gain conceptual understanding of the various techniques for determining the significance of group differences, (3) to use statistical software to run the analyses, and (4) to interpret and report the results according to the style used in research journals.

With these objectives in mind, you will be assigned a variety of computer homework problems to complete for course credit. This guidebook provides a working example for each type of statistical analysis to help you get started with each assignment. The section of this guidebook that addresses statistical analysis problems contains:

1. Procedures decision model (algorithm) for inferential statistical examples
2. An example of research problems with necessary data
3. A guide to SPSS for Windows Versions 20.0, with explanatory notes and tips
4. Selected portions of the SPSS printout with commentary
5. An example of how to report results and provide discussion

These example problems are basic and intended only as a guide. The steps you take to do an analysis on your own particular problem may vary slightly based upon your data and the outcome of your analysis. You will also be expected to go beyond the examples in your own work. To accomplish this, you will need to attend class regularly, study your text carefully, and complete the recommended non-graded problems assigned from the text.

Do ***NOT*** ignore the many notes explaining many of the finer points in the example to follow. Unlike many explanatory notes you may have encountered in the past, these notes are vitally important to your understanding of how to correctly use SPSS. ***Ignore them at your own peril.***

When you have completed the course, this guidebook should also serve as a ready procedure reference for your future work in your chosen field.

It is our hope this guidebook will help you complete your assignments with confidence, increase your learning, and make your statistics course more enjoyable.

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ABOUT THIS GUIDEBOOK

This guidebook was developed specifically for students taking statistical courses in the Educational Policy Studies department of the College of Education at Georgia State University. Anyone conducting research analysis and new to using SPSS for Windows 7 may find this guide helpful.

This guide is organized into three sections. First, the basic operation of SPSS in the Windows 7 environment is addressed followed by examples of various statistical analyses using the package. The inferential statistical example problems used are exactly the same as those presented in Student Guidebook for SAS™ users developed by Gary L. May and T. Chris Oshima. Some students find a comparison of the several software products helpful as multiple terms are used by different vendor products to refer to inferential data. The final section addresses more advanced tips and tricks that can be used to take full advantage of SPSS for Windows, Versions 20.0. The guide also contains references to common questions and trouble areas which students have encountered in the past.

Every effort has been made to ensure this guidebook is free from errors. If you should find any mistakes within this guide, please contact either Tianna Floyd (tfloyd6@student.gsu.edu) or Dr. Chris Oshima (oshima@gsu.edu) so that corrections can be made to the material.

Certain assumptions were made in the writing for this guidebook. For example, it is assumed you accepted the installation program default values when placing SPSS for Windows Version 20.0 on your computer. If this is not the case, you will need to consider how you modified the default installation when reading this guidebook. Secondly, this guide was composed specifically with the Windows 7 operating systems in mind. You should already possess a basic knowledge of Windows navigation techniques in order to successfully use the SPSS product. You may find that a more advanced knowledge of Windows navigation is required to perform some of the tasks discussed in the “Tips and Tricks” section of this guide.

As the guidebook progresses from one problem type to another, certain levels of detail, such as each window concerning data entry, are omitted due to space limitations. A cumulative working knowledge of SPSS is assumed as the guidebook progresses.

Getting Started with SPSS™ for Windows 7

Versions 20.0

Getting Started
With SPSS for Windows
Versions 20.0

Introduction

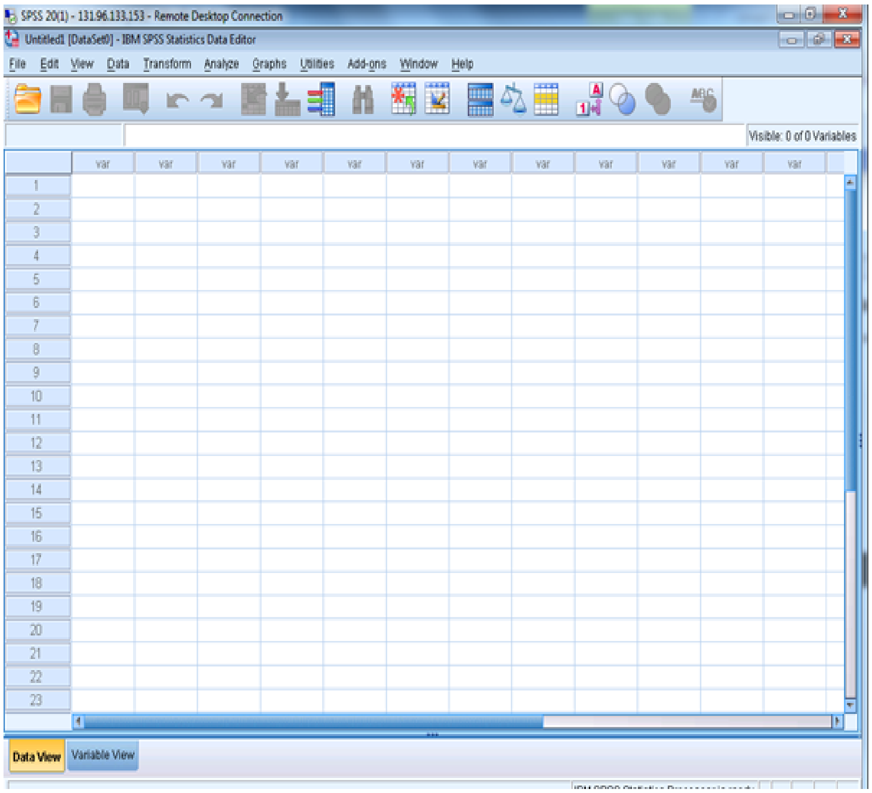
SPSS for Windows, Version 20.0, is a powerful Microsoft Windows compliant package that allows easy statistical analysis of data. Additionally, Version 20.0 addresses many of the shortcomings noted in earlier versions of SPSS to provide many improved functions including enhanced paper management and charting capabilities. Becoming familiar with the package and its default operation prior to starting actual analysis can save the student many hours of time and a great degree of frustration. As a minimum, it is recommended that the user complete the SPSS "Tutorial" and completely familiarize him or herself with SPSS 's capabilities. The purpose of the ***Getting Started*** section of this manual is to explain the basic operation of this software package and to make suggestions that will ease the burden of becoming familiar with the operation of SPSS.

This section is divided into the following areas:

1. A few words on the use of Microsoft Windows
2. Initial software interface presentation
3. Explanation of a matrix concept of entering data for analysis
4. A more in-depth look at several of the data entry / results windows used by SPSS
5. Concluding remarks

Use of Microsoft Windows

This manual is written with the assumption the user has a basic understanding of how to navigate in a Microsoft Windows 7 environment. It is strongly recommended that you become familiar with Windows 7 prior to use of SPSS, Version 20.0. Many one or two day courses regarding Windows 7 are available through commercial vendors or through local universities. Use of SPSS, Version 20.0 without a basic understanding of the Windows 7 environment will prove more difficult, time consuming, and may prove very frustrating



SPSS starts with an Untitled - SPSS Data Editor window. The Data Editor provides most of the controls (menu and button selections) you will use to enter and manipulate data as you perform statistical analyses.

Notice also that across the top of the window is a row of ‘cells’ labeled ‘var’ in grayed out lettering while down the left side of the window is a series of numbers beginning with ‘1’ and subsequently incremented by ‘1’. The row across the top is used to name data variables while the column on the left hand side of the window represents the ‘case’ number. Case is the term used in SPSS to identify the observation number of the record within the data set to be analyzed.

A second window called ‘Output’ will be displayed once you begin performing operations with SPSS. This is where you will be able to see the results of your analyses and to determine if you wish to perform additional analyses or otherwise manipulate your data. SPSS automatically brings the ‘Output’ window to the fore-ground when all execution of an analysis is complete.

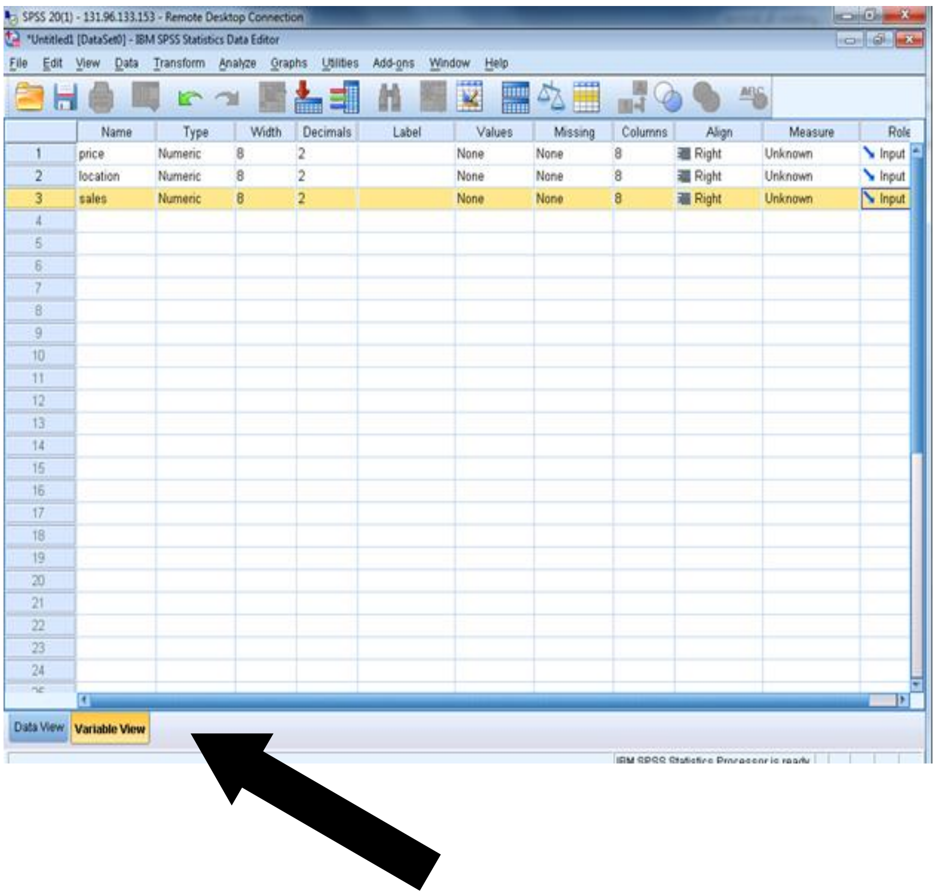
A third window, known as the ‘SPSS Syntax’ window, may also be present when requested or during certain steps of your analyses. The syntax window is only mentioned at this point and will be covered in more depth during specific example problems and in the Advanced Tips and Tricks section of the guidebook. The utility of this method of data entry, while possibly not apparent at this time, will become more visible as you progress in the analysis of your various data sets.

A More In-Depth Look at SPSS Data Entry and Results Windows

Now that you have a concept of how to initialize SPSS for use and a conceptual framework for the entry of data to be analyzed, a more in-depth look at variable definition will prove useful

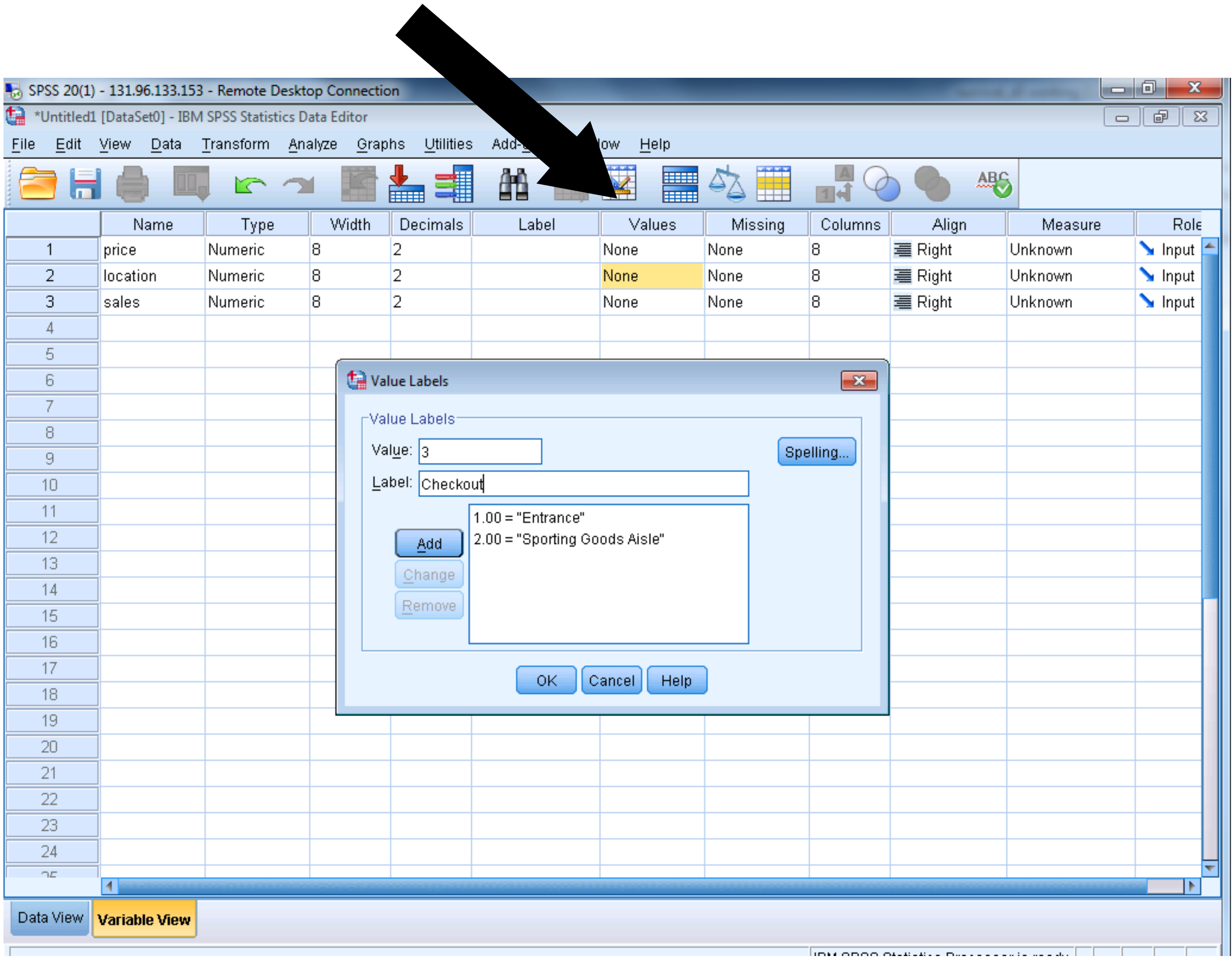
Data Entry Window

The data variables represented in the problem analysis must be defined for SPSS. This is done as follows:

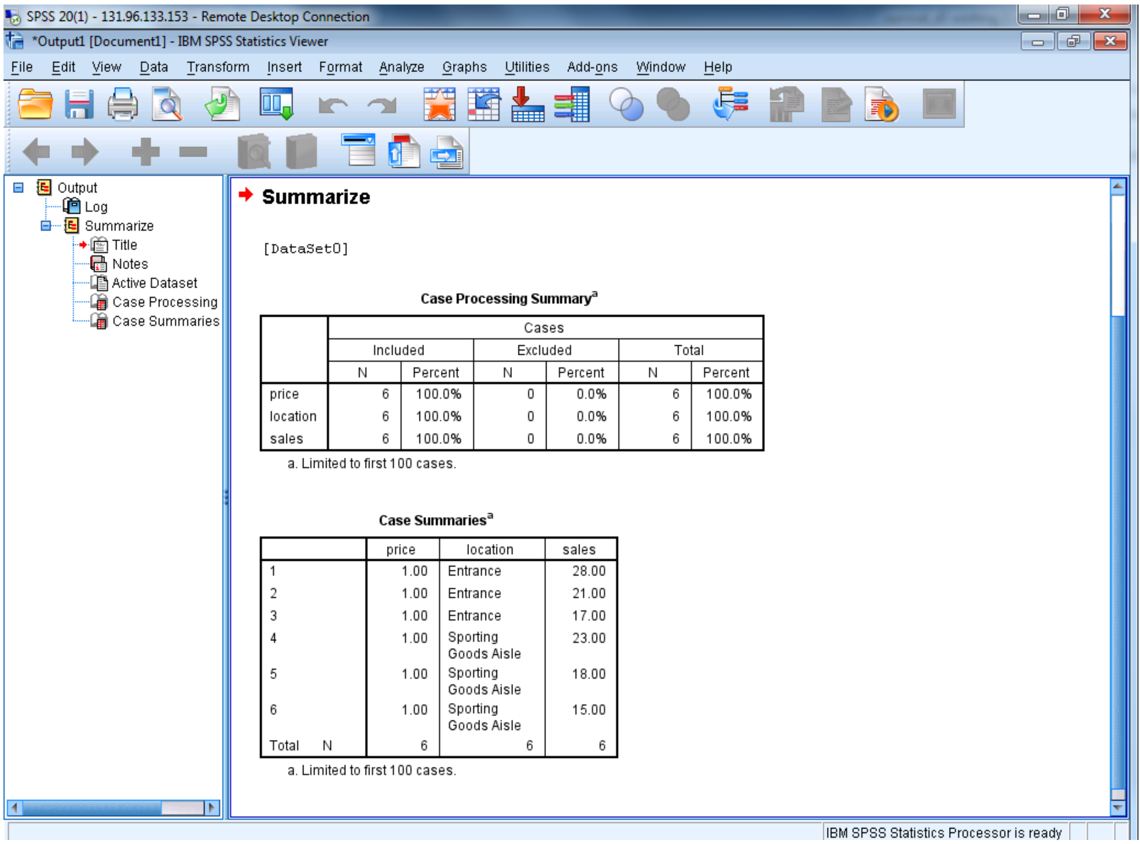


Data variables are defined by clicking on the 'Variable View' tab below. This view can also be activated by double clicking on the grayed 'var' column heading illustrated earlier.

From the 'Variable View' screen, SPSS allow you to create and edit all of the variables in your data file. Each column represents some property of a variable, and each row represents a variable. All variables must be given a name. Just click on the first empty cell in the Name column and type in a name. Perform these same steps for the other variables.



Many users find it imperative to have assigned labels for the various values of a data variable. This allows you the ability to associate a description with variables. Furthermore, these descriptions can describe the variables themselves or the values of the variables. Click the cell you want to assign values to on the 'Values' column. You will see a small gray box Click this box and this will bring up the 'Value Labels' box. In this box you will type in a value, such as 1 with a label of Entrance, and click add. Continue this process for as many values required for your variable. In the measure column, make sure you select the appropriate measurement type for each variable either scale (interval or ratio), ordinal or nominal.



Output Window

All results generated as results of running analyses are automatically sent to the 'Output' SPSS Output Navigator' window.

In Conclusion

Always remember to save your data using the 'SAVE' option listed under the 'FILE' menu selection on the SPSS Menu Bar. If your data is particularly important, you should also consider maintaining a second copy of the data and your SPSS syntax using the 'SAVE AS' option. While not necessary for the problems you will be doing in this course, keep in mind the American Psychological Association suggests research data be saved a minimum of five years. Considering the lead time regarding research article submission, editing, acceptance, and publication, many professionals recommend saving your data and program for seven years. Additional information regarding the use of the various SPSS windows is presented in the Advanced Tips and Tricks section at the end of this guidebook.

Descriptive Statistics

Measures of Central Tendency

Measures of Variation

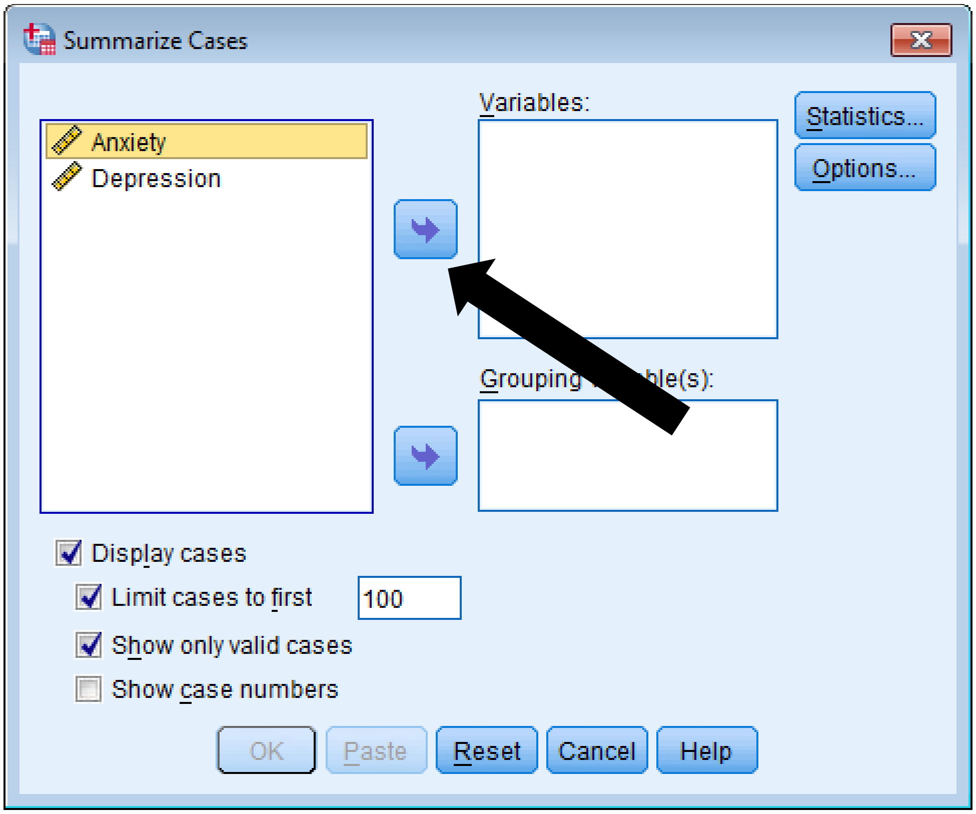
Correlation

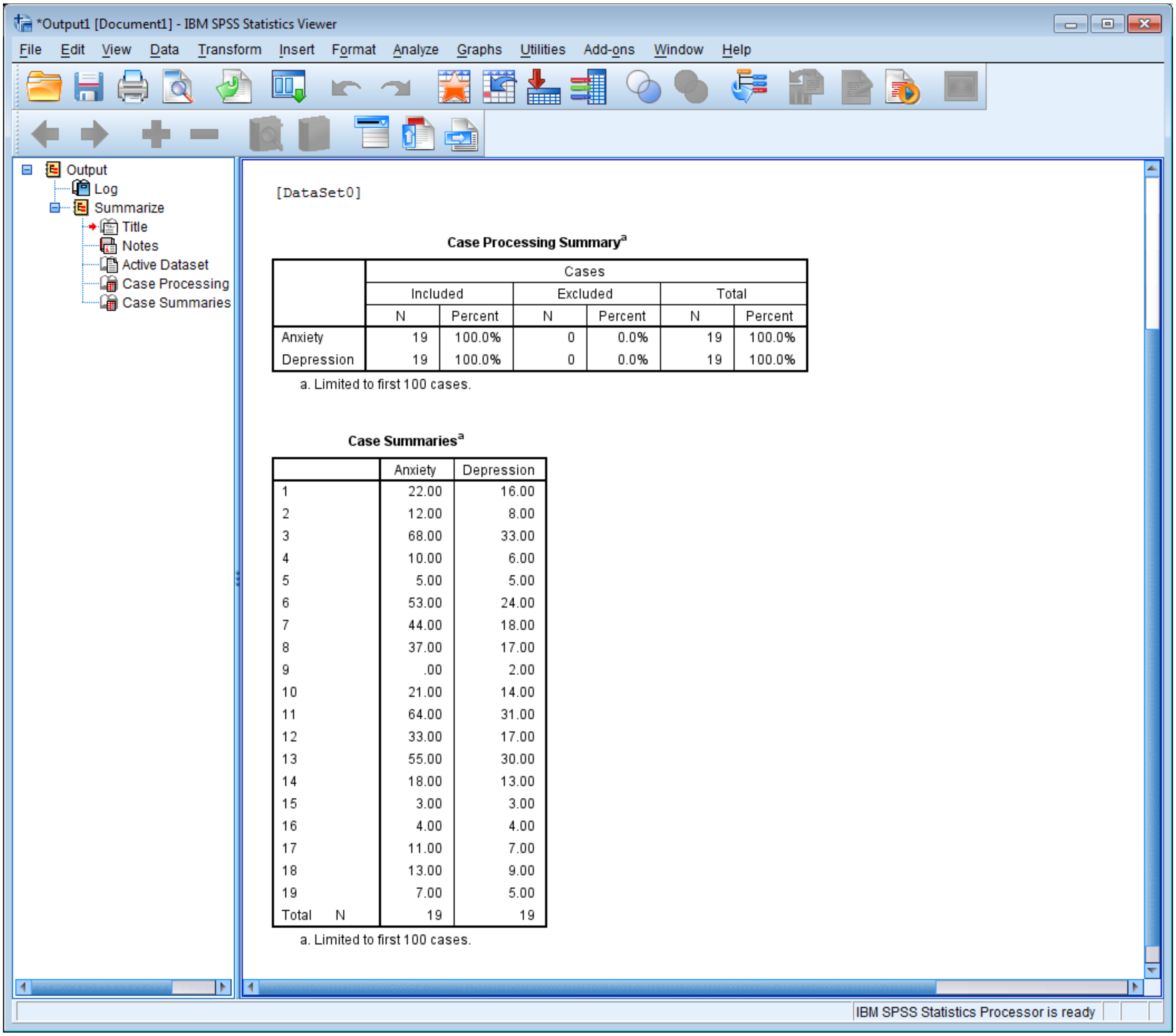
Descriptive Statistics
Example Problem

A counselor working with a group of caregivers of patients living with a terminal illness is interested in forming a support group to share experiences and therefore reduce the sense of isolation often associated with catastrophic illness. The counselor, working with hospital staff, administers a depression and anxiety inventory to each caregiver that has volunteered for the program. The counselor feels that knowing the levels of depression and anxiety within the group will help in the design of an effective intervention program. The scores obtained from the administration of the two inventories are given below.

Individual	Anxiety Score	Depression Score
1	22	16
2	12	8
3	68	33
4	10	6
5	5	5
6	53	24
7	44	18
8	37	17
9	0	2
10	21	14
11	64	31
12	33	17
13	55	30
14	18	13
15	3	3
16	4	4
17	11	7
18	13	9
19	7	5

First we need to enter the data. Please refer to the introduction section to see how to enter the numbers. You should always verify the accuracy of your data entry. The most obvious method to do so is to review your data in the 'Data Editor' window. You can also obtain a list of all of your data by clicking on the command sequence 'Analyze', 'Reports', and 'Case Summaries…' in the main SPSS menu. Click on the right pointing arrow located between the two text boxes to move the variables to the 'Variables' text box Click 'OK' to instruct SPSS to create a summary list of cases.





Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Anxiety	19	100.0%	0	0.0%	19	100.0%
Depression	19	100.0%	0	0.0%	19	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

		Anxiety	Depression
1		22.00	16.00
2		12.00	8.00
3		68.00	33.00
4		10.00	6.00
5		5.00	5.00
6		53.00	24.00
7		44.00	18.00
8		37.00	17.00
9		.00	2.00
10		21.00	14.00
11		64.00	31.00
12		33.00	17.00
13		55.00	30.00
14		18.00	13.00
15		3.00	3.00
16		4.00	4.00
17		11.00	7.00
18		13.00	9.00
19		7.00	5.00
Total	N	19	19

a. Limited to first 100 cases.

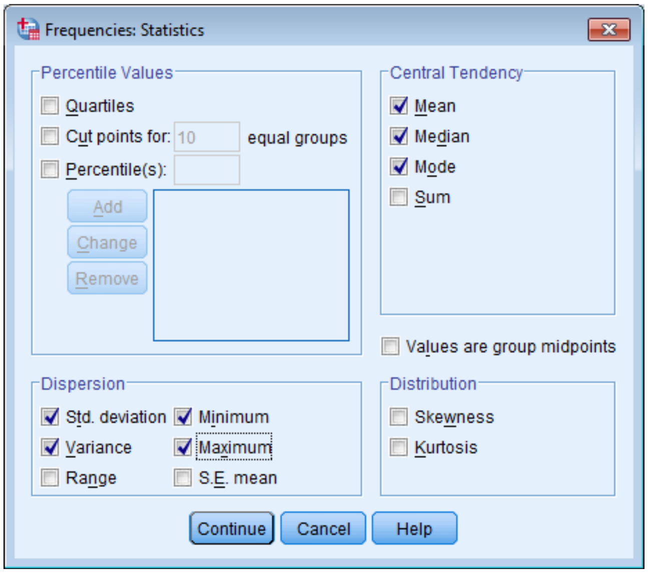
The results are automatically displayed in the 'Output 1 - SPSS Output Navigator' window.

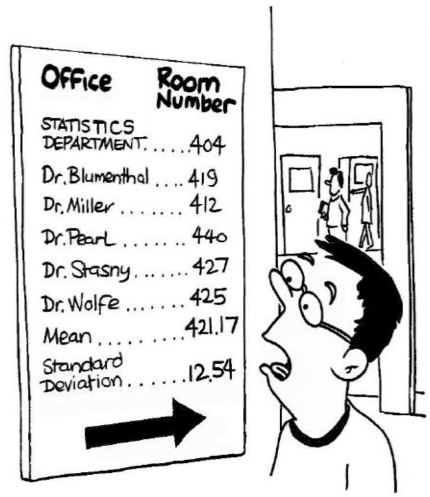
Now we will instruct SPSS to calculate frequency distribution(s), measures of central tendency, and measures of dispersion.

Using the mouse pointer, highlight 'Analyze', 'Descriptive Statistics', and 'Frequencies' starting from the menu selection on the SPSS main menu.

Using the same techniques previously discussed to highlight and move variables from one text box to another, move the variables to the 'Variable(s)' text box. Ensure the 'Display frequency tables' check box is checked. Using the mouse pointer, click on the 'Statistics' button.

The 'Frequencies: Statistics' window will be displayed. Click on the box to the left each measure of central tendency and each measure of dispersion to be calculated. Click on 'Continue' to proceed. The 'Frequencies' window will be redisplayed. Click on 'OK' to continue. The results of the analyses will be automatically displayed in the 'SPSS Output Navigator' window.





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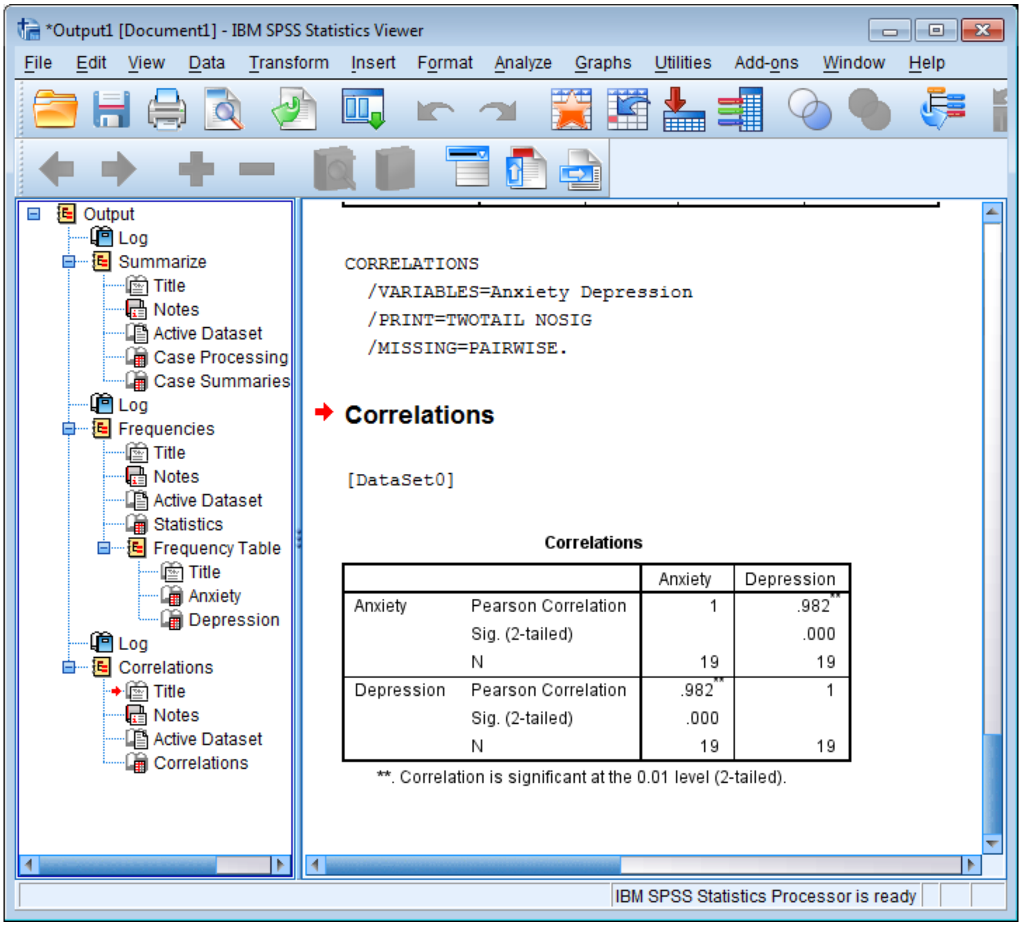
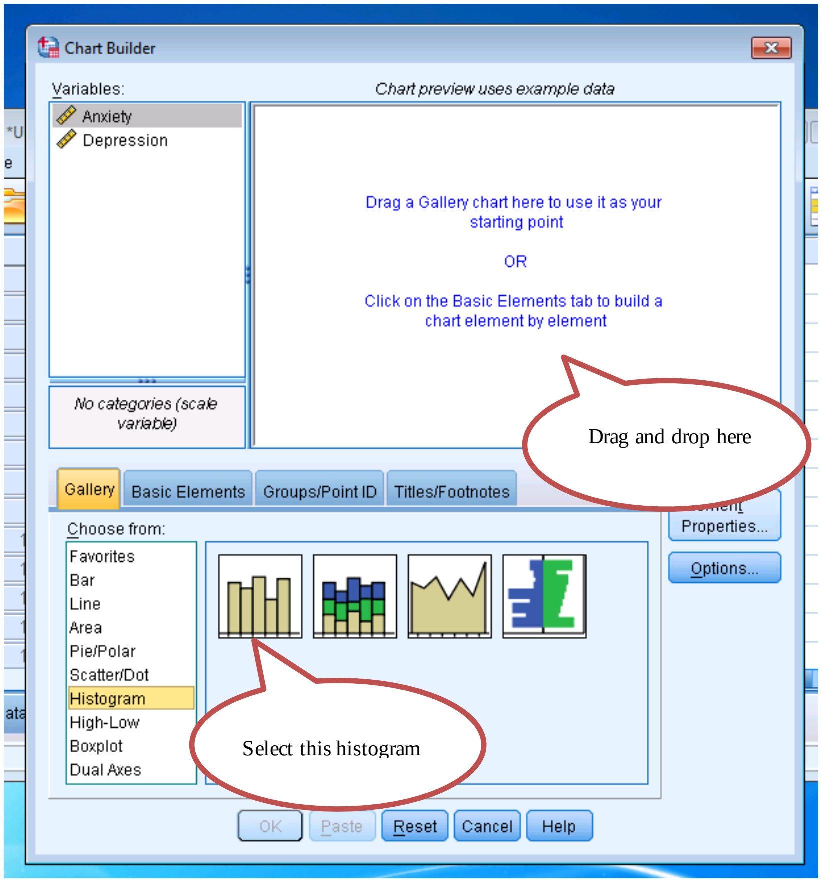
We can also have SPSS calculate the correlation between two variables. From the SPSS for Windows main dialog, choose 'Analyze', 'Correlate' and 'Bivariate'. The 'Bivariate Correlations' window will be displayed. Using the mouse pointer, highlight both variables, 'Anxiety' and 'Depression', and click on the right pointing arrow to move the variable to the 'Variables' text box. Click on the type of correlation coefficient you wish to produce. The default correlation coefficient is the Pearson Correlation Coefficient. After moving the variables to the 'Variables' text box, click on 'OK' to continue. The results of the correlation analysis will be automatically displayed in the 'SPSS Output Navigator' window.



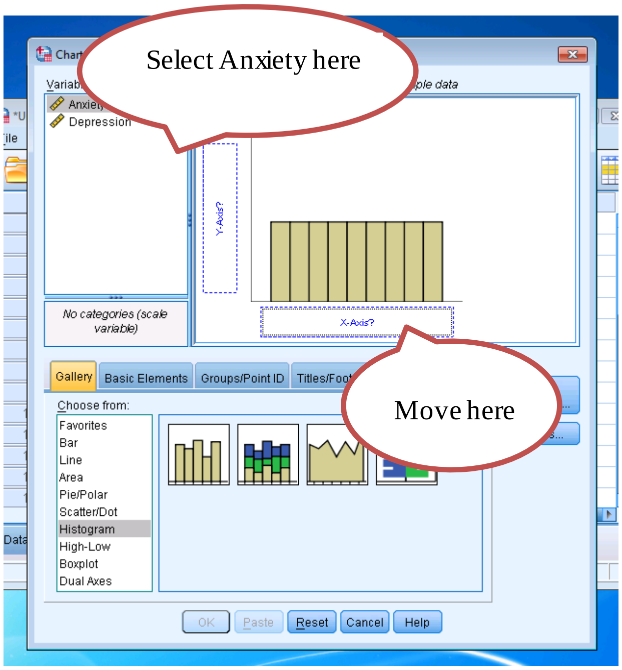
The output that is given is in the form of a data matrix. For every possible combination of variables (anxiety, anxiety; anxiety, depression; depression, anxiety; and depression, depression) the correlation coefficient, the number of cases used to perform the correlation, and the 'p' value are given. As you might expect, a variable is perfectly correlated with itself which is indicated by the correlation coefficient of 1. This output shows the correlation between anxiety and depression is r = .98.

SPSS Procedures for Graphing

Making graphs is a bit easier in the newer versions of SPSS. Procedures for producing a histogram and scatterplot, are outlined below.

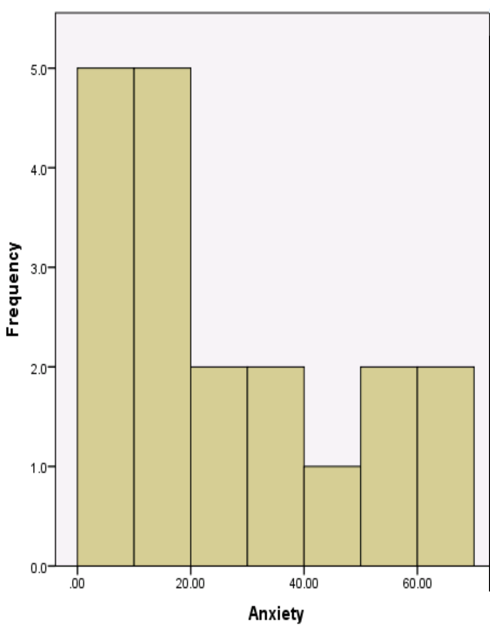


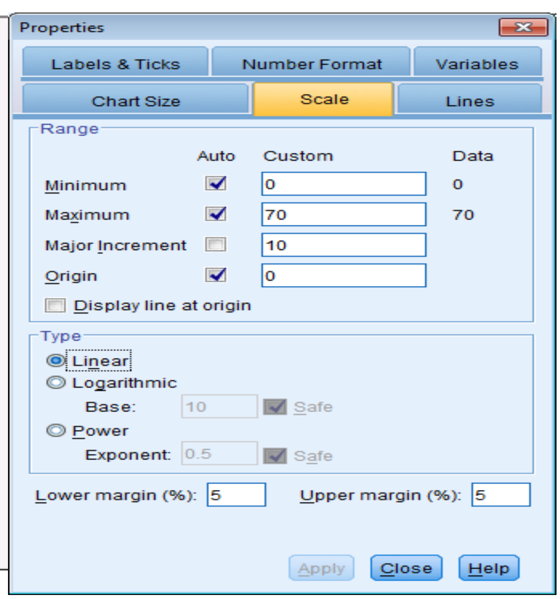
To make a Histogram, from the SPSS for Windows main dialog, choose ‘Graphs’, ‘Chart Builder’. SPSS might give you a warning to remind you that you need to set the correct measurement level for each variable. You can select ‘Define Variable Properties’ to make sure variables are identified correctly or you can select ‘OK” to proceed. Now the chart builder window will appear. You will need to select histogram from the list of available graph types in the left hand side. You will click on the histogram that is on the far left and drag and drop it to the chart preview area.

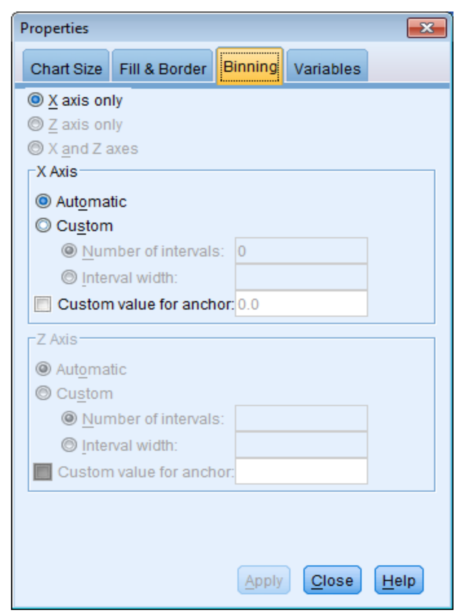


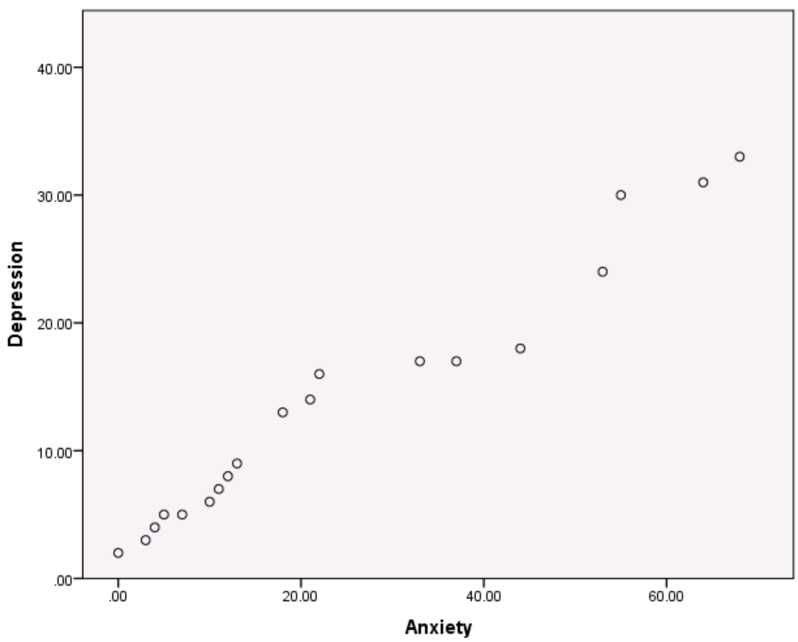
Now we need to format the graph. The 'Element Properties' menu will appear. We will exit out of that for now. We would like our histogram to show the frequency information for anxiety levels. We will drag and drop anxiety from the variables window to the x axis. Select 'OK' and the histogram will be shown in the output window

Now double click on the graph in the output window. This will open up the "Chart Editor". In this window we can modify the graph. In order to change the X-axis, go to 'Edit', "Select X axis". A new window will open and you can click on the 'Scale' tab. Here we can change the scale of the X axis. We want to change the major increments to 10. If we want to change the bin size, first click on one of the bins in the chart editor window, go to 'Edit', 'Properties' and click on the 'Binning' tab. This will give options to customize the bins by either specifying the number of intervals or the bin size

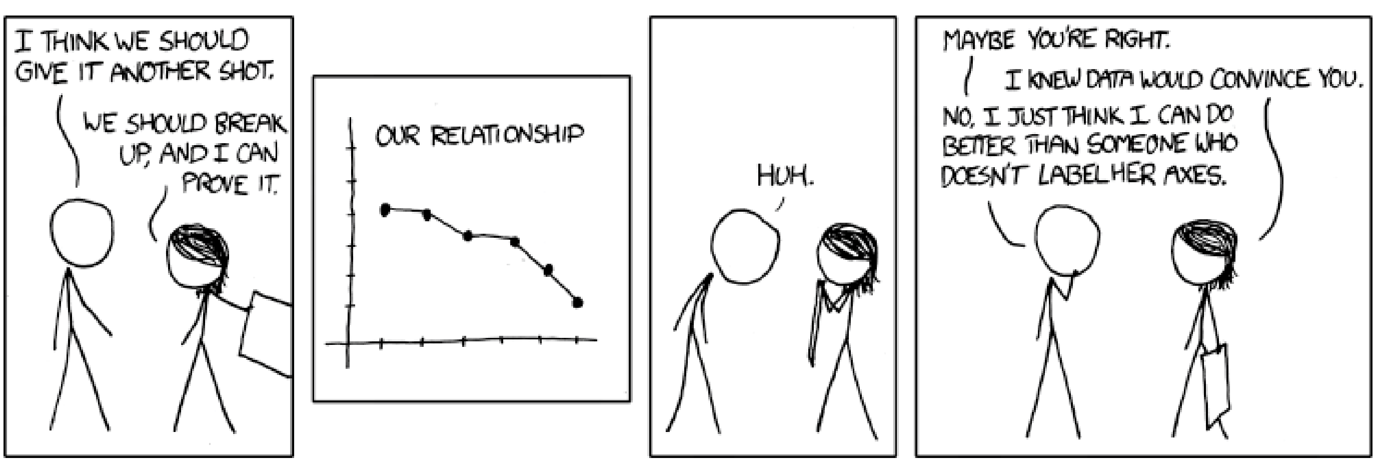








Creating a scatter plot is very similar. Go to "Graphs", "Chart Builder". The same histogram might be in the chart preview menu which is OK because we will replace it. On the left hand side select 'Scatter/Dot' and drag and drop the first scatter/dot plot into the window. We will place Anxiety on the X- axis and Depression in the Y-Axis. Select 'OK' and the graph will come out in the output window.



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Example Reporting of Results
Results

Table 1 presents the mean, median, mode, minimum and maximum scores, and standard deviations for anxiety and depression scores administered to caregivers of terminally ill individuals. Comparison of the mean, median, and mode indicates the distribution of anxiety and depression are both somewhat positively skewed. The mean for anxiety and depression are both affected by a small number of high scores suggesting the median may be a more reflective measure of central tendency. The standard deviation and range of values for both variables indicate a wide dispersion among scores of individuals.

A histogram of the anxiety frequency distribution is depicted in Figure 1. This identifies the number of individuals falling into the levels of anxiety.

A Person's coefficient of correlation was calculated between the variables of anxiety and depression. The high positive correlation, $r(17) = .98$, $p < .001$, indicates the greater an individual's level of depression, the greater the expected level of anxiety and vice versa. Figure 2 presents a scatterplot of the correlation.

Table 1

Mean, Median, Mode, Minimum and Maximum Scores, and Standard Deviations for Anxiety and Depression Scores

Variable	Sample Size	Minimum	Maximum	Mean	Median	Mode	Standard Deviation
Anxiety	19	0.00	68.00	25.26	18.00	N/A*	21.99
Depression	19	2.00	33.0	13.79	13.00	5,17	9.85

* Not Applicable

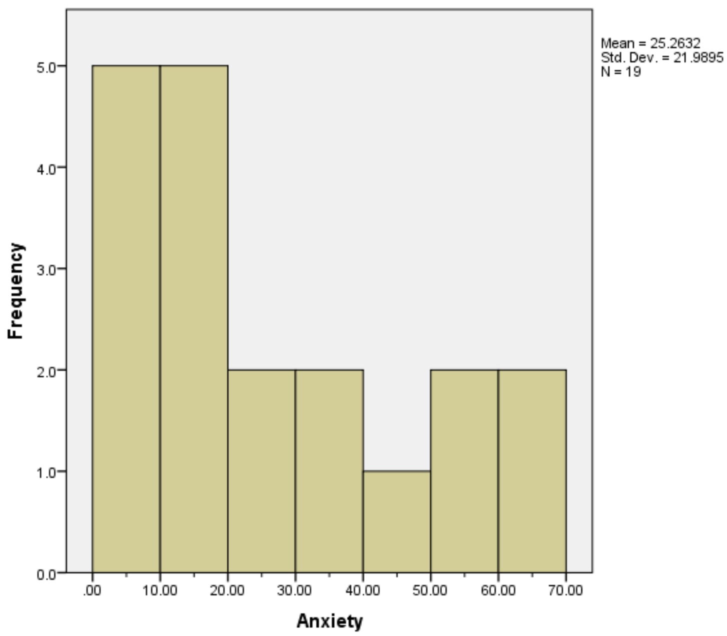


Figure 1. Histogram of the anxiety score frequency distribution

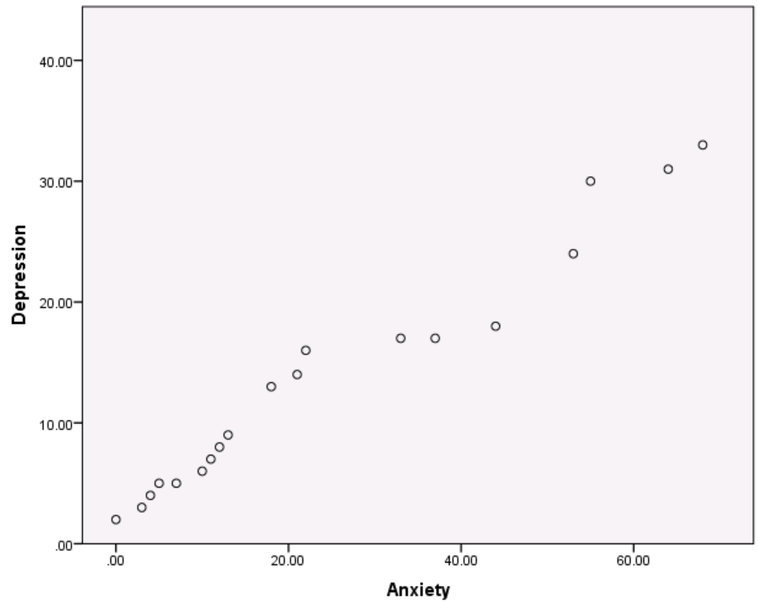
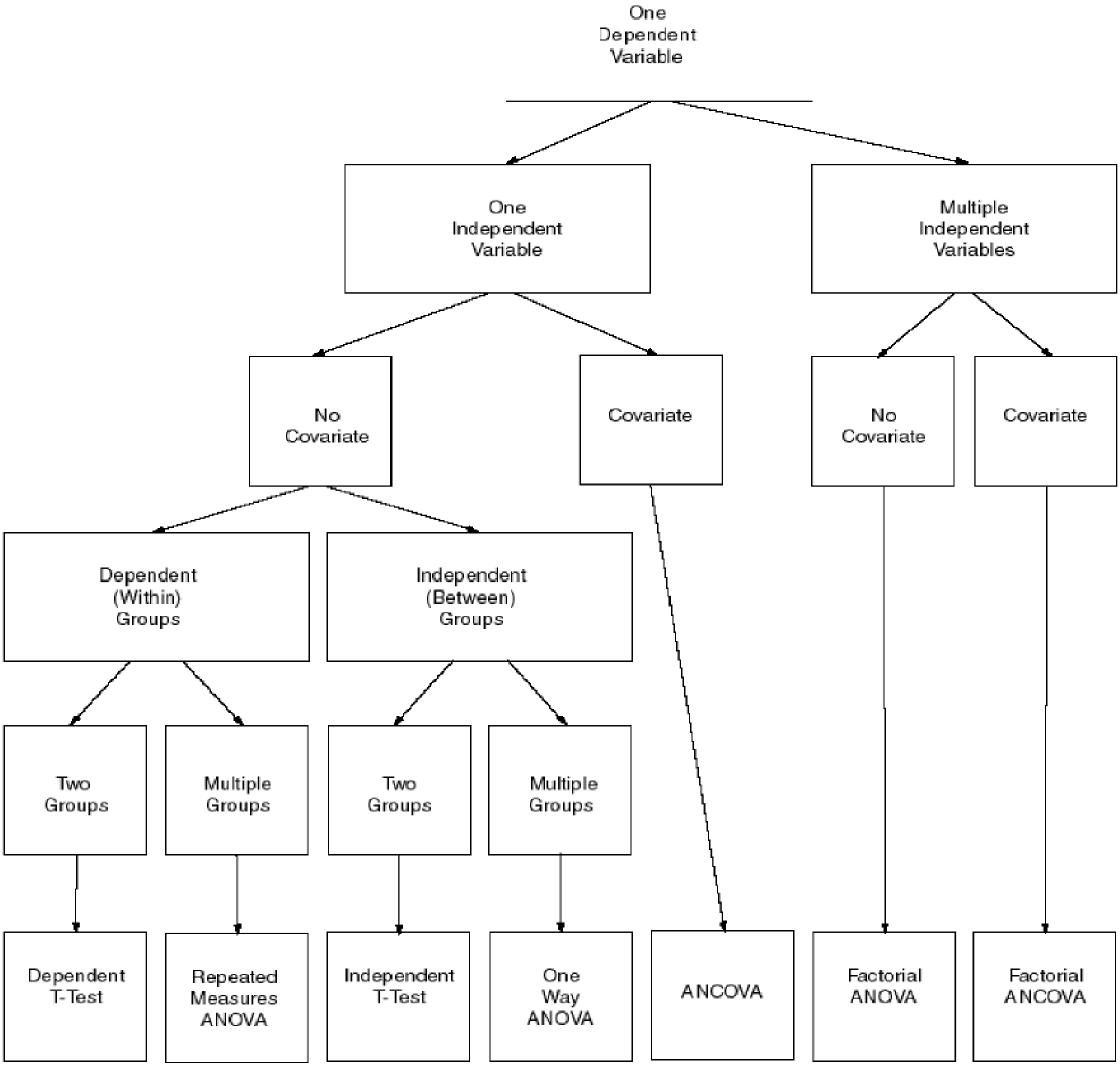


Figure 2. Scatterplot of correlation between anxiety and depression

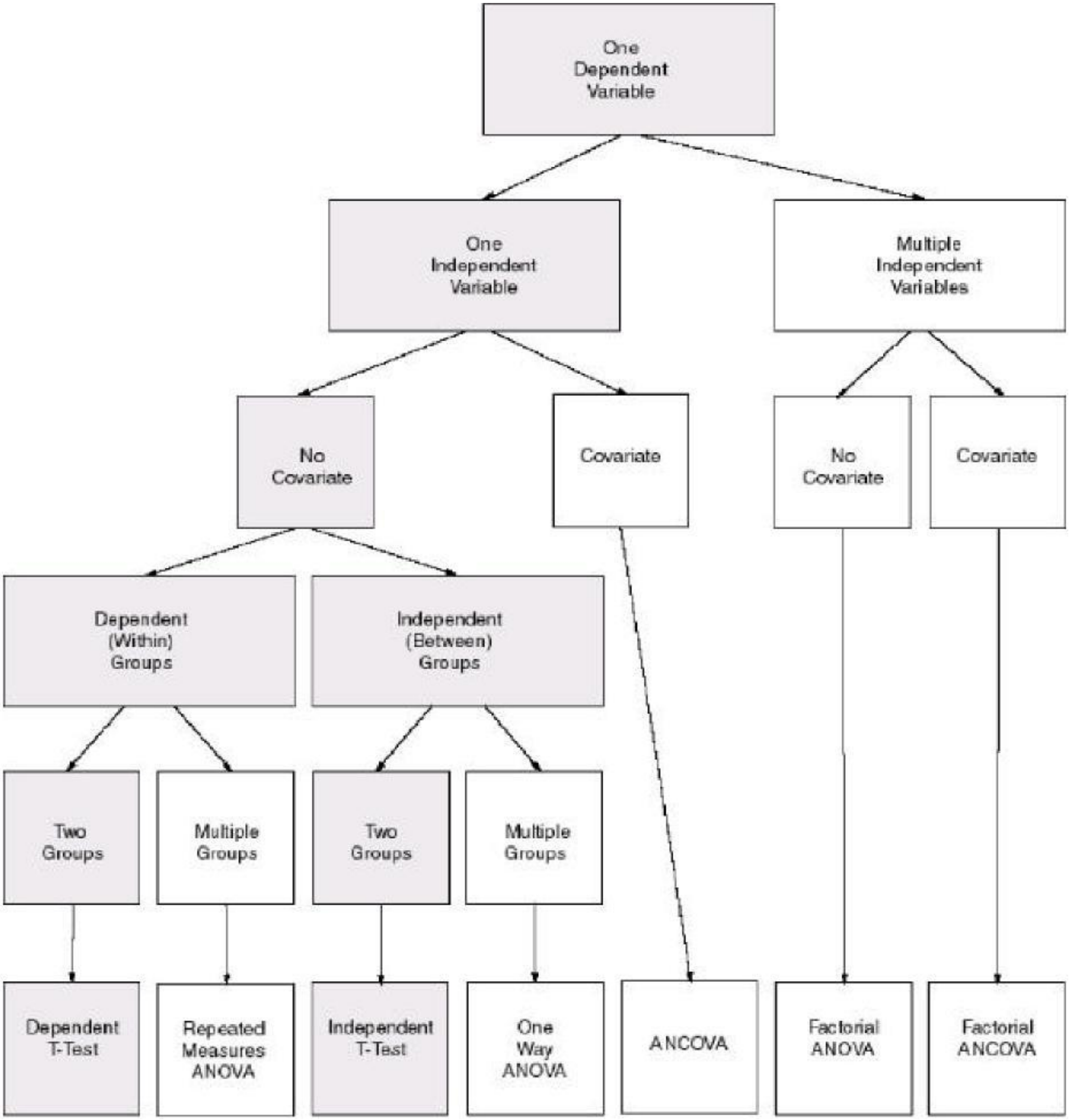
Inferential Statistics

PROCEDURAL MODEL: OVERVIEW

Research Issue: Significance of Group Difference



Independent T-Test Dependent T-Test



INDEPENDENT T-TEST

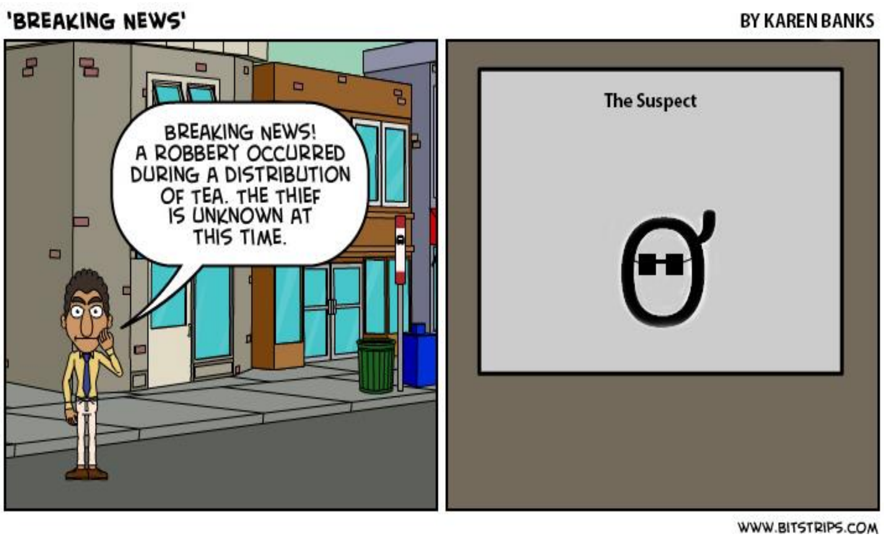
Example Problem

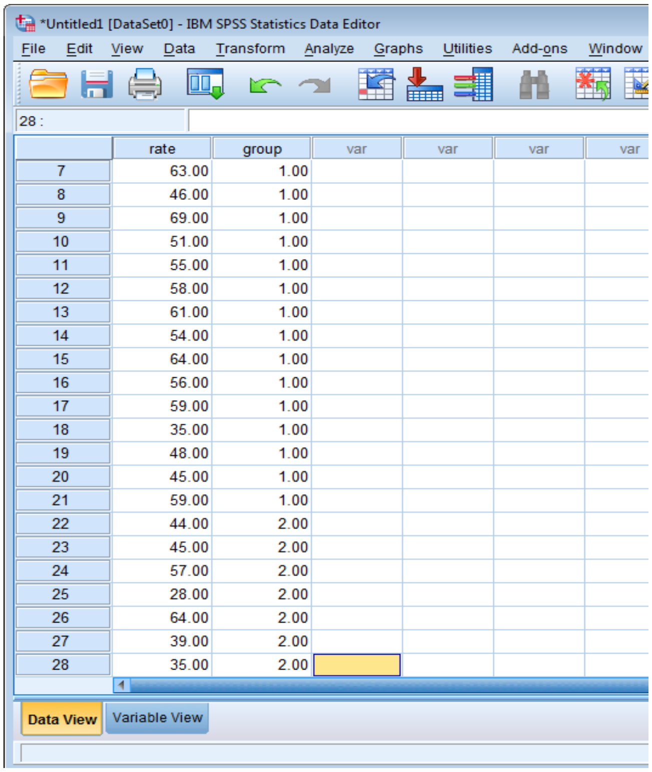
A training manager believes that a new interactive computer based training package will help improve the production rate of order assemblers. She arranges for a production area of 21 experienced employees to complete the new training package over a six week period. Another group from the production area of 23 employees received no additional training. Following are the average production rates per person per hour based on a 12 week period following the training:

Table 1

Production Rates: Completed Assemblies Per Person Per Hour

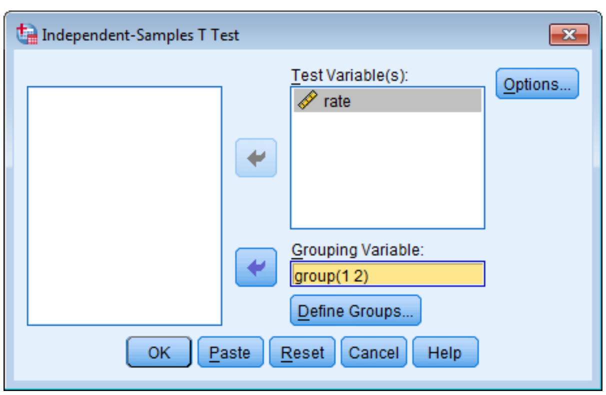
Training Group	Control Group
26	44
45	45
60	57
73	28
45	64
51	39
63	35
46	43
69	21
51	56
55	22
58	87
61	48
54	12
64	19
56	62
59	55
35	44
48	39
45	44
59	57
	30
	30

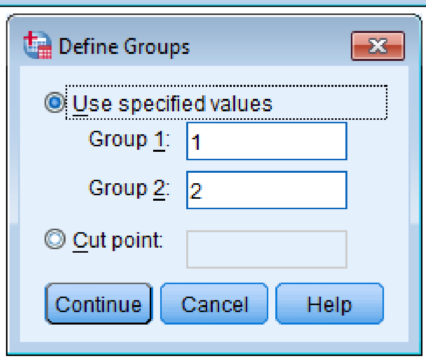




In order to do the t-test, we will have to enter the data. In this case we will add a new variable called "Group" and code 1 for "Training and 2 for "Control". Then we will enter each production rate as a new entry for a total of 44 entries. Do not forget to define the values for the group variable.

Now we can enter the data (only a sample of the data entry is shown). The 'SPSS Data Editor' window is shown with a sample of data. Remember, a total of 44 'Cases' or observations are entered. Notice the complete listing of cases is not shown in the example window at the left.





Now we will conduct the t test. Select 'Analyze', 'Compare Means' and "independent sample T test'. We want 'rate' to be in the test variable box and 'group' to be in the grouping variable. Now select 'Define Groups'. This will allow us to distinguish what two groups we want to compare. The group one value is '1' and the group 2 value is '2'.

At this point, SPSS will perform the statistical analysis directing the results to the 'Output1 SPSS Output Navigator' window which automatically displays the results of the analysis.

T-Test

[DataSet0]

The SPSS results provide the mean values of the scores for the training and control groups, along with the standard deviations and standard errors.

Group Statistics

	group	N	Mean	Std. Deviation	Std. Error Mean
rate	training	21	53.4762	11.00736	2.40200
	control	23	42.6522	17.31161	3.60972

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
rate	Equal variances assumed	2.872	.098	2.448	42	.019	10.82402	4.42228	1.89950	19.74854
	Equal variances not assumed			2.496	37.672	.017	10.82402	4.33586	2.04401	19.60402

Levene's Test of equality of variances performs hypothesis testing for equality of variances.
If the probability (significance) is less than .05 ($p < .05$), then the hypothesis that the variances are equal is rejected which is not the case in this example so we can continue with interpreting the results of the t test.

In interpretation of the results, use the t-value, df, and probability (Sig, 2-tailed), labeled **UNEQUAL variances assumed** if the probability from the Levene's test is less than .05. If the probability is greater than .05, use the EQUAL variances assumed line. The Equal variance assumes line is what we will use.

INDEPENDENT T-TEST

Example Results Write Up

Results

Table 1 presents the means and standard deviations by group. The results show that order assemblers in the training group produced on average about 10 more assemblies per person per hour (*M* = 53.48, *SD* = 11.01) than the assemblers in the control group (*M* = 42.65, *SD* = 17.31) and they also had more homogeneous production rates. This mean difference resulted in the effect size of .75 (Cohen's *d*), which is considered to be medium.

Since the measurements in the training group and control group were unrelated to each other, an independent t-test was performed. The assumption of homogeneous variances was satisfied using (Levene's test, F (1,42) = 2.87, p = .098). The mean score for the training group was significantly higher than the mean score for the control group, $t(42) = 2.45$, p = .019.

Table 1

Mean Assemblies Per Person Per Hours and Standard Deviations

Group	M	SD
Control	42.65	17.31
Training	53.48	11.01

The new computer-based training package used with the training group had a significant and positive effect on production rates. Therefore, it is appropriate for management to consider providing the new training to employees in all assembly areas.

DEPENDENT T-TEST

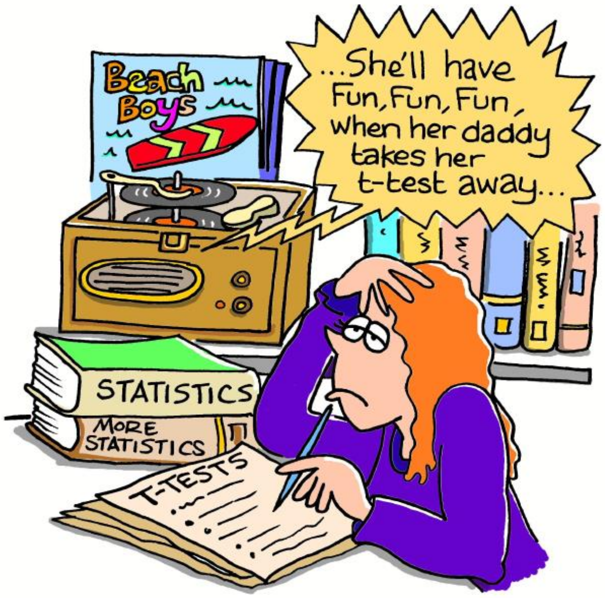
Example Problem

A sports psychologist was interested in testing the effect of a simple relaxation technique on college basket-ball players' free throw shooting accuracy. Each player was asked to shoot 20 consecutive free throws and the number of successful attempts was recorded. The players were then trained to use a simple 5 second relaxation technique while preparing to shoot a free throw. The players then returned to the court and shot 20 consecutive free throws again. The resulting data are given below:

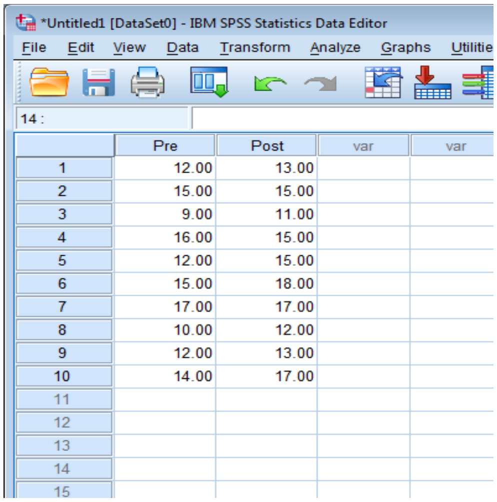
Table 1

Number of Free Throws Completed Per Twenty Attempts

Pre-Training	Post Training
12	13
15	15
9	11
16	15
12	15
15	18
17	17
10	12
12	13
14	17

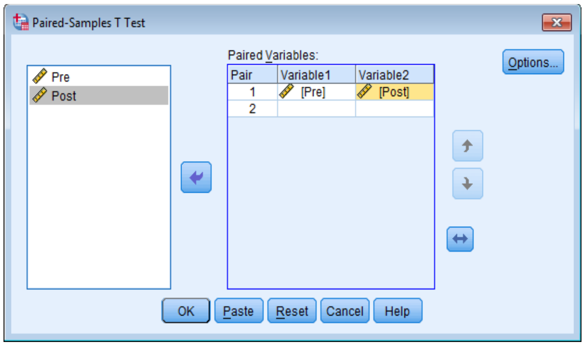


J.B. Landers © www.CAUSEweb.org



As usual, the first thing we need to do is enter the data. Make sure that you label the variable "pre" and "post"

Now go to 'Analyze', "Compare Means', and 'Paired Sample T Test'.



You want to add 'Pre' to the variable 1 column and 'Post' to the variable 2 column. Now we are ready to run the test. Select 'OK'.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre	13.2000	10	2.61619	.82731
	Post	14.6000	10	2.31900	.73333

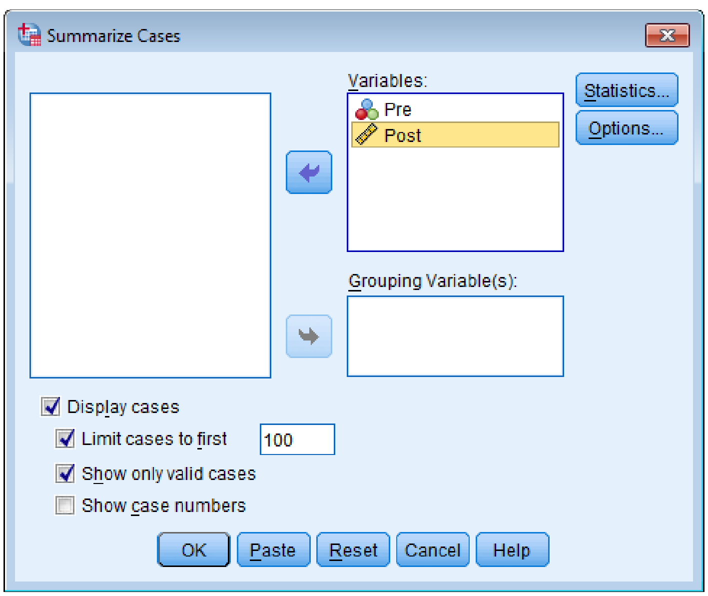
Paired Samples Correlations

	N	Correlation	Sig.
Pair 1 Pre & Post	10	.839	.002

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 Pre - Post	-1.40000	1.42984	.45216	-2.42285	-.37715	-3.096	9	.013

The Mean in the analysis is the mean of the difference between the 'Pre' and 'Post' training scores.



A listing of data can be obtained by choosing 'Analyze', 'Reports', and 'Case Summaries' from the SPSS main menu.

As before, using the mouse pointer, highlight the variables 'Pre' and 'Post'. Click on the right hand pointing arrow to move the variables to the 'Variables' text box. Click on 'OK' to list the data.

As before, the results will be displayed in the 'Output 1 SPSS Output Navigator' window.

Case Processing Summary[a]

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Pre	10	100.0%	0	0.0%	10	100.0%
Post	10	100.0%	0	0.0%	10	100.0%

a. Limited to first 100 cases.

Case Summaries[a]

		Pre	Post
1		12.00	13.00
2		15.00	15.00
3		9.00	11.00
4		16.00	15.00
5		12.00	15.00
6		15.00	18.00
7		17.00	17.00
8		10.00	12.00
9		12.00	13.00
10		14.00	17.00
Total	N	10	10

a. Limited to first 100 cases.

The ‘Case Processing Summary’ and ‘Case Summaries’ listings provide a quick and convenient synopsis of the cases comprising your study.

DEPENDENT T-TEST Example Reporting of Results

Results

Because the data from the pre-training observations were logically tied to the data from the post-training observations, a dependent t-test was performed. The mean difference between the pre-and post-training scores was 1.40, which was statistically significant, $t(9) = 3.10$, $p = .013$.

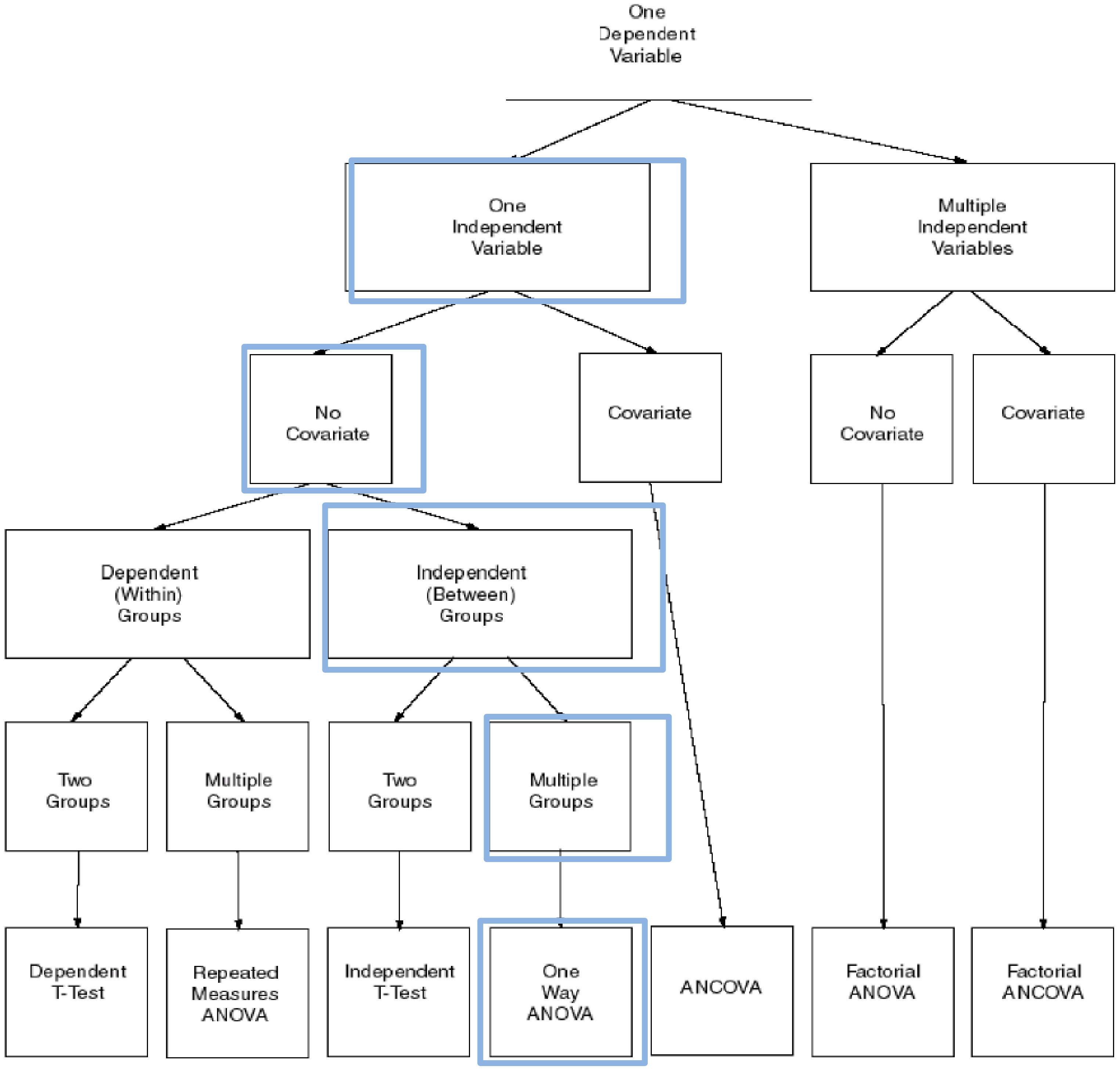
Discussion

The results showed the post-training scores to be significantly higher after exposure to the relaxation technique. This means that the relaxation technique appears to have a positive effect on the player's free throw shooting accuracy.

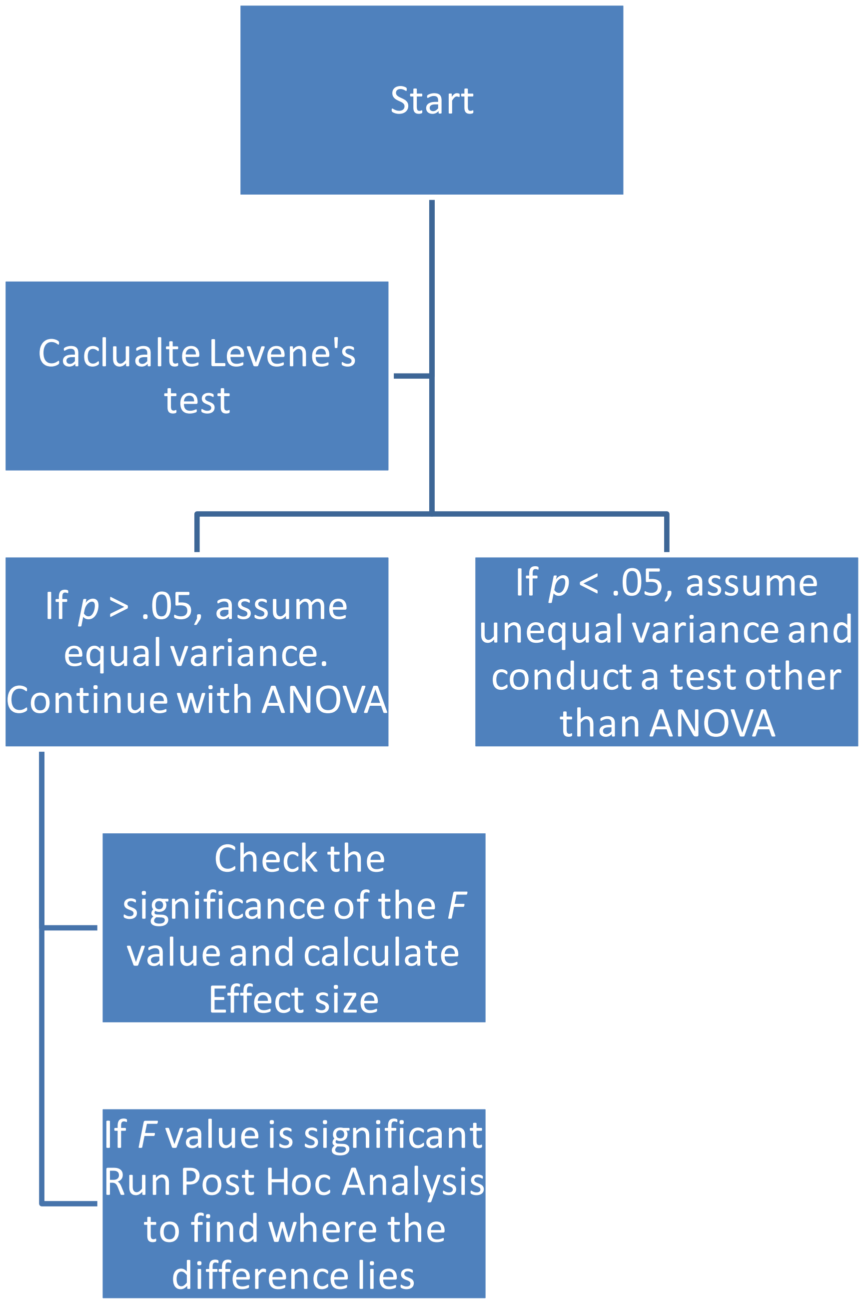
ANALYSIS OF VARIANCE

One-Way ANOVA

ANALYSIS OF VARIANCE



ONE-WAY ANOVA
Procedural Model



Example Problem

Balanced groups

A direct marketer of insurance wanted to evaluate the effect of age on the response rate to a new insurance product. Below are the response rates per 1,000 mailings by age group from 12 different metropolitan areas.

Table 1

Response Rate per One Thousand Mailings

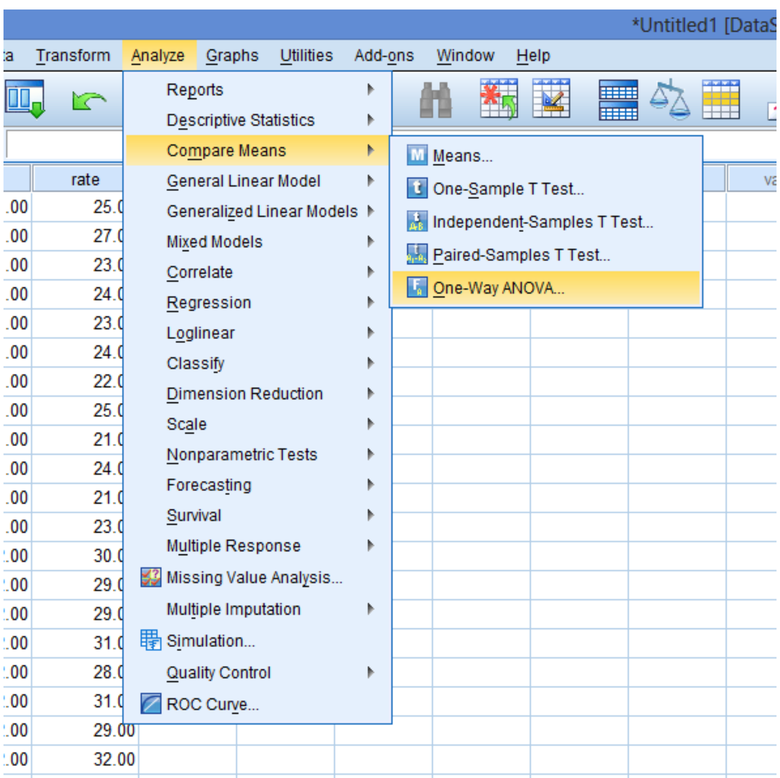
Young	Middle	Elderly
25	30	25
27	29	22
23	29	27
24	31	23
23	28	24
24	31	25
22	29	23
25	32	22
21	30	21
24	29	22
21	28	24
23	31	23

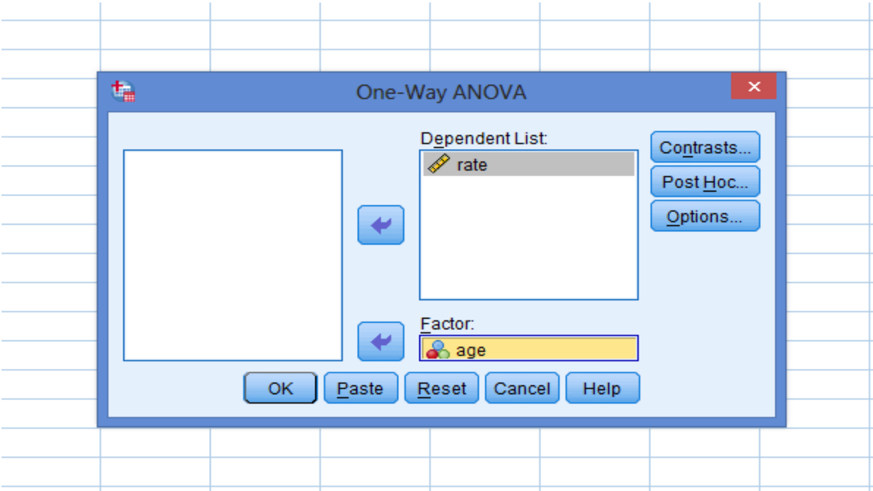
BALANCED ONE-WAY ANOVA

SPSS Procedures

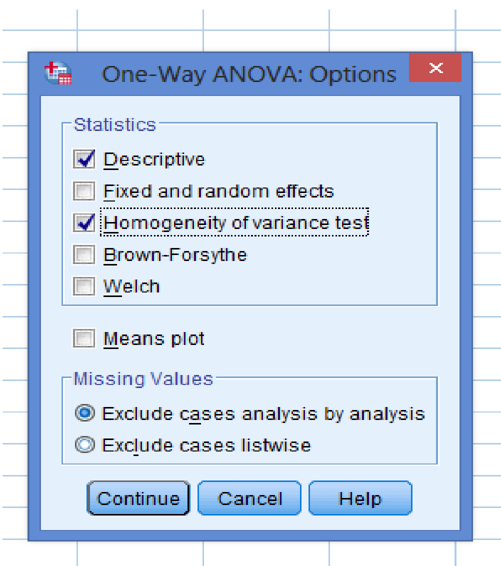
Define variables ‘Age’ and ‘Rate’ using the procedures described in the Independent T-Test. Thirty-six cases are entered for this example.

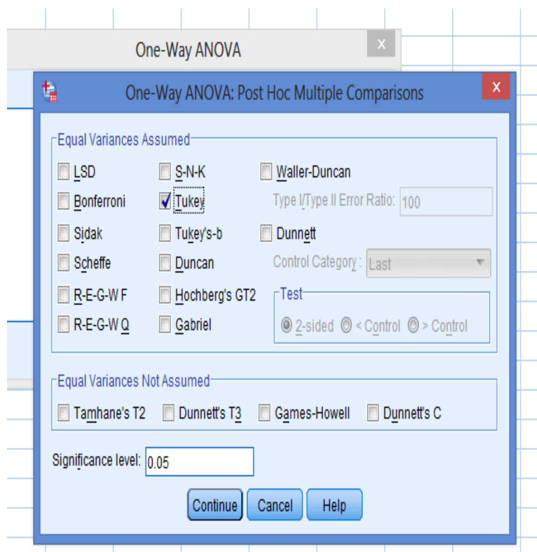
Go to ‘ Analyze”, ‘ Compare Means’, ‘One-Way ANOVA’





Place 'rate' in the box for dependent variable and 'age' in as the factor.





In the options box, make sure "Descriptives" and 'Homogeneity of Variance' are selected and select continue. In the Post Hoc box make sure 'Tukey" is selected and select continue again. Finally when back to the One Way ANOVA screen select OK.

The following is the SPSS output from SPSS

This shows the means and standard deviation for each group as well as the grand mean (Total)

Descriptives

rate

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
young	12	23.5000	1.73205	.50000	22.3995	24.6005	21.00	27.00
middle	12	29.7500	1.28806	.37183	28.9316	30.5684	28.00	32.00
elderly	12	23.4167	1.67649	.48396	22.3515	24.4819	21.00	27.00
Total	36	25.5556	3.37592	.56265	24.4133	26.6978	21.00	32.00

Levene's test results

Test of Homogeneity of Variances

rate

Levene Statistic	df1	df2	Sig.
.302	2	33	.741

One Way ANOVA results. Use this to calculate η^2.

$$\eta 2 = \frac{SS\ Between}{SS\ total}$$

ANOVA

rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	316.722	2	158.361	63.601	.000
Within Groups	82.167	33	2.490		
Total	398.889	35			

Tukey's Post Hoc Results

Multiple Comparisons

Dependent Variable: rate

Tukey HSD

(I) age	(J) age	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
young	middle	-6.25000*	.64419	.000	-7.8307	-4.6693
	elderly	.08333	.64419	.991	-1.4974	1.6640
middle	young	6.25000*	.64419	.000	4.6693	7.8307
	elderly	6.33333*	.64419	.000	4.7526	7.9140
elderly	young	-.08333	.64419	.991	-1.6640	1.4974
	middle	-6.33333*	.64419	.000	-7.9140	-4.7526

ONE-WAY ANOVA

Example Results Write Up

Table 1 presents the means and standard deviations by age group. A one-way analysis of variance yielded a significant difference among the age group means, $F(2,33) = 63.60$, $p < .001$, $\eta^2 = .794$. Levene's test showed that the assumption of equal variances was tenable ($F(2, 33) = .302$, $p = .741$). Table 2 presents the analysis of variance summary. A post hoc analysis using Tukey's procedure ($\alpha = .05$) revealed the mean for the middle age group was significantly higher than the young and elderly age groups. There was no significant difference between the means of the young and elderly groups.

Table 1
Response Rate per One Thousand Mailings by Age Groups and Standard Deviations

Group	*N*	*M*	*SD*
Young	12	23.50	1.73
Middle	12	29.75	1.29
Elderly	12	23.42	1.68

Table 2
Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Square*	*F*
Age	316.72	2	158.36	63.60*
Error	82.17	33	2.49	
Total	398.89	35		

*$p < .001$

Discussion

The results indicate a significantly higher response rate from the middle age group for this particular insurance product. Therefore, it is recommended that the direct marketer targets the middle age group for selling the new insurance product.

ONE-WAY ANOVA
Unbalanced Groups

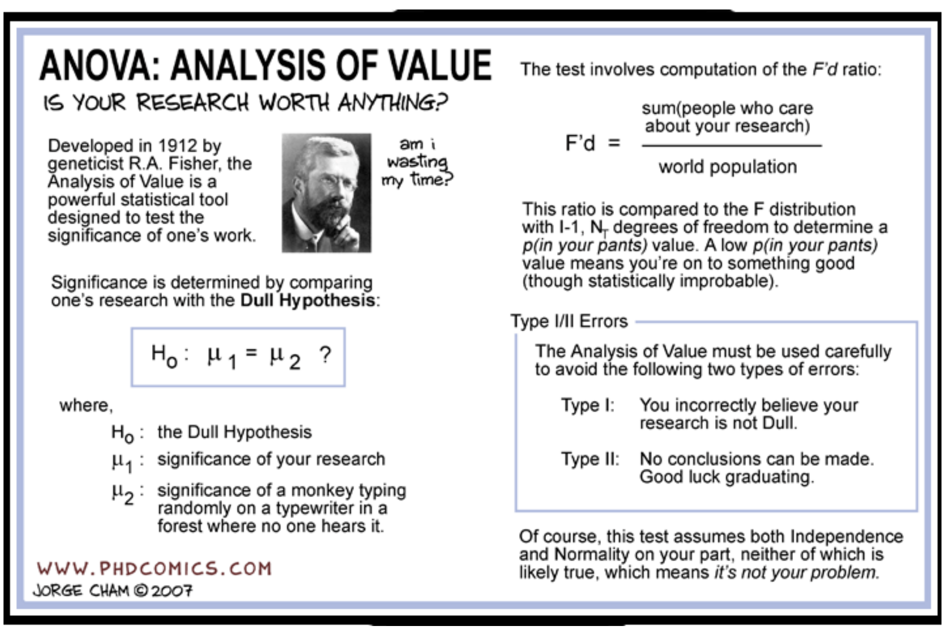
Example problem

Locus of Control is a widely used concept that concerns individuals' perceptions about who or what influences important outcomes in their lives. A nursing administrator was interested in examining the relationship between locus of control and open heart surgery patients' length of stay in the hospital. Working with Counseling Services, the administrator arranged for the Multidimensional Health Locus of Control (MHLC) to be administered to 24 patients scheduled for heart valve replacement. Based on the MHLC scores and norms, the patients were then classified into one of three groups: high, average, or low. High locus of control indicates a sense of personal control. Low locus of control indicates a sense of control by outside factors. The number of days required in the hospital by patient by classification is presented below.

Table 1

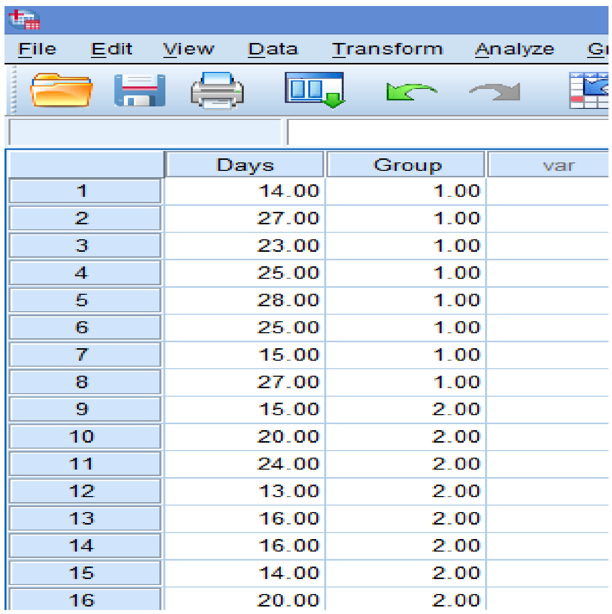
Number of Hospital Days by Locus of Control Group

Group	Hospital days by Patient									
Low	14	27	23	25	28	25	15	27		
Average	15	20	24	13	16	16	14	20	14	18
High	11	17	6	5	8	7				

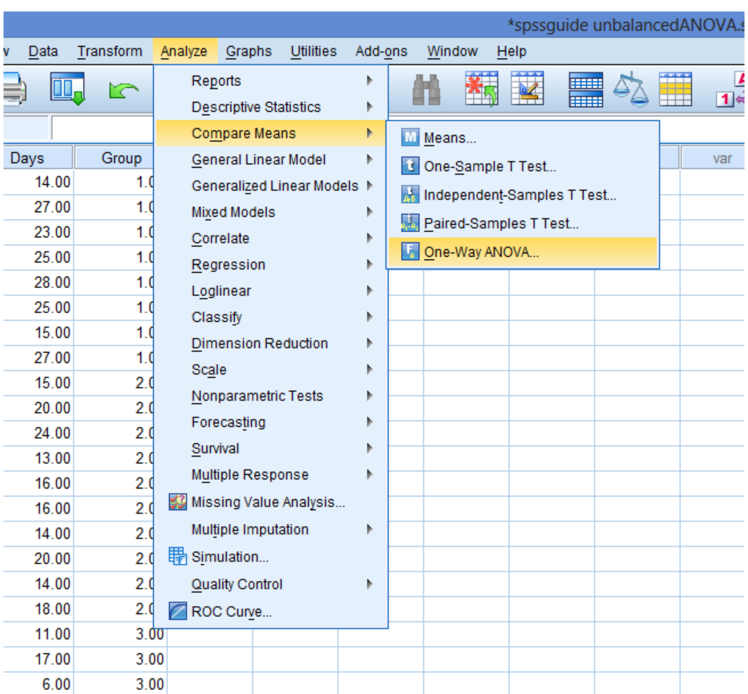


UNBALANCED ONE-WAY ANOVA

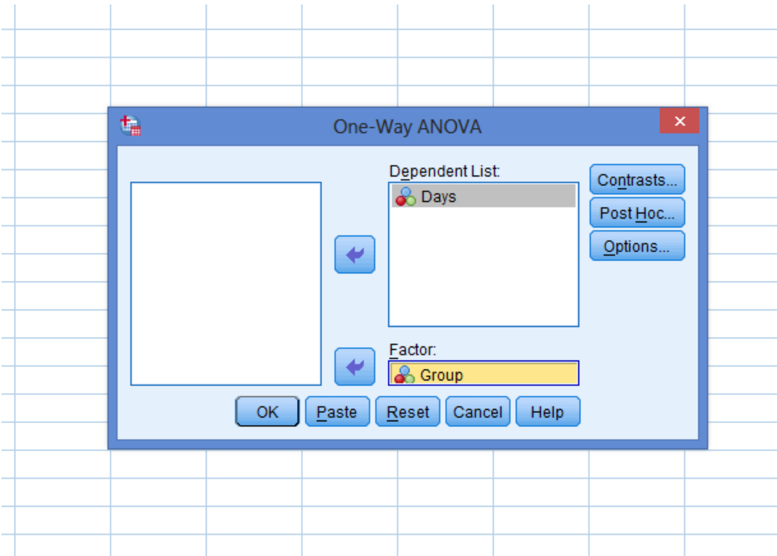
SPSS Procedures



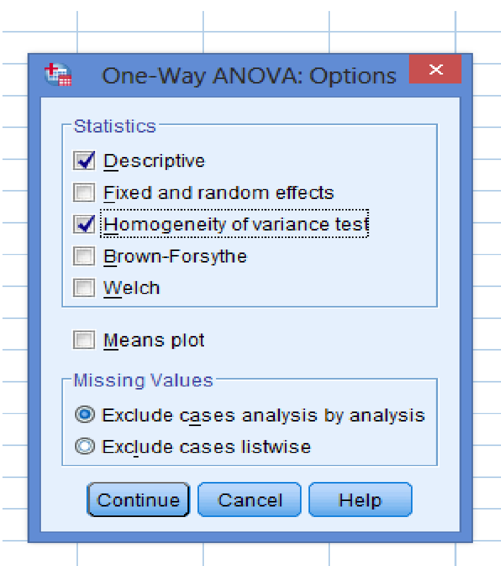
Define variables 'Days' and 'Group'.

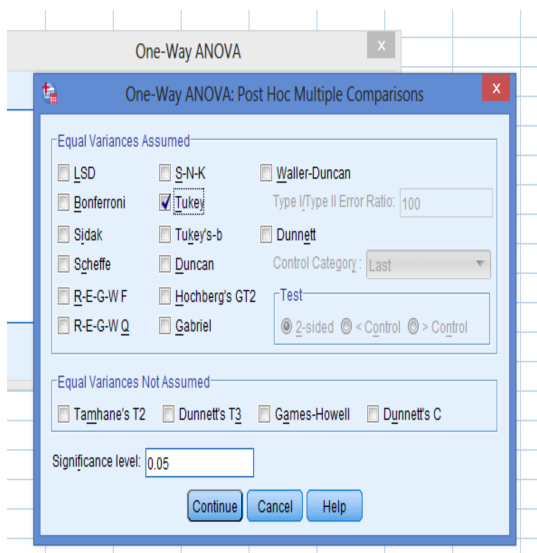


Go to ' Analyze", ' Compare Means', 'One-Way ANOVA'



Place 'Days' in the box for dependent variable and 'Group' in as the factor.





In the options box, make sure "Descriptives" and 'Homogeneity of Variance' are selected and select continue. In the Post Hoc box make sure 'Tukey" is selected and select continue again. Finally when back to the One Way ANOVA screen select OK.

This shows the means and standard deviation for each group as well as the grand mean (Total)

Descriptives

Days

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
low	8	23.0000	5.47723	1.93649	18.4209	27.5791	14.00	28.00
average	10	17.0000	3.46410	1.09545	14.5219	19.4781	13.00	24.00
high	6	9.0000	4.42719	1.80739	4.3540	13.6460	5.00	17.00
Total	24	17.0000	6.87782	1.40393	14.0958	19.9042	5.00	28.00

Levene's test results.

Test of Homogeneity of Variances

Days

Levene Statistic	df1	df2	Sig.
.781	2	21	.471

One Way ANOVA results. Use this to calculate η^2.

$$\eta 2 = \frac{SS\ Between}{SS\ total}$$

ANOVA

Days

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	672.000	2	336.000	16.962	.000
Within Groups	416.000	21	19.810		
Total	1088.000	23			

Multiple Comparisons

Tukey's Post Hoc Results

Dependent Variable: Days

Tukey HSD

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
low	average	6.00000*	2.11119	.025	.6786	11.3214
	high	14.00000*	2.40370	.000	7.9413	20.0587
average	low	-6.00000*	2.11119	.025	-11.3214	-.6786
	high	8.00000*	2.29838	.006	2.2068	13.7932
high	low	-14.00000*	2.40370	.000	-20.0587	-7.9413
	average	-8.00000*	2.29838	.006	-13.7932	-2.2068

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

UBALANCED ONE-WAY ANOVA

Example Reporting of Results

Table 1 shows the mean number of hospital days and standard deviations by locus of control group. Levene's test showed that the assumption of equal variances was tenable ($F(2, 21) = .781$, $p = .471$). The one-way analysis of variance procedure yielded a significant difference among the locus of control group means $F(2,21) = 16.96$, $p < .001$, $\eta^2 = .62$. Table 2 presents the analysis of variance summary. A post hoc analysis using Tukey's procedure ($\alpha = .05$) revealed the mean number of hospital days for all three groups were significantly different (see Figure 1).

Table 1

Mean Hospital days and Standard Deviations by Locus of Control Groups

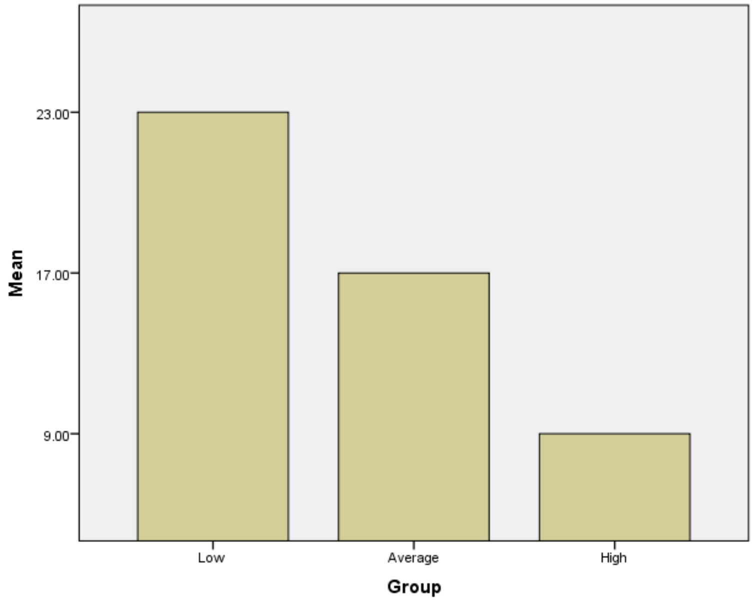
Group	*N*	*M*	*SD*
Low	8	23.00	5.48
Average	10	17.00	3.46
High	6	9.00	4.43

Table 2
Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Square*	*F*
Group	672.00	2	336.00	16.96*
Error	416.00	21	19.81	
Total	1088.00	23		

*$p < .001$

Figure 1.
Mean Number of Hospital Days



Discussion

The results of this study showed that patients who have a high locus of control, that is, feel they have a high degree of personal control over events, appear to be discharged much sooner than those patients with average or low locus of control. Furthermore, even patients with average locus of control can be expected to be discharged sooner than patients with a low locus of control. Figure 1 clearly shows the relationship of locus of control to the mean number of hospital days by group.

Comments about the Results and Discussion Section:
There are three ways you can report the results of the statistical treatments: (1) within the text of the section, (2) with one or more summary tables, and (3) graphically. As illustrated in this example, an appropriate graph (technically called a figure) sometimes can help the reader gain a clearer understanding of how the study turned out.

Note: Figure 1 was produced in SPSS. See the Descriptive statistics portion of this guide for instructions of how to produce the graph.

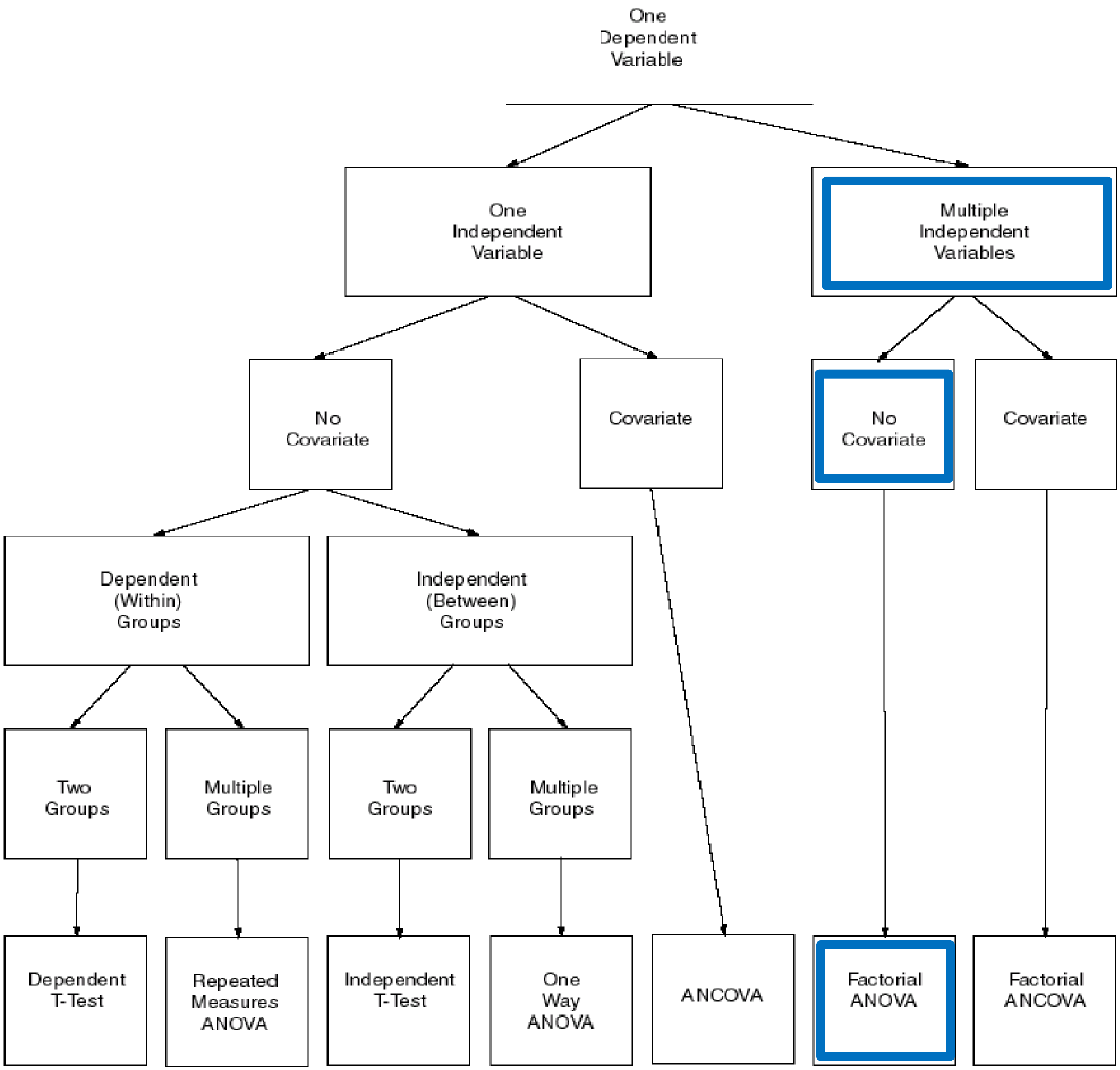
FACTORIAL ANALYSIS OF VARIANCE

Two-Way ANOVA

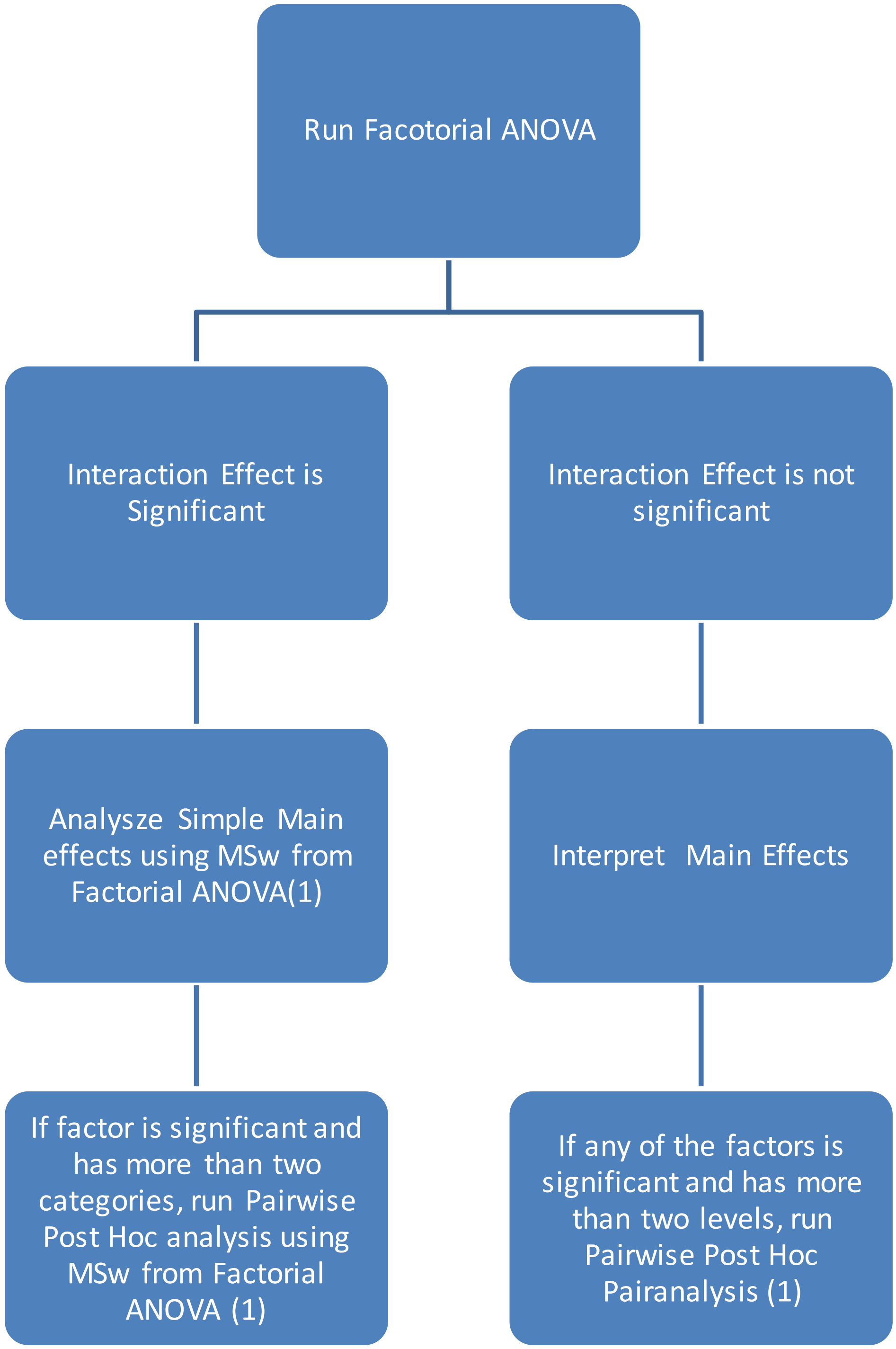
Two-Way ANOVA with Significant Interaction

PROCEDURAL MODEL: OVERVIEW

Research Issue: Significance of Group Difference



Factorial ANOVA Procedure Model



(1) The MSw term from the main factorial ANOVA is more reflective of the population variance. The MSw term from the main factorial ANOVA should be used as the error term for the subsequent simple main effects analysis and in the post hoc analysis.

TWO-WAY ANOVA

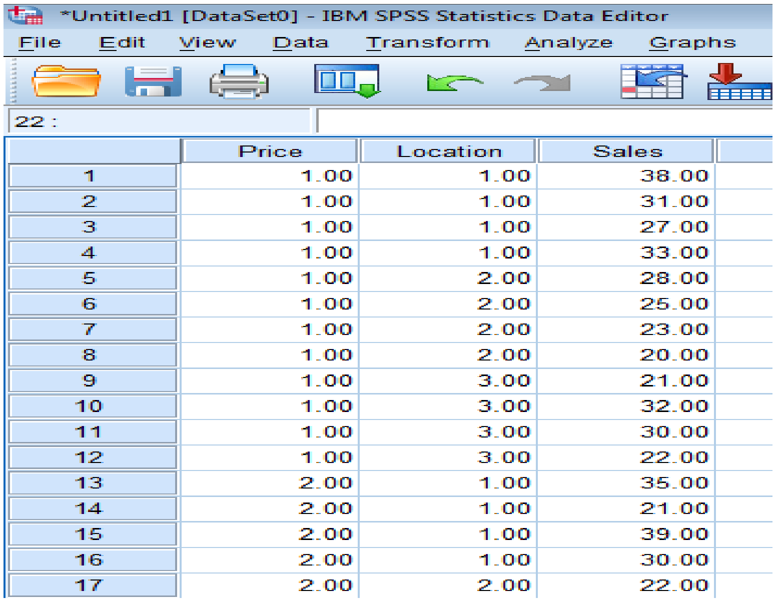
Example Problem

A marketing manager for a supermarket chain was interested in the effect of both retail price and display location on a new promotional line of cookies. A group of 24 stores with matching store volume, layout, and customer demographics was split at random into 6 groups of 4 stores each. One group was assigned to each of the 6 combinations of retail price (regular retail vs. discounted retail) and display location (entrance aisle, cookie aisle, and checkout). Below are the average weekly unit sales by store over a 13 week period.

Table 1

Promotional Cookie: Average Weekly Unit Sales

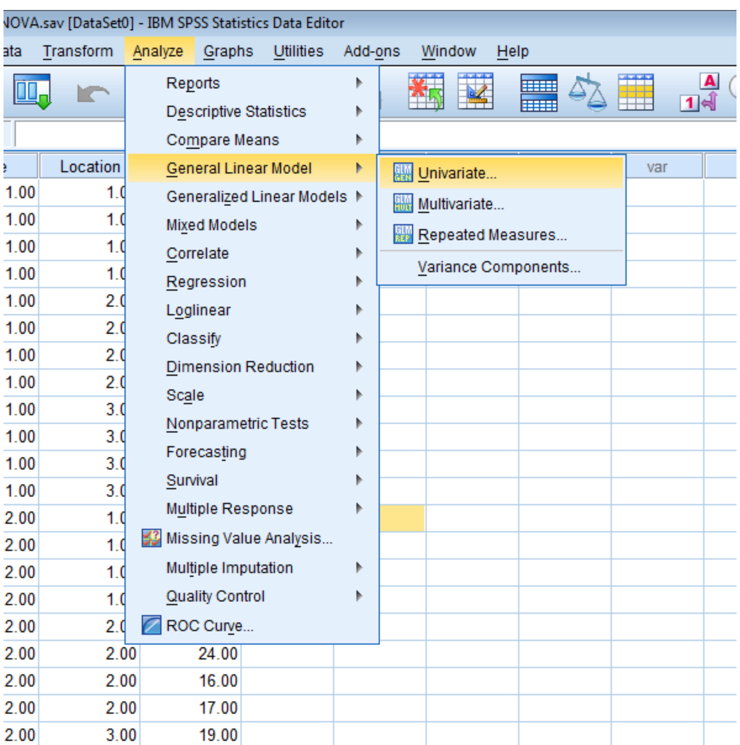
		DISPLAY LOCATIONS		
		1 Entrance	2 Cookies	3 Checkout
	1. Regular Retail	38	28	21
		31	25	32
		27	23	30
		33	20	22
Price				
	2. Discount Retail	35	22	19
		21	24	15
		39	16	25
		30	17	20



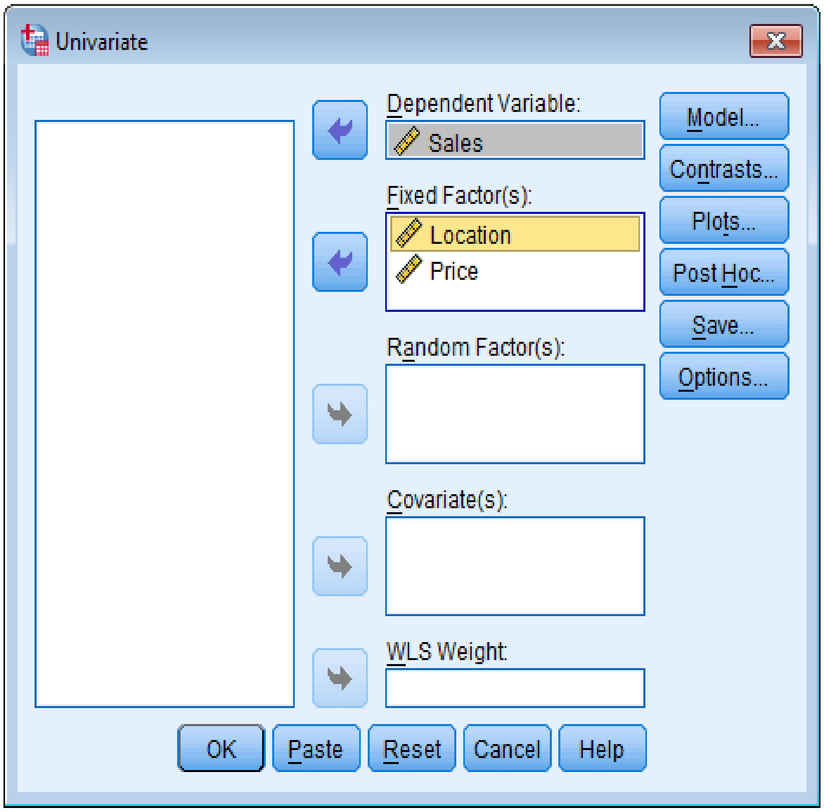
Define three variables as: ‘Price’, ‘Location’, and ‘Sales’.

For the variable ‘Price’, assign the variable labels of ‘Retail’ to the value of ‘1’ and ‘Discount’ to the value of ‘2’.

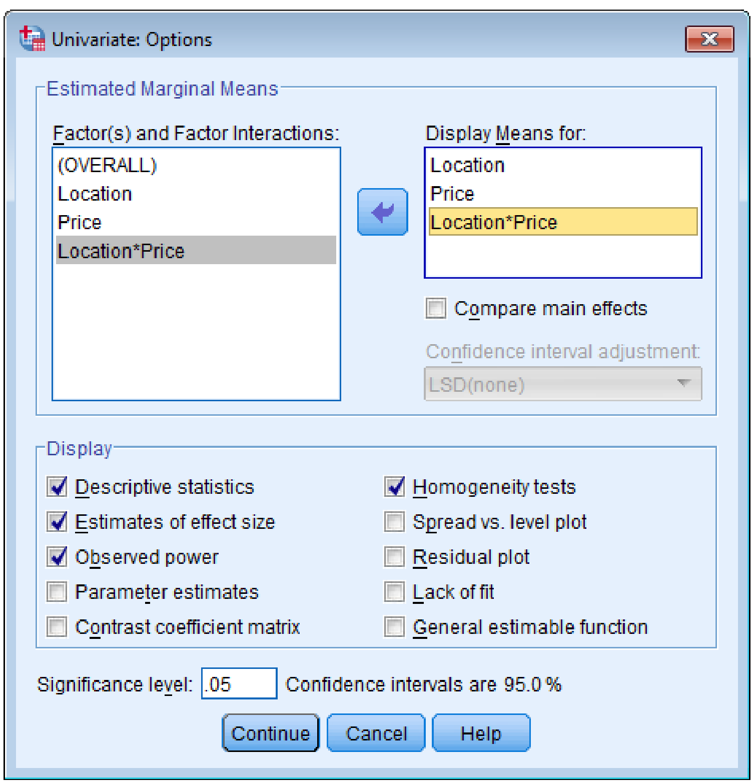
For the variable ‘Location’, assign the variable labels of ‘Entrance’ to the value of ‘1’, ‘Aisle’ to the value ‘2’, and ‘Checkout’ to the value of ‘3’.
Note: The entire data set is not displayed.



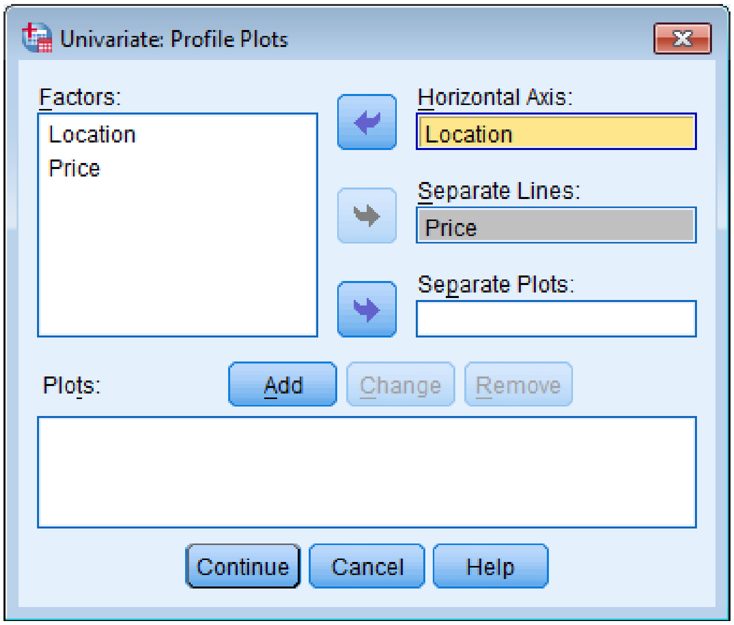
Go to ‘Analyze’, ‘General Linear Model’, and select ‘Univariate’ since you have only one dependent variable.



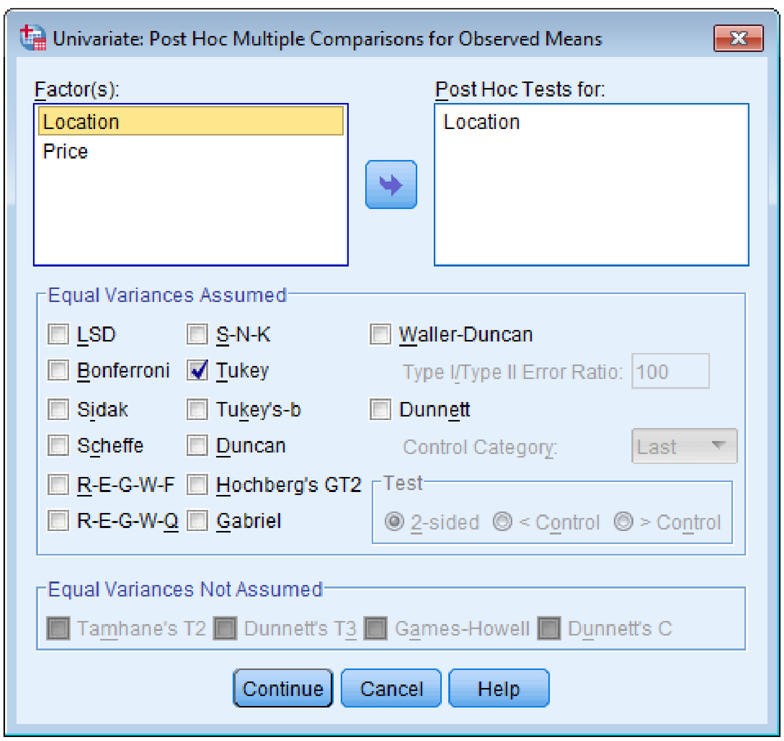
Place 'Sales' in the Dependent variable box and 'Location' and 'Price' in the Fixed Factor(s) box.



In the options menu we want to make sure 'Descriptive statistics", 'Estimates of Effect Size', 'Observed power', and 'Homogeneity test' are selected. We also want to display group means for 'Location', 'Price' and 'Location*Price'. Select 'Continue'



We also would like to see plots so under the plots menu. Place 'Location' in the Horizontal Axis box and 'Price' in the Separate lines box. Select 'Add' to add this plot then 'Continue'. This will take you back to the Univariate box.



Finally, let's go to the Post Hoc menu where we will place 'Location' in the box and select Tukey for the Post Hoc analysis. We do not need to do a Post Hoc analysis on Price since there are only two categories. Select 'Continue', then select 'OK' in the Univariate box.

SELECTED SPSS OUTPUT

Descriptive Statistics

Dependent Variable: Sales

Location	Price	Mean	Std. Deviation	N
	Regular	32.2500	4.57347	4
Entrance	Discount	31.2500	7.76209	4
	Total	31.7500	5.92211	8
	Regular	24.0000	3.36650	4
Cookies	Discount	19.7500	3.86221	4
	Total	21.8750	4.05101	8
	Regular	26.2500	5.56028	4
Checkout	Discount	19.7500	4.11299	4
	Total	23.0000	5.70714	8
	Regular	27.5000	5.51856	12
Total	Discount	23.5833	7.56137	12
	Total	25.5417	6.77578	24

Descriptive statistics with cell means and Standard deviations

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Sales

F	df1	df2	Sig.
1.120	5	18	.385

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Location + Price + Location * Price

Levene's Test

ANOVA Table

Tests of Between-Subjects Effects

Dependent Variable: Sales

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	590.208[a]	5	118.042	4.562	.007	.559	22.810	.908
Intercept	15657.042	1	15657.042	605.103	.000	.971	605.103	1.000
Location	467.583	2	233.792	9.035	.002	.501	18.071	.947
Price	92.042	1	92.042	3.557	.076	.165	3.557	.431
Location * Price	30.583	2	15.292	.591	.564	.062	1.182	.133
Error	465.750	18	25.875					
Total	16713.000	24						
Corrected Total	1055.958	23						

a. R Squared = .559 (Adjusted R Squared = .436)

b. Computed using alpha = .05

Notes:

[1] Initial interpretation.

[a] The main effects are significant. The question is ***'which main effect(s)'*** is/are significant?

[b] The 'LOCATION' effect is significant, $p = .002$.

[c] The 'PRICE' effect is not significant, $p = .076$.

[d] The 'LOCATION PRICE' is called an interaction term. If the location differences were not the same for the two price factors, we would expect a significant interaction. For example, if the regular price did better in the entrance location, but the discount price did better at the checkout, we'd have an interaction, i.e., the effect of price depends on location. In this example, the interaction is not significant, $p = .564$

Tukey HSD

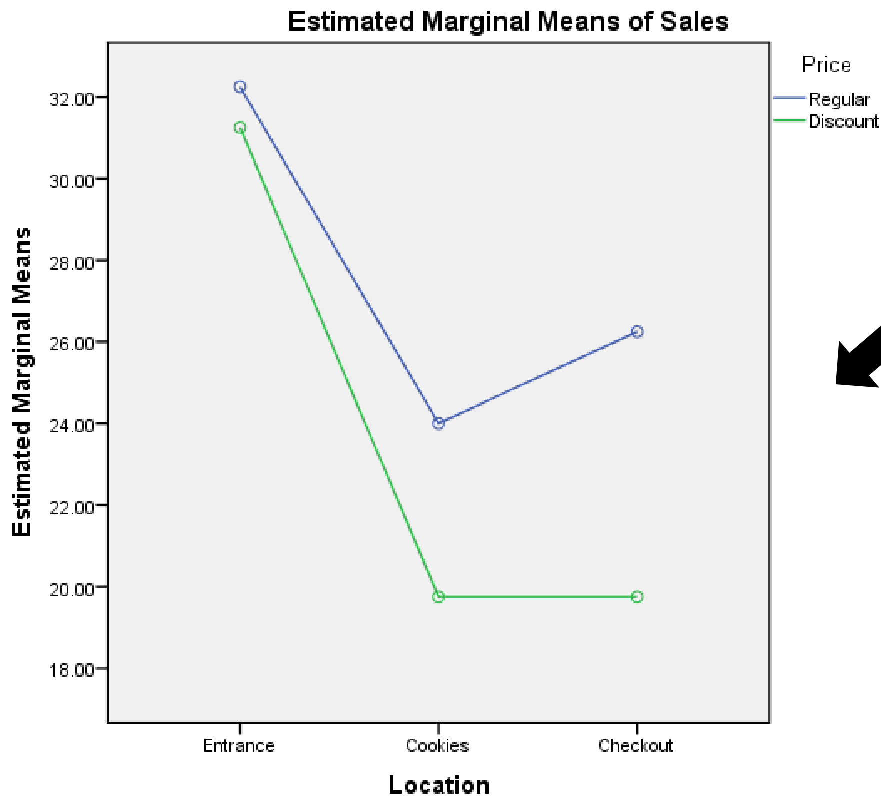
(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Entrance	Cookies	9.8750*	2.54337	.003	3.3839	16.3661
	Checkout	8.7500*	2.54337	.008	2.2589	15.2411
Cookies	Entrance	-9.8750*	2.54337	.003	-16.3661	-3.3839
	Checkout	-1.1250	2.54337	.898	-7.6161	5.3661
Checkout	Entrance	-8.7500*	2.54337	.008	-15.2411	-2.2589
	Cookies	1.1250	2.54337	.898	-5.3661	7.6161

Post Hoc results

Based on observed means.

The error term is Mean Square(Error) = 25.875.

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



Cell means plot

Note: This graph shows that the graphs are basically parallel. You can see a large different between the means at the three locations however the difference between the prices is not as big.

TWO-WAY ANOVA

Example Results and Discussion

Results

A two-way analysis of variance yielded no significant sales difference due to price and no significant interaction between price and display location. However, there was a significant difference among the display locations, $F(2,18) = 9.04$, $p = .002$. A post hoc analysis using Tukey's procedure ($\alpha = .05$) revealed the mean sales for the entrance location was significantly higher than both the cookie aisle and checkout location. There was no significant difference between the mean sales of cookie aisle and checkout location. Table 1 presents the means and standard deviations by group. Table 2 presents the analysis of variance summary.

Table 1
Mean Sales and Standard Deviations of Unit Sales as a Function of Price and Display Location

		Display Location			
Retail Price		Entrance	Cookies	Checkout	Combined
Regular					
	N	4	4	4	12
	M	32.25	24.00	26.25	27.50
	SD	4.57	3.37	5.56	5.52
Discount					
	N	4	4	4	12
	M	31.25	19.75	19.75	23.58
	SD	7.76	3.86	4.11	7.56
Combined					
	N	8	8	8	24
	M	31.75	21.88	23.00	25.54
	SD	5.92	4.05	5.71	6.78

Table 2

Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Square*	*F Value*	*p value*
Price	92.04	1	92.04	3.56	.076
Location	467.58	2	233.79	9.04	.002
Price*Location	30.58	2	15.29	.591	.564
Error	465.75	18	25.86		

Discussion

Locating the new promotional cookie display in the entrance aisle appears to produce the most unit sales. It is interesting to note that there was no significant difference in sales based on retail price. The company can enjoy higher profits by displaying the cookies at regular price, regardless of the location therefore it is recommended that the store keep regular prices and locate the cookies where customers can see them as they enter the store.

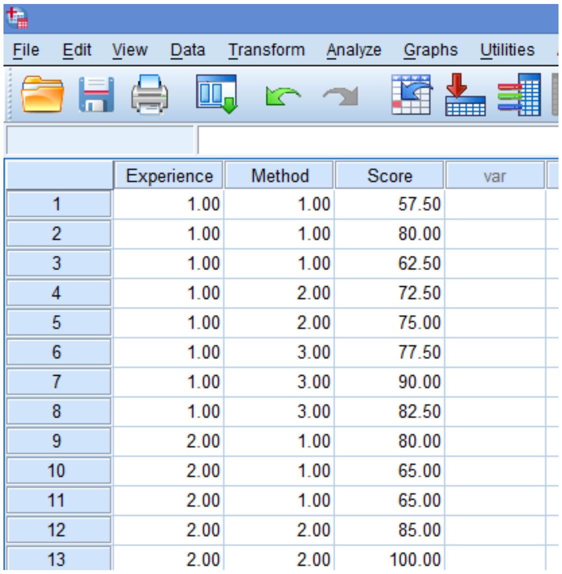
TWO WAY ANOVA
With Significant interaction

Example Problem

Eighteen students were randomly assigned to one of three different classroom teaching methods (online, hybrid, and in person) to learn a new math concept. At the end of 12 weeks, students were given a test to assess their understanding of the concepts. A two-way ANOVA will be run to assess the difference between the teaching methods as well as between student's previous online experiences. The table below shows the scores by gender and method. Two students did not finish the 12 week course so the distribution between the teaching methods and the experience was not equal.

	1.In person	2. Hybrid	3. Online
1. Experienced(Has taken an online course in the past)	57.5 80 62.5	72.5 75	77.5 90 82.5
2. Not Experienced (Has not taken an online class in the past)	80 65 65	85 100 87.5	57.5 65

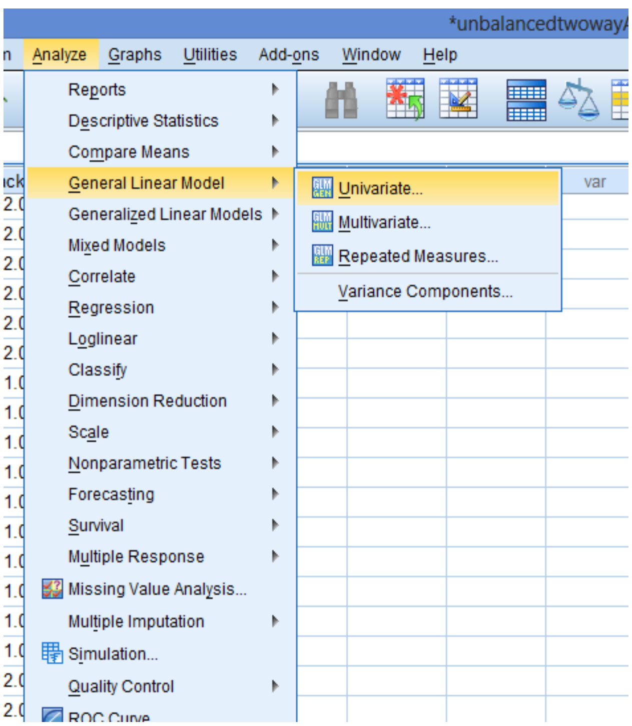
SPSS Procedure



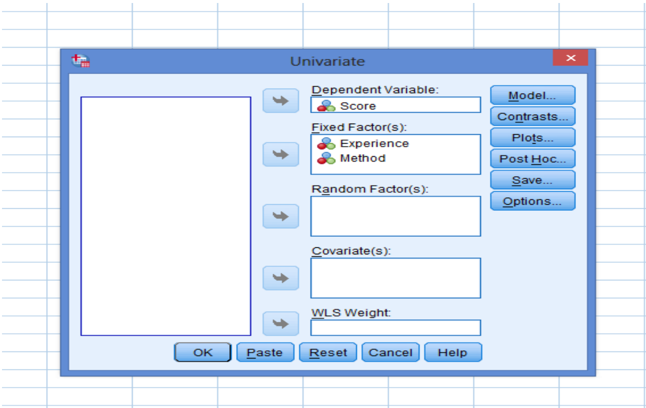
Define three variables for your data set: 'Experience', 'Method', and 'Score'.

Define variable labels for 'Experience' of '1' indicating experienced, and '2' indicating not experienced.

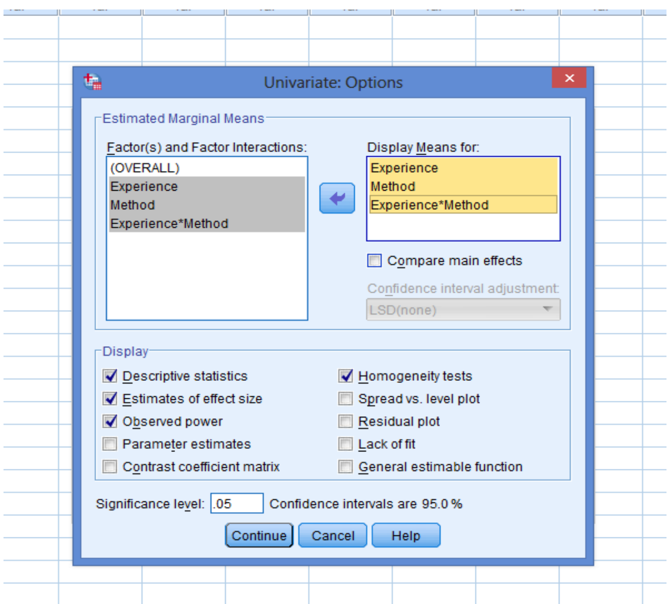
Define variable labels for 'Method' of '1' indicating in person and '2' indicating hybrid and '3' indicating online.



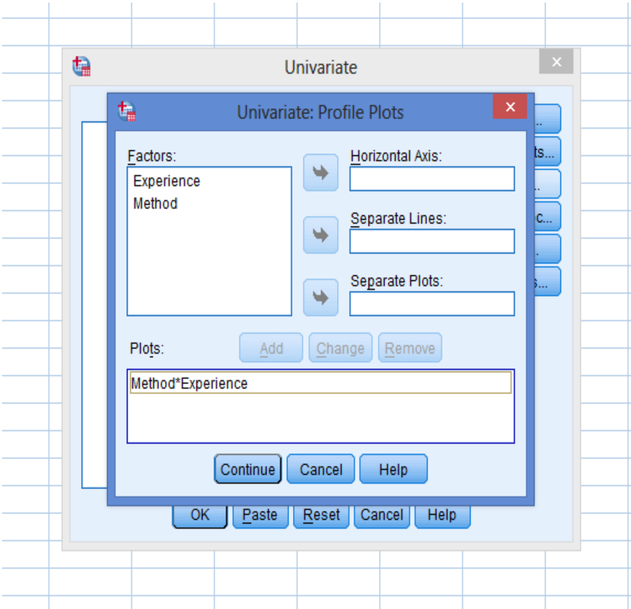
Go to 'Analyze', 'General Linear Model', and select 'Univariate' since you have only one dependent variable



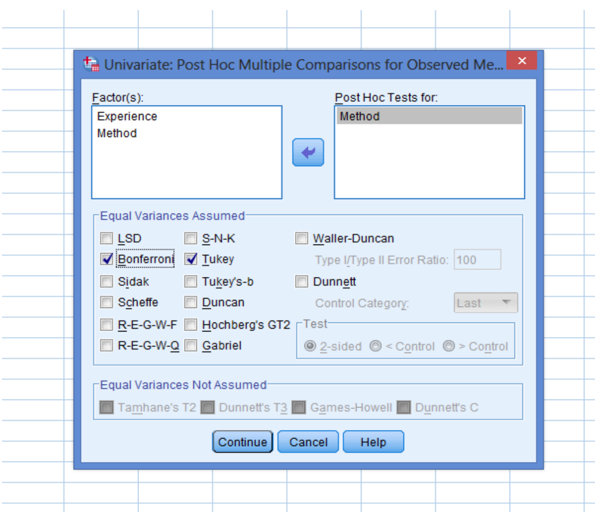
Place 'Score' in the Dependent variable box and 'Experience' and 'Method' in the Fixed Factor(s) box.



In the options menu we want to make sure 'Descriptive statistics", 'Estimates of Effect Size', 'Observed power', and 'Homogeneity test' are selected. We also want to display group means for 'Experience', 'Method' and 'Experience*Method'. Select 'Continue'



We also would like to see plots so under the plots menu. Place 'Method' in the Horizontal Axis box and 'Experience' in the Separate lines box. Select 'Add' to add this plot then 'Continue'



Since we have three groups we will need to perform a post hoc test if we see group significance. In the Post Hoc box add Method to the box for Post Hoc test and select Bonferoni and Tukey as the post hoc test to run. Select 'Continue'.

This will take you back to the Univariate box.

Select 'OK' in the Univariate box. To run the analysis.

SELECTED SPSS OUTPUT

Descriptive Statistics

Descriptive Statistics

Dependent Variable: Score

Experience	Method	Mean	Std. Deviation	N
experienced	in person	61.6667	11.81454	3
	hybrid	73.7500	1.76777	2
	online	83.3333	6.29153	3
	Total	72.8125	12.35180	8
not experienced	in person	65.0000	8.66025	3
	hybrid	90.8333	8.03638	3
	online	61.2500	5.30330	2
	Total	73.7500	15.69804	8
Total	in person	63.3333	9.44281	6
	hybrid	84.0000	10.98294	5
	online	74.5000	13.15770	5
	Total	73.2813	13.65402	16

Levene's Test

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Score

F	df1	df2	Sig.
1.779	5	10	.205

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Experience + Method + Experience * Method

ANOVA table

Tests of Between-Subjects Effects

Dependent Variable: Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	2127.734[a]	5	425.547	6.363	.007	.761	31.817	.934
Intercept	81407.440	1	81407.440	1217.308	.000	.992	1217.308	1.000
Experience	1.190	1	1.190	.018	.897	.002	.018	.052
Method	959.391	2	479.696	7.173	.012	.589	14.346	.833
Experience * Method	951.827	2	475.913	7.116	.012	.587	14.233	.830
Error	668.750	10	66.875					
Total	88718.750	16						
Corrected Total	2796.484	15						

a. R Squared = .761 (Adjusted R Squared = .641)

b. Computed using alpha = .05

Note:

A significant interaction effect exists between the independent variables of 'Method' and 'Experience'.

Always check for an interaction effect first when performing analysis on a higher order design. If a significant interaction exists, do not interpret the main interaction. Instead, perform a 'simple main effects' analysis.

'Simple main effects' analysis is a One-Way ANOVA which is conducted to reduce the analysis to the levels of the independent variables in order to examine the cause of the interaction effects.

In this case, we wish to compare the cell means for the three teaching methods for each experience level horizontally in terms of the data chart (Figure 1.).

Post Hoc analysis

Multiple Comparisons

Dependent Variable: Score

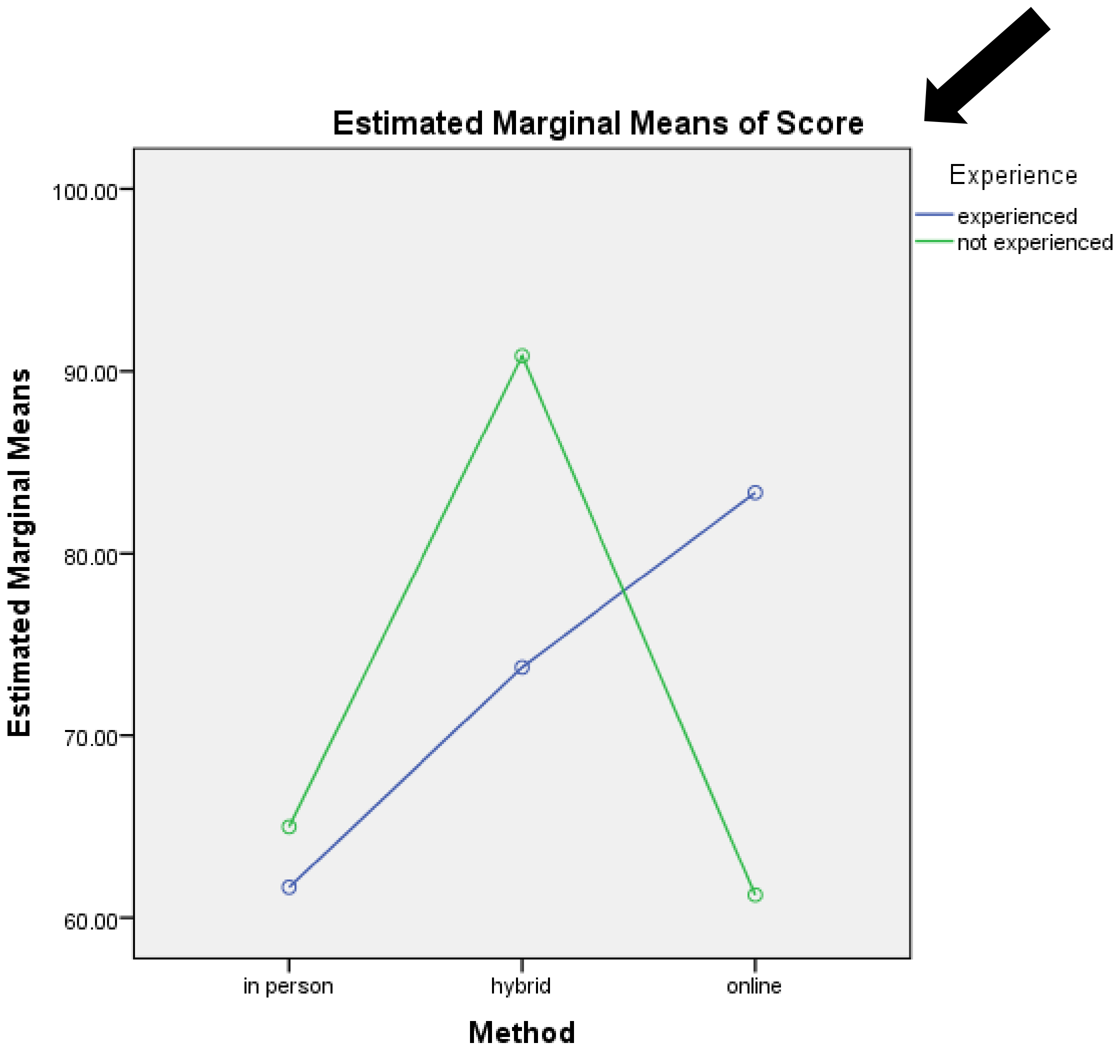
	(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	in person	hybrid	-20.6667*	4.95185	.005	-34.2412	-7.0922
		online	-11.1667	4.95185	.110	-24.7412	2.4078
	hybrid	in person	20.6667*	4.95185	.005	7.0922	34.2412
		online	9.5000	5.17204	.207	-4.6781	23.6781
	online	in person	11.1667	4.95185	.110	-2.4078	24.7412
		hybrid	-9.5000	5.17204	.207	-23.6781	4.6781
Bonferroni	in person	hybrid	-20.6667*	4.95185	.006	-34.8788	-6.4545
		online	-11.1667	4.95185	.143	-25.3788	3.0455
	hybrid	in person	20.6667*	4.95185	.006	6.4545	34.8788
		online	9.5000	5.17204	.288	-5.3441	24.3441
	online	in person	11.1667	4.95185	.143	-3.0455	25.3788
		hybrid	-9.5000	5.17204	.288	-24.3441	5.3441

Based on observed means.

The error term is Mean Square(Error) = 66.875.

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

Interaction plot



Investigating Simple Main Effects

There are two ways to analyze simple main effects. The figures below show both the horizontal and vertical way to analyze the effects.

Figure 1. Simple Main Effects in a Horizontal Direction.

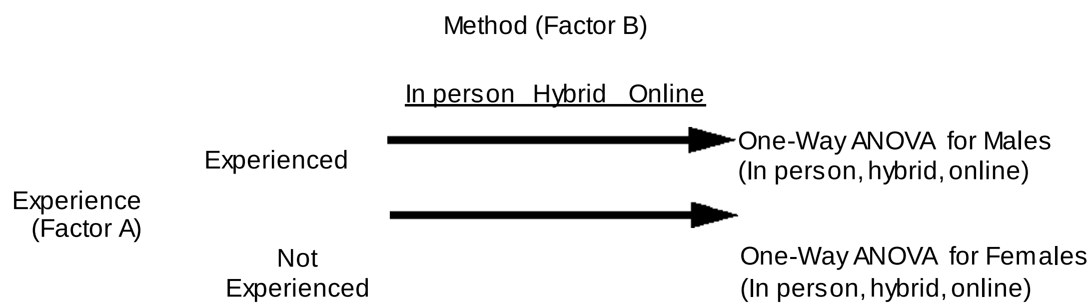
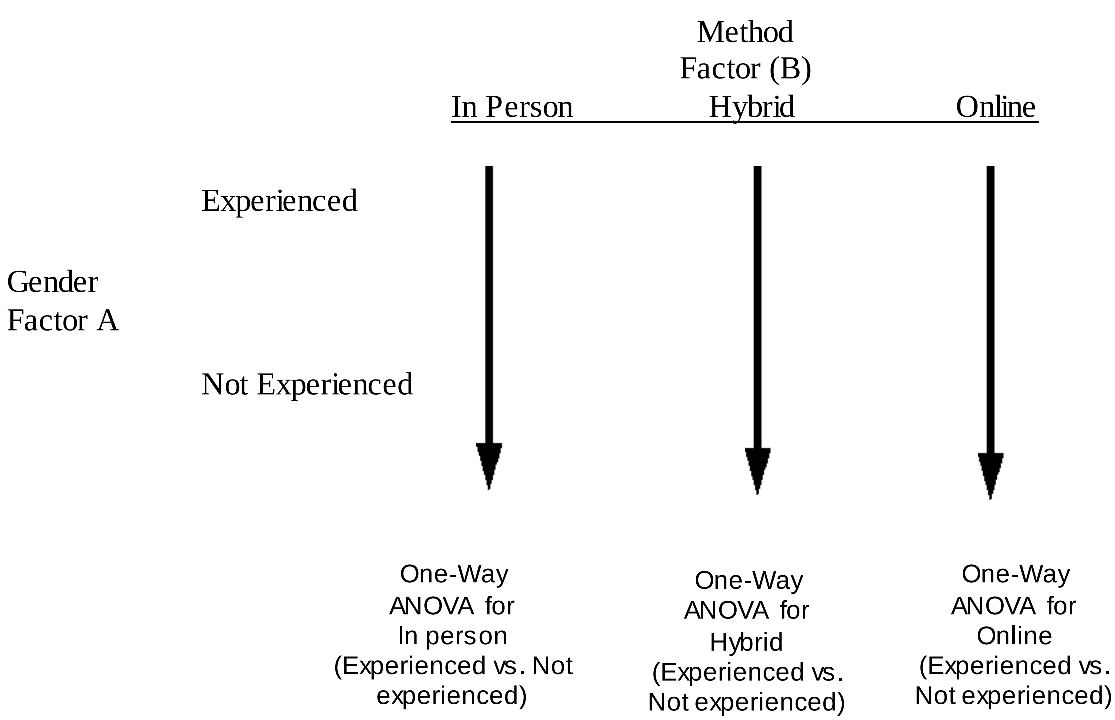


Figure 2. Simple Main Effects in a Vertical Direction.



If one of the variables in the analysis is an attribute variable such as gender and another variable is an active variable such as method, performing a simple main effects analysis within each gender level is sufficient. Since gender cannot be randomly assigned, it makes sense to answer the following questions:

(a) Given females, which method (1, 2, or 3) works better?

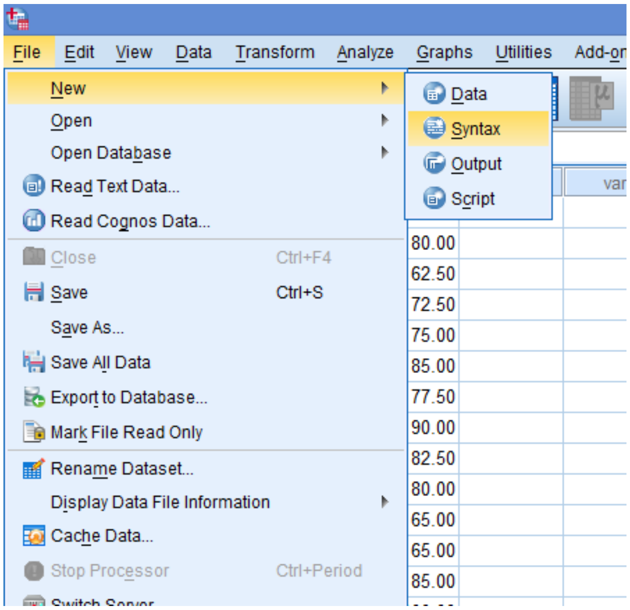
(b) Given males, which method (1, 2, or 3) works better?

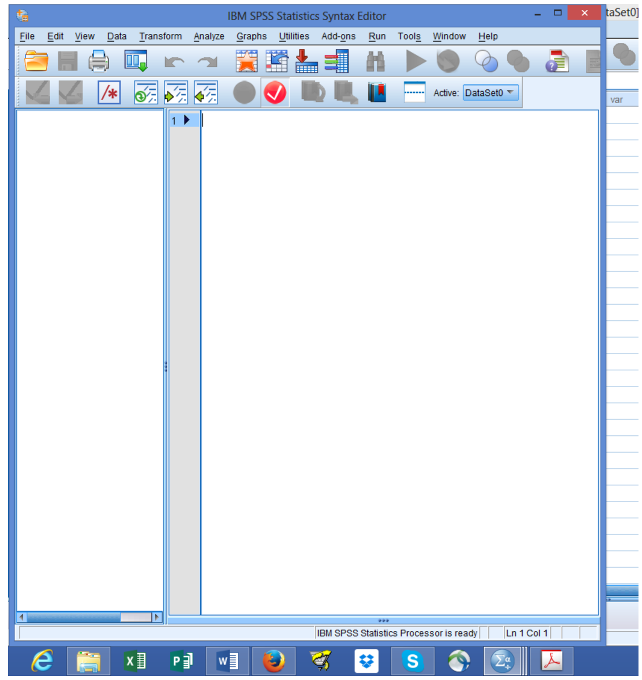
Instead of conducting a simple main effects analysis as described above, many researchers will use an alternative method to understand the nature of a significant interaction. In the alternative method, all pair wise comparisons among all cell means are made using a post hoc test such as the Scheffe′ test.

In our case, experience will be the assigned (moderator) variable because it is intrinsic to the participant and method will be the active (focal) variable because it is determined by the researcher. We are assuming that the effect of the method depends on experience. For more information about simple main effects, please read the Interaction handout (Oshima & McCarty 2000) available at http://coeweb.gsu.edu/coshima/statistics_2.htm

Simple main analysis can be done in SPSS using Syntax. If you are not familiar with how to use syntax, the SPSS Tips and Tricks will give you a short overview of what it is and how to use it. The example that follows just shows a little on how to use SPSS syntax.

Syntax for simple main effects

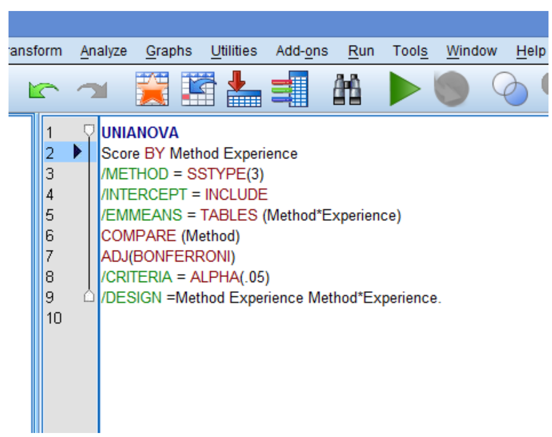


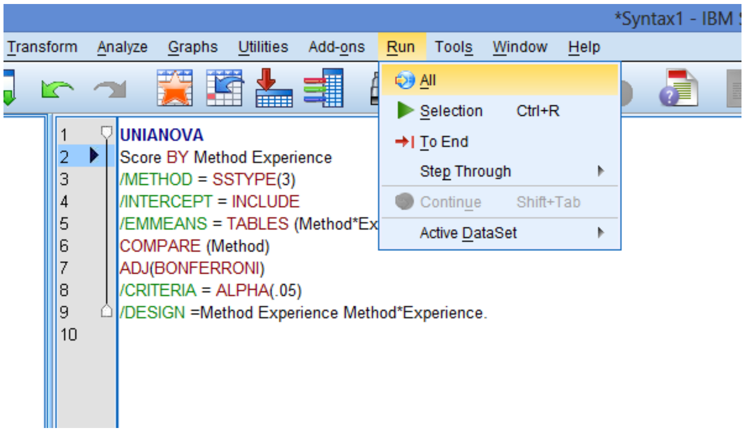


With the data open, navigate to 'File', 'New', 'Syntax' and a new syntax editor will pop up

Copy and paste the following directly into the syntax editor as it is written.

```
UNIANOVA
Score BY Method Experience
/METHOD = SSTYPE(3)
/INTERCEPT = INCLUDE
/EMMEANS = TABLES (Method*Experience)
COMPARE (Method)
ADJ(BONFERRONI)
/CRITERIA = ALPHA(.05)
/DESIGN =Method Experience Method*Experience.
```





Finally select 'Run', 'All'

SPSS Output

Descriptive statistics

Between-Subjects Factors

		Value Label	N
Method	1.00	in person	6
	2.00	hybrid	5
	3.00	online	5
Experience	1.00	experienced	8
	2.00	not experienced	8

Regular ANOVA table

Tests of Between-Subjects Effects

Dependent Variable: Score

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2127.734[a]	5	425.547	6.363	.007
Intercept	81407.440	1	81407.440	1217.308	.000
Method	959.391	2	479.696	7.173	.012
Experience	1.190	1	1.190	.018	.897
Method * Experience	951.827	2	475.913	7.116	.012
Error	668.750	10	66.875		
Total	88718.750	16			
Corrected Total	2796.484	15			

a. R Squared = .761 (Adjusted R Squared = .641)

Cell means

Estimates

Dependent Variable: Score

Method	Experience	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
in person	experienced	61.667	4.721	51.147	72.187
	not experienced	65.000	4.721	54.480	75.520
hybrid	experienced	73.750	5.783	60.866	86.634
	not experienced	90.833	4.721	80.313	101.353
online	experienced	83.333	4.721	72.813	93.853
	not experienced	61.250	5.783	48.366	74.134

Bonferroni Post Hoc test

Pairwise Comparisons

Dependent Variable: Score

Experience	(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
experienced	in person	hybrid	-12.083	7.465	.410	-33.509	9.342
		online	-21.667*	6.677	.026	-40.830	-2.503
	hybrid	in person	12.083	7.465	.410	-9.342	33.509
		online	-9.583	7.465	.685	-31.009	11.842
	online	in person	21.667*	6.677	.026	2.503	40.830
		hybrid	9.583	7.465	.685	-11.842	31.009
not experienced	in person	hybrid	-25.833*	6.677	.009	-44.997	-6.670
		online	3.750	7.465	1.000	-17.676	25.176
	hybrid	in person	25.833*	6.677	.009	6.670	44.997
		online	29.583*	7.465	.008	8.158	51.009
	online	in person	-3.750	7.465	1.000	-25.176	17.676
		hybrid	-29.583*	7.465	.008	-51.009	-8.158

Based on estimated marginal means

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

b. Adjustment for multiple comparisons: Bonferroni.

Simple Main Effects ANOVA table

Univariate Tests

Dependent Variable: Score

Experience		Sum of Squares	df	Mean Square	F	Sig.
experienced	Contrast	706.510	2	353.255	5.282	.027
	Error	668.750	10	66.875		
not experienced	Contrast	1417.708	2	708.854	10.600	.003
	Error	668.750	10	66.875		

Each F tests the simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

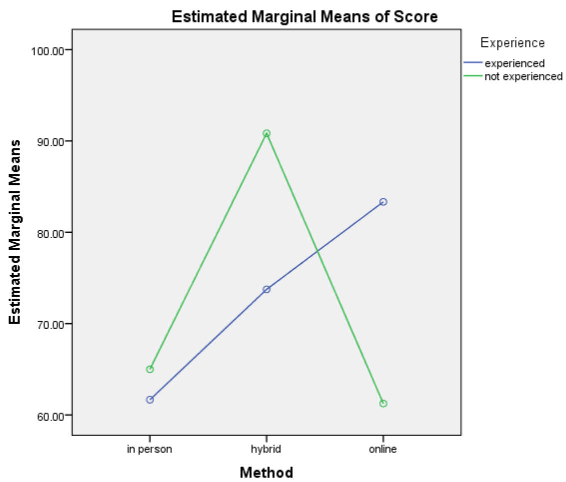
TWO WAY ANOVA with Significant Interaction

Example Reporting of Results

A two-way analysis of variance was conducted to investigate the effect of three teaching methods on math concept retention. The two independent variables in the analysis were method and experience. The interaction of the method factor by experience was significant, $F(2,10) = 7.12$, $p = .012$, suggesting that method is moderated through experience (see Figure 1).

Figure 1.

Estimated Marginal Means



A simple main effects analysis using method as the focal variable indicated the mean score for the methods were significantly different for those with experience, $F(2,10) = 5.82$, $p = .027$ as well as those without experience, $F(2,10) = 10.60$, $p = .003$. A follow up Bonferroni post hoc analysis shows that for students with previous online experience, the mean online score is significantly higher than the mean in person score. The post hoc results also show that the hybrid score is significantly higher than both the in person score and the online score for students who do not have previous online experience. Table 1 presents the number of subject, means, and standard deviations for all the groups. Table 2 presents the analysis of variance summary.

Table 1

Descriptive statistics

Experience		Methods			
		In person	Hybrid	Online	Combined
Experienced	Number of Subjects	3	2	3	8
	Mean Scores	61.67	73.75	83.33	72.81
	Standard deviation	11.81	1.77	6.29	12.35
Not Experienced	Number of Subjects	3	3	2	8
	Mean Scores	65.00	90.83	61.25	73.75
	Standard deviation	8.66	8.04	5.30	15.70
Combined	Number of Subjects	6	5	5	16
	Mean Scores	63.33	84.00	74.50	73.28
	Standard deviation	9.44	10.98	13.16	13.65

Table 2.

Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Squares*	*F value*	*p value*
Method	959.39	2	479.70	7.17	.012
Experience	1.19	1	1.19	.018	.897
Method* Experience	951.83	2	475.91	7.12	.012
Error	668.75	10	66.86		

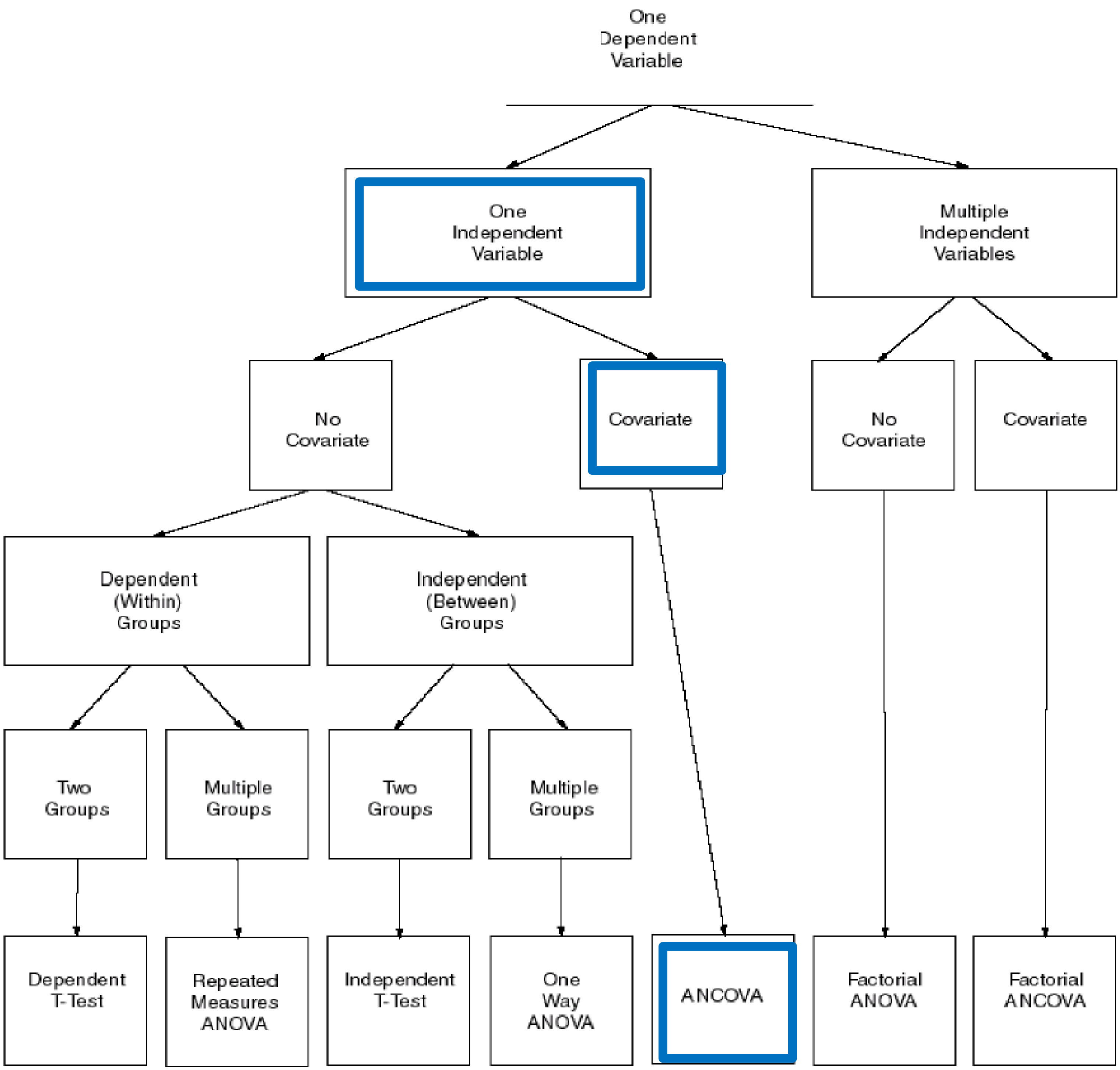
When those without experience are taught new math concepts using the hybrid method, they have significantly higher concept retention scores than the other methods. Those with experience had significantly higher online scores than in person scores. Due to these results, it is recommended that when teaching new math concepts, teachers should take students past online experiences into consideration when selecting a teaching method.

ANALYSIS OF COVARIANCE

One-Way ANCOVA

PROCEDURAL MODEL: OVERVIEW

Analysis of Covariance



One Way ANCOVA

Example Problem

A personnel manager wished to evaluate the effect of positive and negative reinforcement on tardiness in a large manufacturing plant. A group of 30 chronic late arrivers were identified based on their previous tardiness records. They were then randomly assigned in equal numbers to one of three study groups: (1) positive reinforcement when on time, (2) negative reinforcement when late, and (3) no reinforcement. After a 10 week treatment period, data was collected on the number of tardies over an additional 10 week period. The data below presents the number of tardies for 10 weeks prior to the intervention and 10 weeks following termination of the treatment.

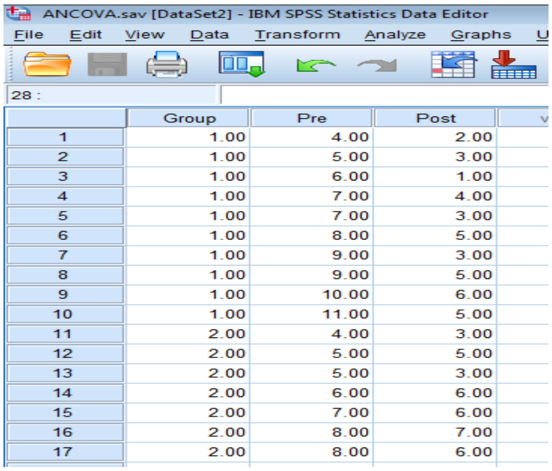
Table 1.

Number of Tardies

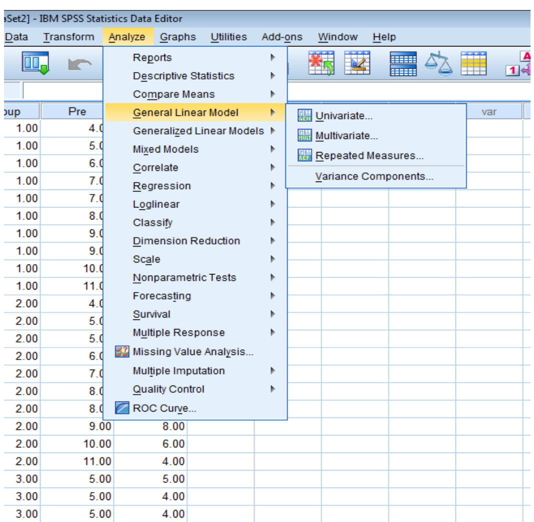
Type of Reinforcement

1. Positive Reinforcement		2. Negative Reinforcement		3. No reinforcement	
Pre	Post	Pre	Post	Pre	Post
4	2	4	3	5	5
5	3	5	5	5	4
6	1	5	3	5	4
7	4	6	6	6	8
7	3	7	6	8	8
8	5	8	7	8	9
9	3	8	6	9	7
9	5	9	8	10	10
10	6	10	6	10	8
11	5	11	4	7	10

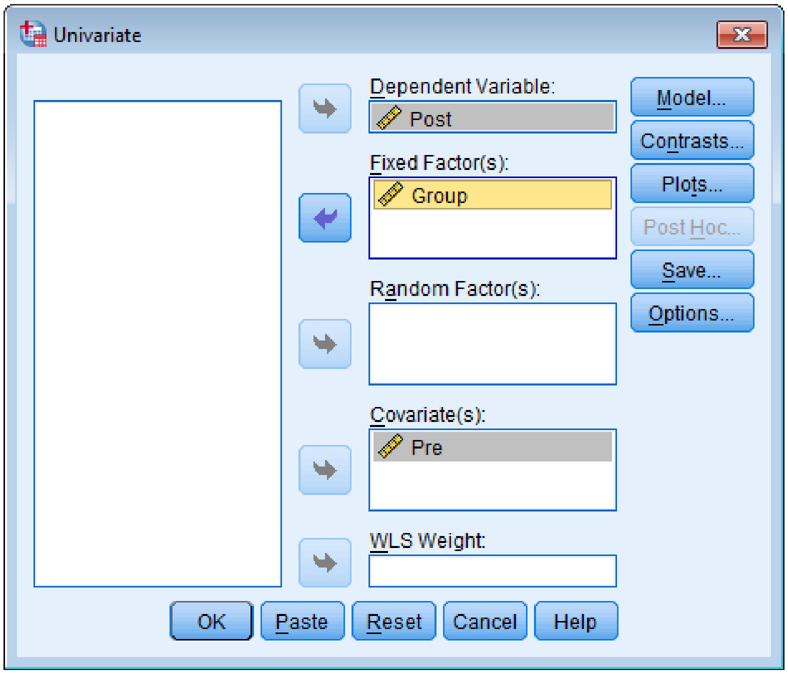
One Way ANCOVA
SPSS Procedures



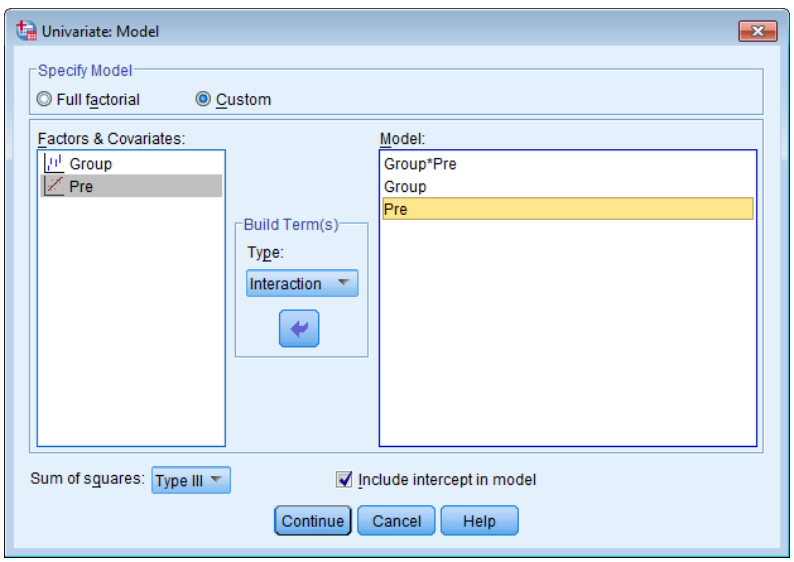
Define three variables for the ANCOVA: ‘Group’, ‘Pre’, and ‘Post’. Assign appropriate variable labels to each level of the ‘Group’ factor.



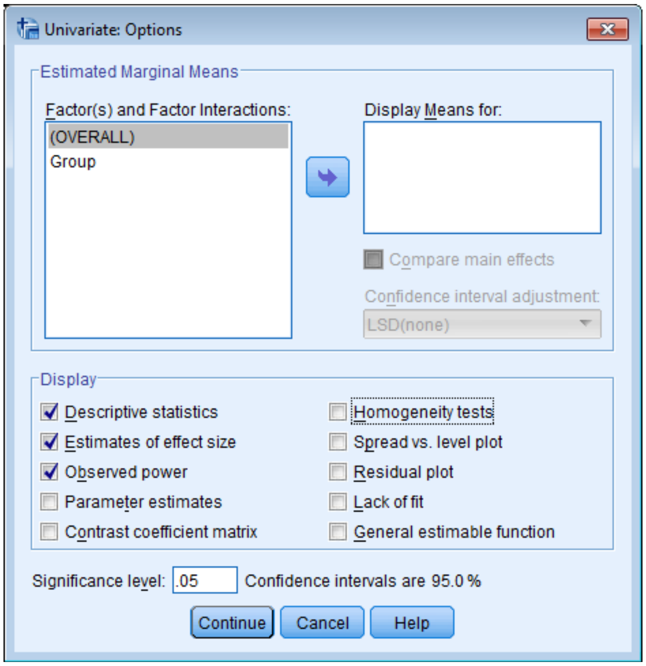
Navigate to ‘Analyze’, ‘General Linear Model’, ‘Univariate’



‘Post’ is the dependent variable, ‘Group’ is the fixed factor and ‘Pre’ is the covariate.



In the model menu, we want to specify a custom model. Make sure that custom is chosen and then highlight both ‘Group’ and ‘Pre’ and place that into the model box, then place ‘Group’ and ‘Pre’ by themselves in the model box. Select ‘Continue’



In the options menu make sure you check off 'Descriptive statistics', 'Estimates of effect size', and 'Observed Power'. Select 'Continue' and then 'OK' to run the model.

One Way ANCOVA

Selected SPSS Output

Tests of Between-Subjects Effects

Dependent Variable: Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	106.272[a]	5	21.254	9.964	.000	.675	49.820	1.000
Intercept	3.907	1	3.907	1.832	.189	.071	1.832	.255
Group * Pre	4.704	2	2.352	1.103	.348	.084	2.205	.221
Group	4.369	2	2.184	1.024	.374	.079	2.048	.207
Pre	39.302	1	39.302	18.424	.000	.434	18.424	.984
Error	51.195	24	2.133					
Total	1054.000	30						
Corrected Total	157.467	29						

a. R Squared = .675 (Adjusted R Squared = .607)

b. Computed using alpha = .05

The interaction is not significant

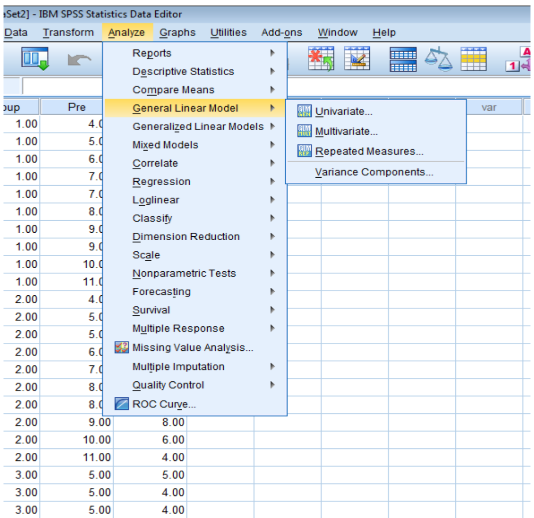
The assumption of homogeneity of regression slopes (are the slopes parallel?) is tested in the interaction between 'GP' * 'PRE'. If the interaction is NOT significant, the assumption of homogeneity of regression slopes is found tenable (the slopes are parallel).

In this example, the interaction is not significant; therefore the assumption of homogeneity of regression slopes is tenable.

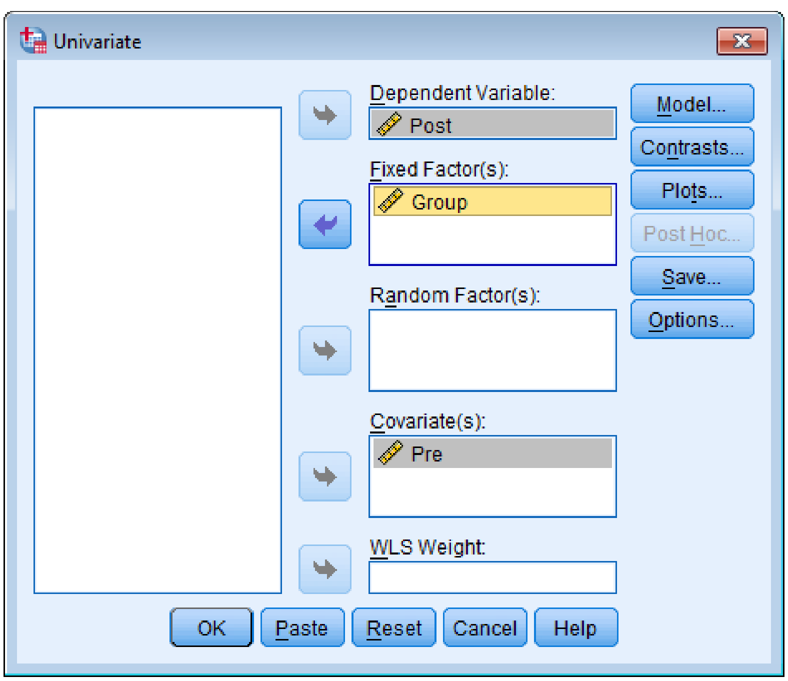
One Way ANCOVA

SPSS Procedures (Part 2)

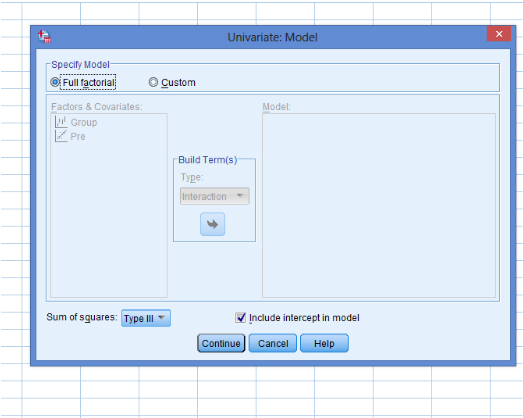
Test of significance. Once the assumption of homogeneity of regression slopes is found tenable, the ANCOVA is repeated using the 'Full Factorial' Model.



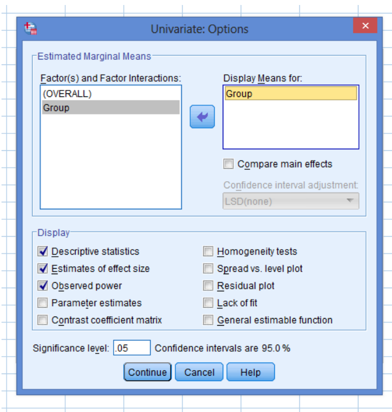
Navigate to 'Analyze', 'General Linear Model', 'Univariate'



"Post' is the dependent variable, 'Group' is the fixed factor and 'Pre' is the covariate.



This time we are going to run the full factorial model. Make sure this option is selected.



In the options box we want to display the means for the groups so make sure 'Group' is in the display means box. Also make sure 'Descriptive statistics', 'Estimates of effect size', and 'Observed Power' are selected. Select 'Continue' and then 'OK' to run the model.

One-Way ANCOVA

Selected SPSS Output

Descriptive Statistics

Dependent Variable: Post

Group	Mean	Std. Deviation	N
1.00	3.7000	1.56702	10
2.00	5.4000	1.64655	10
3.00	7.3000	2.26323	10
Total	5.4667	2.33021	30

These are the unadjusted means

Tests of Between-Subjects Effects

Dependent Variable: Post

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	101.567[a]	3	33.856	15.747	.000	.645	47.241	1.000
Intercept	4.989	1	4.989	2.320	.140	.082	2.320	.311
Pre	36.701	1	36.701	17.070	.000	.396	17.070	.978
Group	70.456	2	35.228	16.385	.000	.558	32.771	.999
Error	55.899	26	2.150					
Total	1054.000	30						
Corrected Total	157.467	29						

a. R Squared = .645 (Adjusted R Squared = .604)

b. Computed using alpha = .05

Indicates at least one pair of means is significantly different.

Indication of a significant difference between *adjusted* means.

.

Group

Dependent Variable: Post

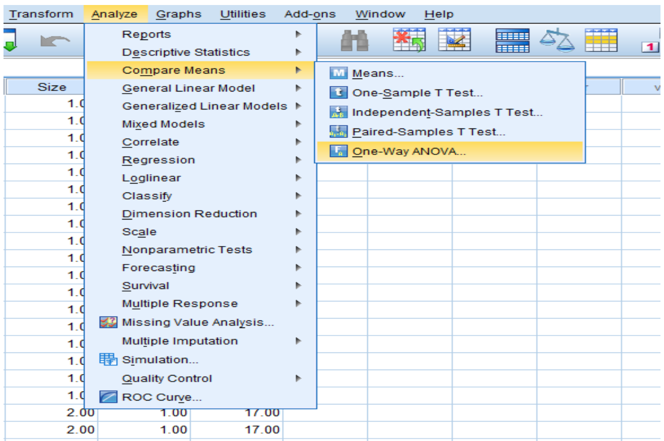
Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1.00	3.593[a]	.464	2.639	4.548
2.00	5.453[a]	.464	4.500	6.407
3.00	7.353[a]	.464	6.400	8.307

a. Covariates appearing in the model are evaluated at the following values: Pre = 7.4000.

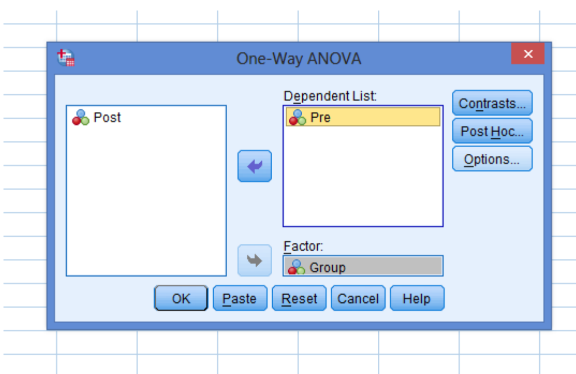
Adjusted means

As there are more than two groups and this significance cannot be interpreted by visual inspection, it is necessary to perform a Bryant-Paulson post hoc analysis for randomized designs

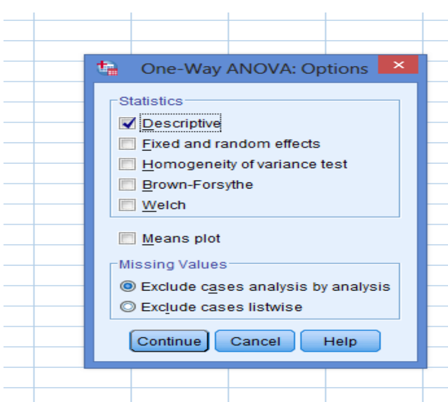
One Way ANCOVA
Bryant-Paulson Post Hoc Procedure in SPSS



We need to conduct a One Way ANOVA for the covariate. Go to 'Analyze', 'Compare Means', 'One-Way ANOVA'



Move 'Pre' to the Dependent List box. Move the variable 'Group' to the Factor box.



In the options box, make sure you select 'Descriptives'. We will use this information in the write up. Click on 'Continue' then 'OK' to run the analysis.

One Way ANCOVA
Selected SPSS output for Bryant Paulson Test

Pre treatment subgroup means. This will be used in the write up

Descriptives

Pre

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	7.6000	2.22111	.70238	6.0111	9.1889	4.00	11.00
2.00	10	7.3000	2.31181	.73106	5.6462	8.9538	4.00	11.00
3.00	10	7.3000	2.00278	.63333	5.8673	8.7327	5.00	10.00
Total	30	7.4000	2.11073	.38536	6.6118	8.1882	4.00	11.00

ANOVA

Pre

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.600	2	.300	.063	.939
Within Groups	128.600	27	4.763		
Total	129.200	29			

This is the between and within sums of squares that will be used in the Bryant-Paulson post hoc test

Bryant-Paulson equation:

$$BP = \frac{\overline{Y_1^*} - \overline{Y_2^*}}{\sqrt{\frac{MSw^*\left[1+\frac{MSbx}{MSwx}\right]}{n}}} \qquad \text{Remember: } \frac{MSbx}{MSwx} = F$$

The adjusted means are Group 1=3.593, Group 2 = 5.453, and Group 3 = 7.353

Group 2 vs Group 1

BP = $\dfrac{5.453 - 3.593}{\sqrt{\dfrac{2.150[1+.063]}{10}}} = \dfrac{1.86}{.4781} = 3.89$

Group 3 vs Group 2

BP = $\dfrac{7.353 - 5.453}{\sqrt{\dfrac{2.150[1+.063]}{10}}} = \dfrac{1.90}{.4781} = 3.97$

Group 3 vs Group 1

BP = $\dfrac{7.353 - 3.593}{\sqrt{\dfrac{2.150[1+.063]}{10}}} = \dfrac{3.76}{.47817} = 7.86$

$\boldsymbol{BP}_{critical} = \boldsymbol{BP}(.05,3,26)$ which is approximately equal to $\boldsymbol{BP}(.05,3,24) = 3.61$. See Stevens, Appendix B5, for table values. Since all calculated results are greater than the critical value it implies the difference is significant.

One Way ANCOVA
Example Results and Discussion

An analysis of covariance was conducted to determine whether the post treatment tardies for the three groups differed after adjustments were made for pre treatment differences. The assumption of equal regression slopes was tested and found tenable, F (2, 24) = 1.10, p = .348. The ANCOVA indicated at least one pair of means was significantly different, F(2,26) = 16.385, p < .001

A post hoc analysis using the Bryant-Paulson technique (randomized design, a = .05) indicated the mean tardies for the positive reinforcement group was significantly lower than the mean tardies for the negative reinforcement group. Furthermore, the mean tardies for the negative reinforcement group was significantly lower than the mean tardies for the no reinforcement group.

Table 1 presents the means, standard deviations, and adjusted means for all of the groups. Table 2 presents the analysis of covariance summary.

Table 1.

Mean Tardies, Standard Deviations, and Adjusted Means by Type of Reinforcement

	Pre Treatment		Post Treatment		
			Obtained		Adjusted
Reinforcement Type	*M*	*SD*	*M*	*SD*	*M*
Positive	7.60	2.22	3.70	1.57	3.59
Negative	7.30	2.31	5.40	1.65	5.45
None	7.30	2.00	7.30	2.26	7.35

Table 2.

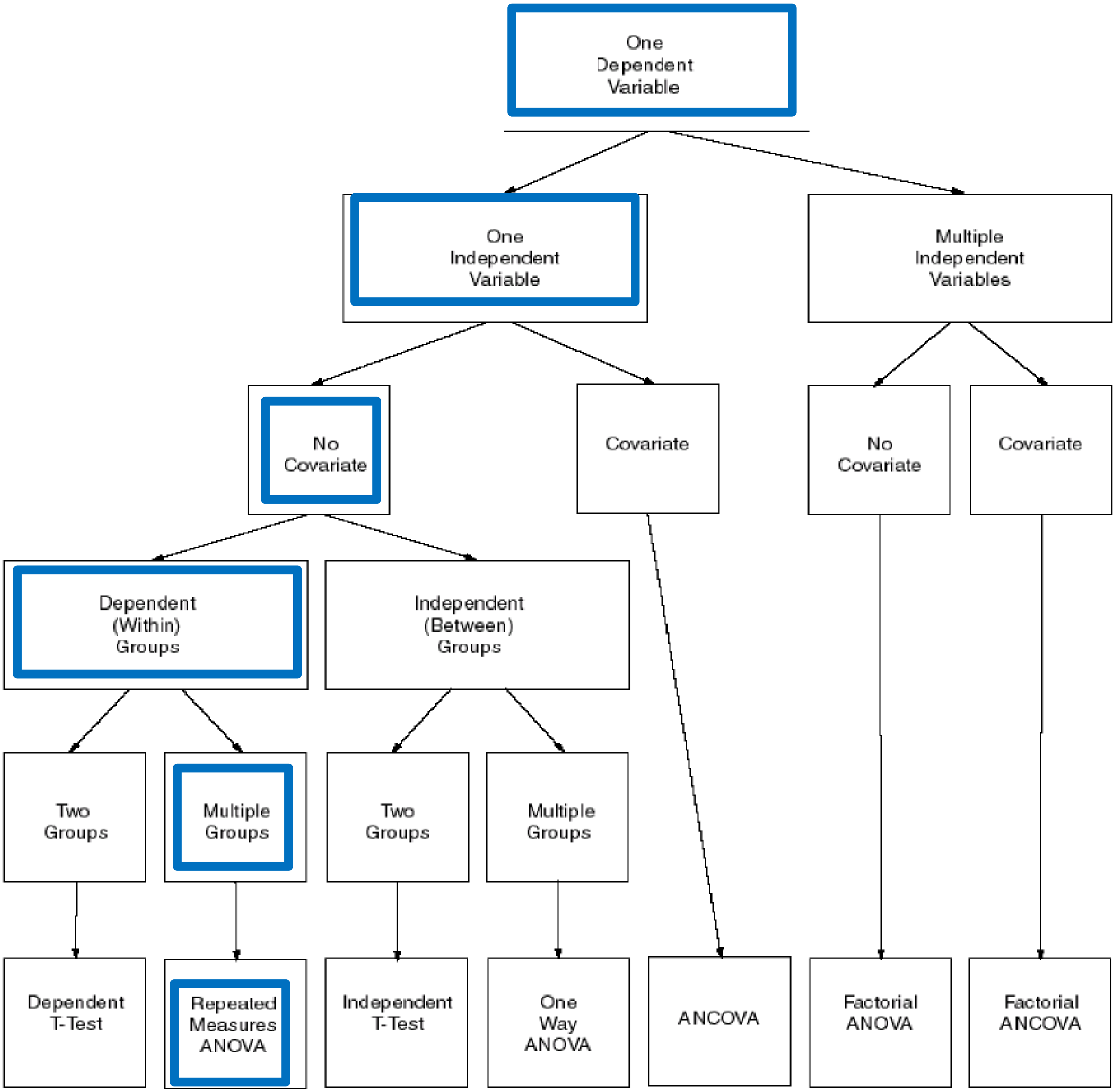
Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Square*	*F value*	*p value*
Pre Treatment	36.70	1	36.70	17.07	<.001
Group	70.46	2	35.23	16.39	<.001
Error	55.90	26	2.15		

Discussion

The method of positively reinforcing the employees when they are on time had the greatest impact on reducing tardiness. Negative reinforcement for lateness was not as effective as positive reinforcement for being on time, but was better than no reinforcement at all.

REPEATED MEASURES ANALYSIS



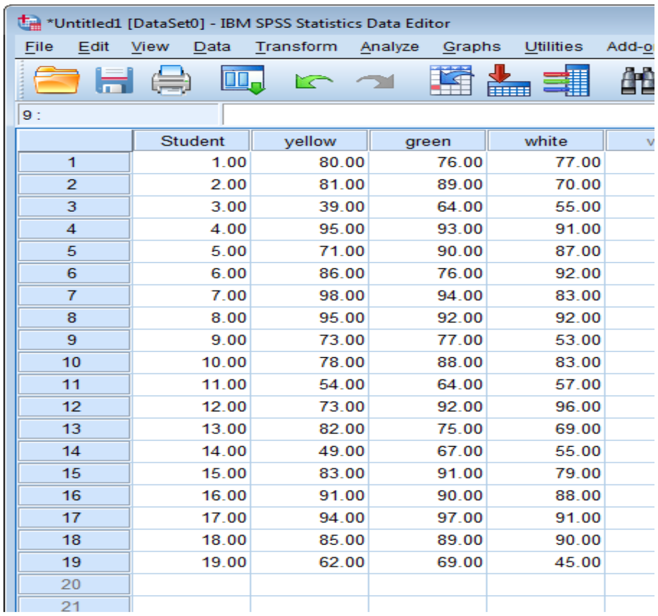
Example Problem
One Within Factor Design

A high school math teacher studies the impact of paper color on mathematics test scores. The hypothesis was test scores would be higher on tests taken on pastel green paper than tests taken on bright yellow paper or traditional white paper because the cool color would have a calming effect and reduce test-taking anxiety. Weekly math tests for an Algebra I class were printed in equal quantities on the three colors of paper. The order of treatment was counterbalanced such that one third of the students were randomly assigned to a different color each week over a three week period. Below are the test scores by student by paper color.

Table1

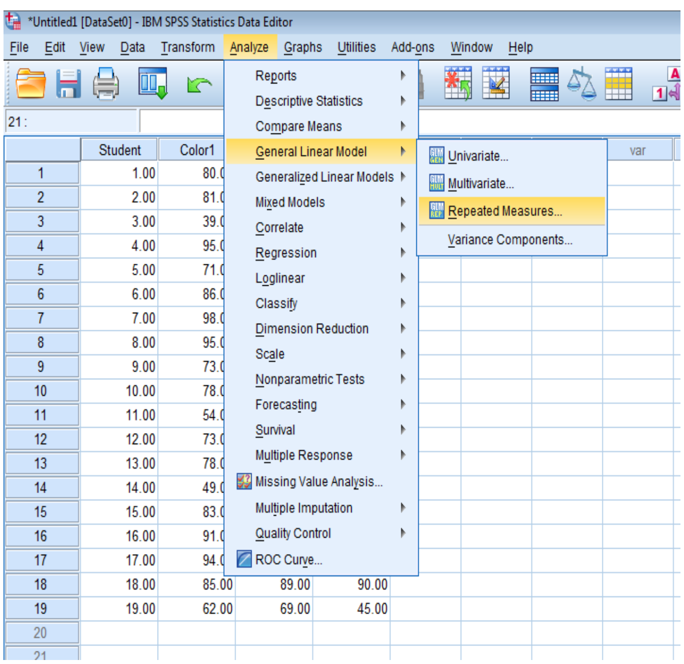
<u>Math Test Scores</u>

	Paper Color		
Student	Yellow	Green	White
1	80	76	77
2	81	89	70
3	39	64	55
4	95	93	91
5	71	90	87
6	86	76	92
7	98	94	83
8	95	92	92
9	73	77	53
10	78	88	83
11	54	64	57
12	73	92	96
13	82	75	69
14	49	67	55
15	83	91	79
16	91	90	88
17	94	97	91
18	85	89	90
19	62	69	45

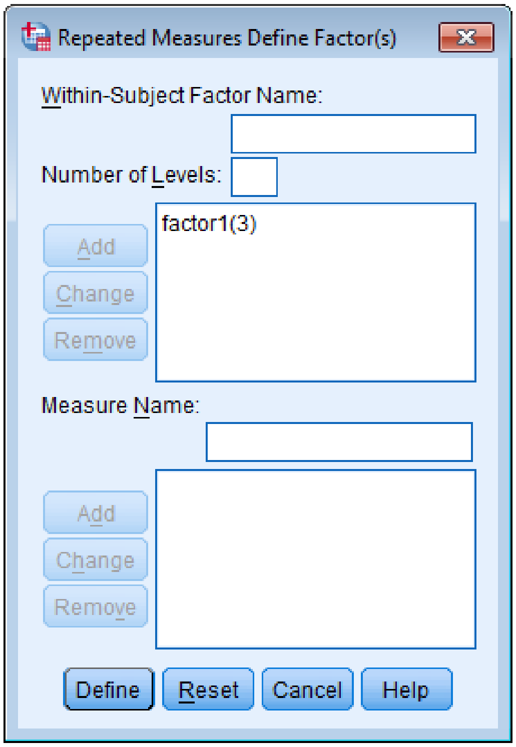


	Student	yellow	green	white
1	1.00	80.00	76.00	77.00
2	2.00	81.00	89.00	70.00
3	3.00	39.00	64.00	55.00
4	4.00	95.00	93.00	91.00
5	5.00	71.00	90.00	87.00
6	6.00	86.00	76.00	92.00
7	7.00	98.00	94.00	83.00
8	8.00	95.00	92.00	92.00
9	9.00	73.00	77.00	53.00
10	10.00	78.00	88.00	83.00
11	11.00	54.00	64.00	57.00
12	12.00	73.00	92.00	96.00
13	13.00	82.00	75.00	69.00
14	14.00	49.00	67.00	55.00
15	15.00	83.00	91.00	79.00
16	16.00	91.00	90.00	88.00
17	17.00	94.00	97.00	91.00
18	18.00	85.00	89.00	90.00
19	19.00	62.00	69.00	45.00
20				
21				

Define and enter initial data. Define four variables: 'Student', 'yellow', 'green', and 'white'. Note that this method of data entry is different from that used in ANOVA and ANCOVA type problems. You previously used this method of data entry to perform the Dependent T-Test, which is a special case of this single group repeated measures design.



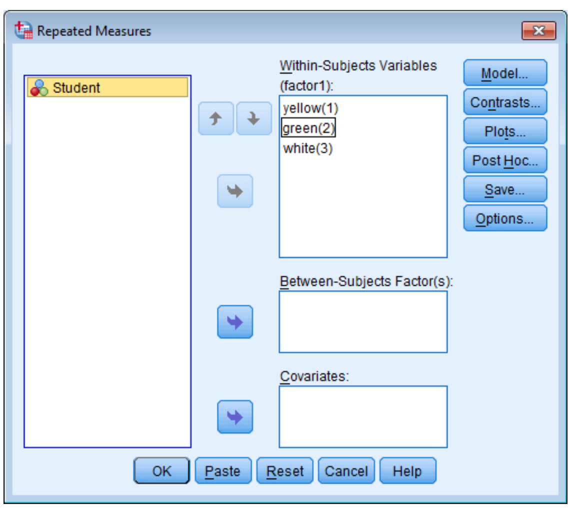
Navigate to 'Analyze', 'General Linear Model' and 'Repeated Measures'



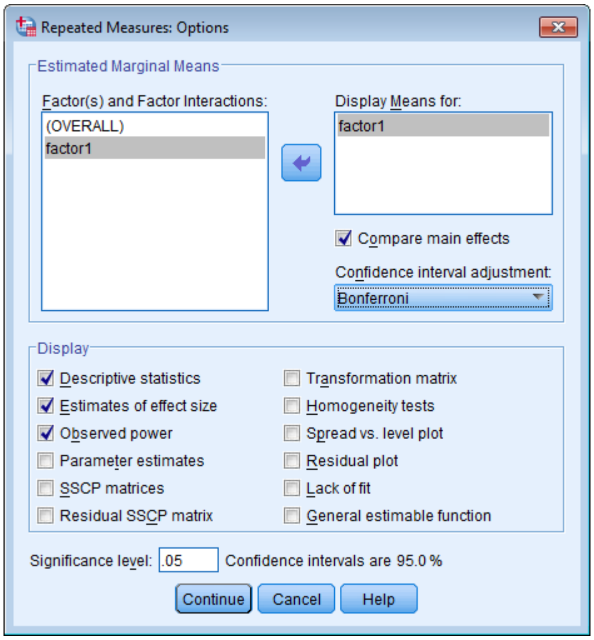
The ‘Repeated Measures Define Factor(s)’ dialog box is displayed. An entry of ‘factor1’ is displayed in the ‘Within-Subject Factor Name:’ text box. Enter the value ‘3’ (corresponding to the number of levels in the study) in the ‘Number of Levels’ text box. Click on the ‘Add’ button.

As a result of clicking on the ‘Add’ button, the term ‘factor1 (3)’ will be inserted into the central text box.

Click on the ‘Define’ button located in the upper right hand corner of the dialog box.



The ‘Repeated Measures’ dialog box is displayed. Highlight the variable ‘yellow’ in the left side text box and then click on the right pointing arrow to move the variable into the ‘Within-Subjects Variable (factor1):’ text box. Move the variables ‘green’ and ‘white’ to the ‘Within-Subjects Variable (factor1):’ text box in the same manner. Once all three variables are in the text box, click on the ‘Options’ button at the bottom right corner of the dialog box.



The 'Repeated Measures: Options' dialog box is displayed. Use the mouse pointer to check 'Descriptive statistics', 'Estimates of effect size' and 'Observed power'

In the 'Display' options section, we want to add 'factor1' to the box and select 'Compare main effects' and select 'Bonferroni' as the confidence interval adjustment.

Click on 'Continue' to return to the 'Repeated Measures' dialog box.

Click on 'OK' to perform the analysis. The results will be displayed in the SPSS Output Navigator window

ONE-WITHIN REPEATED MEASURES

Selected Results from SPSS Execution

Descriptive Statistics

	Mean	Std. Deviation	N
yellow	77.3158	16.42171	19
green	82.7895	11.07840	19
white	76.4737	16.23565	19

You can ignore this table of multivariate tests.

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
factor1	Pillai's Trace	.380	5.202[b]	2.000	17.000	.017	.380	10.404	.755
	Wilks' Lambda	.620	5.202[b]	2.000	17.000	.017	.380	10.404	.755
	Hotelling's Trace	.612	5.202[b]	2.000	17.000	.017	.380	10.404	.755
	Roy's Largest Root	.612	5.202[b]	2.000	17.000	.017	.380	10.404	.755

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.937	1.110	2	.574	.941	1.000	.500

This shows that the sphericity assumption was met.

Using the sphericity assumed line, we see that factor 1 is significant.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
factor1	Sphericity Assumed	446.877	2	223.439	4.141	.024	.187
	Greenhouse-Geisser	446.877	1.881	237.566	4.141	.027	.187
	Huynh-Feldt	446.877	2.000	223.439	4.141	.024	.187
	Lower-bound	446.877	1.000	446.877	4.141	.057	.187
Error(factor1)	Sphericity Assumed	1942.456	36	53.957			
	Greenhouse-Geisser	1942.456	33.859	57.369			
	Huynh-Feldt	1942.456	36.000	53.957			
	Lower-bound	1942.456	18.000	107.914			

Estimates

Measure: MEASURE_1

factor1	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
1	77.316	3.767	69.401	85.231
2	82.789	2.542	77.450	88.129
3	76.474	3.725	68.648	84.299

Bonferroni Post Hoc Results

Pairwise Comparisons

Measure: MEASURE_1

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	-5.474	2.239	.075	-11.383	.436
	3	.842	2.666	1.000	-6.193	7.878
2	1	5.474	2.239	.075	-.436	11.383
	3	6.316*	2.218	.032	.463	12.169
3	1	-.842	2.666	1.000	-7.878	6.193
	2	-6.316*	2.218	.032	-12.169	-.463

Based on estimated marginal means

Example Results and Discussion

A univariate repeated measure analysis of variance indicated a significant difference between the means of the three paper color treatments, F (2,36) = 4.14, p = .024, η_p^2 = .187. The assumption of sphericity was found to be tenable according to Mauchly's test (χ^2 (2) = 1.110, p = .574). A Bonferroni post hoc analysis revealed the mean for the green paper treatment was significantly higher than the white treatment. There was no significant difference between the means of the green and yellow treatments and the yellow and white treatments. Table 1 presents the means and standard deviations for the three paper colors. Table 2 presents the repeated measure analysis of variance summary.

Table 1

Means and Standard Deviations of Math Test Scores as a Function of Paper Color

Paper Color	*N*	*M*	*SD*
Green	19	82. 79	11 .08
Yellow	19	77. 32	16. 42
White	19	76. 47	16. 24

Table 2

Univariate Repeated Measure Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Square*	*F value*	*p value*
Color	446.88	2	223.44	4.14	.024
Error	1942.46	36	53.96		

ONE WITHIN REPEATED MEASURES

Example Results and Discussion

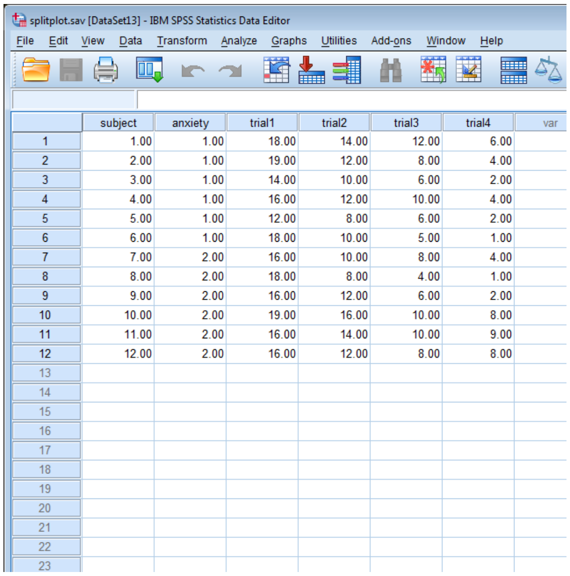
The analysis indicates some support for the idea that paper color could make a difference in math test scores. The pastel green definitely resulted in higher test scores when compared to the traditional white paper. However, the pastel green did not show a large enough difference over the bright yellow to be significant, calling into question the theory on the effect of cool colors. Further study is suggested.

Example Problem
One Within Factor and One Between Factor Design

A researcher wanted to investigate the effect of anxiety on math performance for fourth graders in a variety of testing time constraints. She came up with a 20 question multiplication test and gave it to twelve participants. For the first trial, she allowed participants one hour. For the second trial, participants had 45 min to take the test, the time for the third trial was 30 min and the time for the final trial was 15 min. Prior to giving the math test, she assessed students test anxiety level and students with low test anxiety were in the group one and those with high test anxiety were in the second group. The tests, however, were the same between groups. The data can be seen below [1].

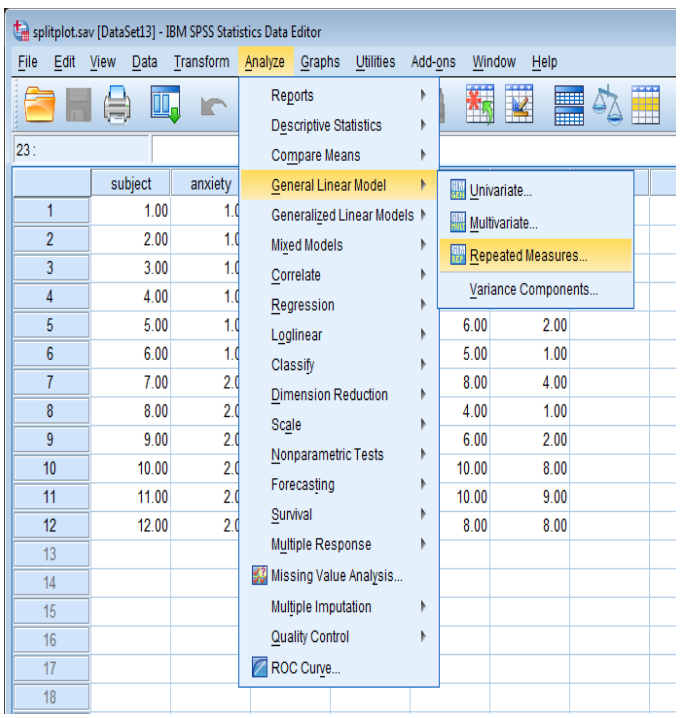
Subject	Anxiety	Trial 1	Trial 2	Trial 3	Trial 4
1	1	18	14	12	6
2	1	19	12	8	4
3	1	14	10	6	2
4	1	16	12	10	4
5	1	12	8	6	2
6	1	18	10	5	1
7	2	16	10	8	4
8	2	18	8	4	1
9	2	16	12	6	2
10	2	19	16	10	8
11	2	16	14	10	9
12	2	16	12	8	8

1. Data was adapted from UC Denver College of Nursing. Their example can be found at http://www.ucdenver.edu/academics/colleges/nursing/Documents/PDF/RepeatedMeasuresANOVA.pdf

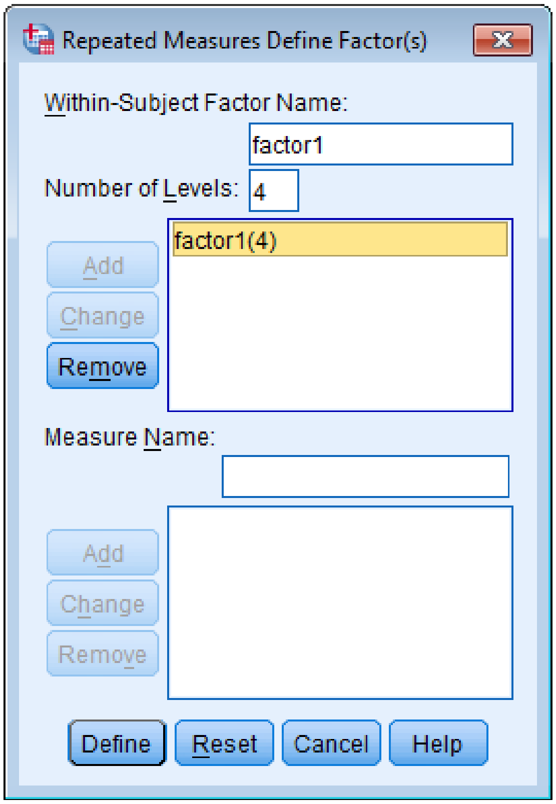


	subject	anxiety	trial1	trial2	trial3	trial4	var
1	1.00	1.00	18.00	14.00	12.00	6.00	
2	2.00	1.00	19.00	12.00	8.00	4.00	
3	3.00	1.00	14.00	10.00	6.00	2.00	
4	4.00	1.00	16.00	12.00	10.00	4.00	
5	5.00	1.00	12.00	8.00	6.00	2.00	
6	6.00	1.00	18.00	10.00	5.00	1.00	
7	7.00	2.00	16.00	10.00	8.00	4.00	
8	8.00	2.00	18.00	8.00	4.00	1.00	
9	9.00	2.00	16.00	12.00	6.00	2.00	
10	10.00	2.00	19.00	16.00	10.00	8.00	
11	11.00	2.00	16.00	14.00	10.00	9.00	
12	12.00	2.00	16.00	12.00	8.00	8.00	

Define and enter initial data. Define four variables: 'Subject', 'Anxiety', 'Trial 1', 'Trial 2', 'Trial 3', and 'Trial 4'.



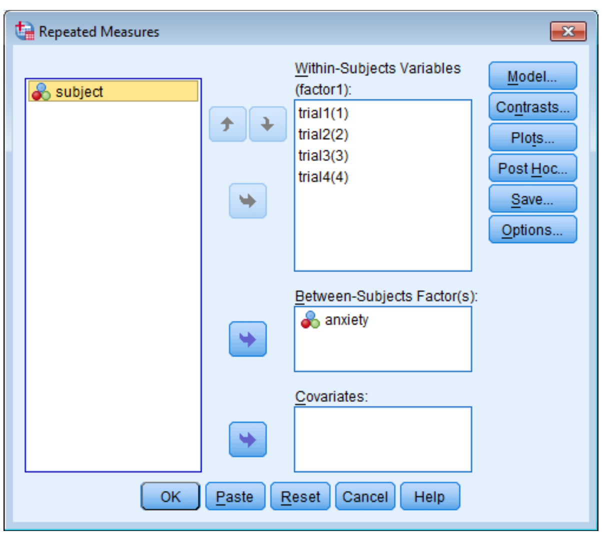
Navigate to 'Analyze', 'General Linear Model' and 'Repeated Measures'



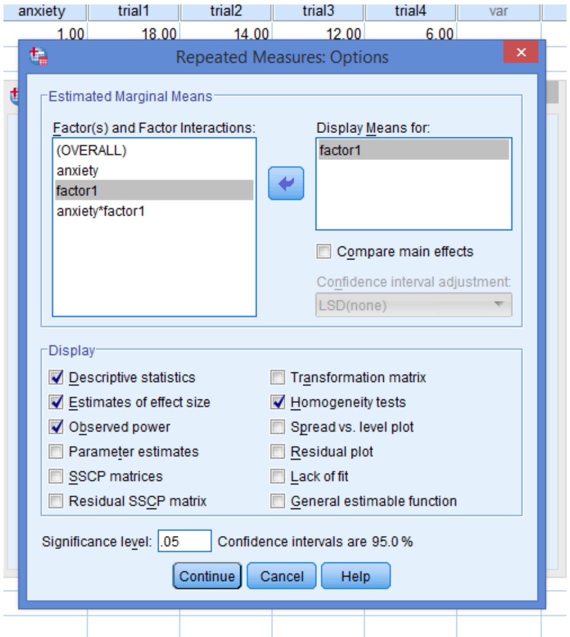
The 'Repeated Measures Define Factor(s)' dialog box is displayed. An entry of 'factor1' is displayed in the 'Within-Subject Factor Name:' text box. Enter the value '4' (corresponding to the number of levels in the study) in the 'Number of Levels' text box. Click on the 'Add' button.

As a result of clicking on the 'Add' button, the term 'factor1 (4)' will be inserted into the central text box.

Click on the 'Define' button located in the upper right hand corner of the dialog box.



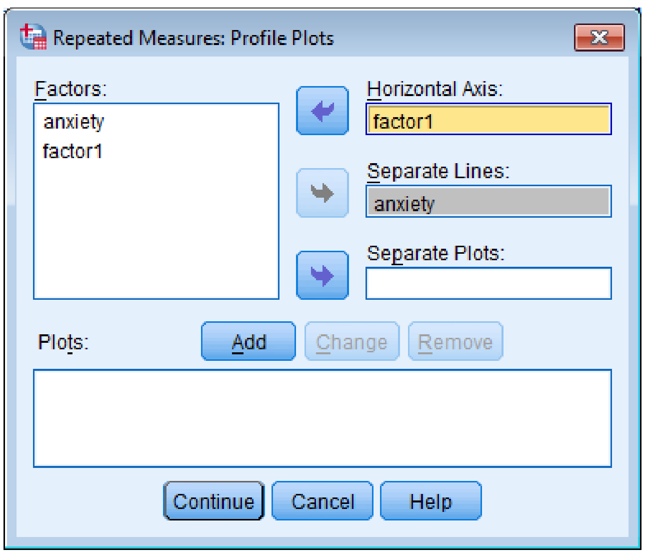
The 'Repeated Measures' dialog box is displayed. Highlight the variable 'trial 1' in the left side text box and then click on the right pointing arrow to move the variable into the 'Within-Subjects Variable (factor1):' text box. Move the variables 'Trial 2', 'Trial 3' and 'Trail 4' to the 'Within-Subjects Variable (factor1):' text box in the same manner. Now move 'anxiety' to the between subject factor. Once all variables are in the text box, click on the 'Options' button at the bottom right corner of the dialog box.



The 'Repeated Measures: Options' dialog box is displayed. Use the mouse pointer to check 'Descriptive statistics' ,'Estimates of effect size', 'Observed power', and 'Homogeneity test'.

In the 'Display' options section, we want to add 'factor1' to the box and select 'Compare main effects' and select 'Bonferroni' as the confidence interval adjustment.

Click on 'Continue' to return to the 'Repeated Measures' dialog box.



The final thing we want to do is to add some plots to the output. On the Repeated Measures Dialog box, select 'Plots'

Next add 'Factor1' to the 'Horizontal Axis' box and 'anxiety' to the 'Separate Lines' box.

Select 'Add' to add the plot then select 'Continue'

Click on 'OK' to perform the analysis. The results will be displayed in the SPSS Output Navigator window

Repeated Measures
Selected SPSS Output

Descriptive Statistics

	anxiety	Mean	Std. Deviation	N
trial1	1.00	16.1667	2.71416	6
	2.00	16.8333	1.32916	6
	Total	16.5000	2.06706	12
trial2	1.00	11.0000	2.09762	6
	2.00	12.0000	2.82843	6
	Total	11.5000	2.43086	12
trial3	1.00	7.8333	2.71416	6
	2.00	7.6667	2.33809	6
	Total	7.7500	2.41680	12
trial4	1.00	3.1667	1.83485	6
	2.00	5.3333	3.44480	6
	Total	4.2500	2.86436	12

You can ignore this table of multivariate tests.

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
factor1	Pillai's Trace	.961	64.854[b]	3.000	8.000	.000	.961	194.561	1.000
	Wilks' Lambda	.039	64.854[b]	3.000	8.000	.000	.961	194.561	1.000
	Hotelling's Trace	24.320	64.854[b]	3.000	8.000	.000	.961	194.561	1.000
	Roy's Largest Root	24.320	64.854[b]	3.000	8.000	.000	.961	194.561	1.000
factor1 * anxiety	Pillai's Trace	.479	2.451[b]	3.000	8.000	.138	.479	7.354	.408
	Wilks' Lambda	.521	2.451[b]	3.000	8.000	.138	.479	7.354	.408
	Hotelling's Trace	.919	2.451[b]	3.000	8.000	.138	.479	7.354	.408
	Roy's Largest Root	.919	2.451[b]	3.000	8.000	.138	.479	7.354	.408

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
factor1	.283	11.011	5	.053	.544	.701	.333

This shows that the sphericity assumption was met.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
factor1	Sphericity Assumed	991.500	3	330.500	128.627	.000	.928	385.881	1.000
	Greenhouse-Geisser	991.500	1.632	607.468	128.627	.000	.928	209.943	1.000
	Huynh-Feldt	991.500	2.102	471.773	128.627	.000	.928	270.329	1.000
	Lower-bound	991.500	1.000	991.500	128.627	.000	.928	128.627	1.000
factor1 * anxiety	Sphericity Assumed	8.417	3	2.806	1.092	.368	.098	3.276	.265
	Greenhouse-Geisser	8.417	1.632	5.157	1.092	.346	.098	1.782	.194
	Huynh-Feldt	8.417	2.102	4.005	1.092	.357	.098	2.295	.220
	Lower-bound	8.417	1.000	8.417	1.092	.321	.098	1.092	.157
Error(factor1)	Sphericity Assumed	77.083	30	2.569					
	Greenhouse-Geisser	77.083	16.322	4.723					
	Huynh-Feldt	77.083	21.016	3.668					
	Lower-bound	77.083	10.000	7.708					

The factor variable is significant, the interaction is not.

a. Computed using alpha = .05

Test of Equal Variance

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
trial1	3.312	1	10	.099
trial2	.156	1	10	.701
trial3	.266	1	10	.617
trial4	7.788	1	10	.019

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + anxiety

Within Subjects Design: factor1

ANOVA results for the between subject factor

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	4800.000	1	4800.000	280.839	.000	.966	280.839	1.000
anxiety	10.083	1	10.083	.590	.460	.056	.590	.107
Error	170.917	10	17.092					

a. Computed using alpha = .05

Bonferroni Post Hoc results

Pairwise Comparisons

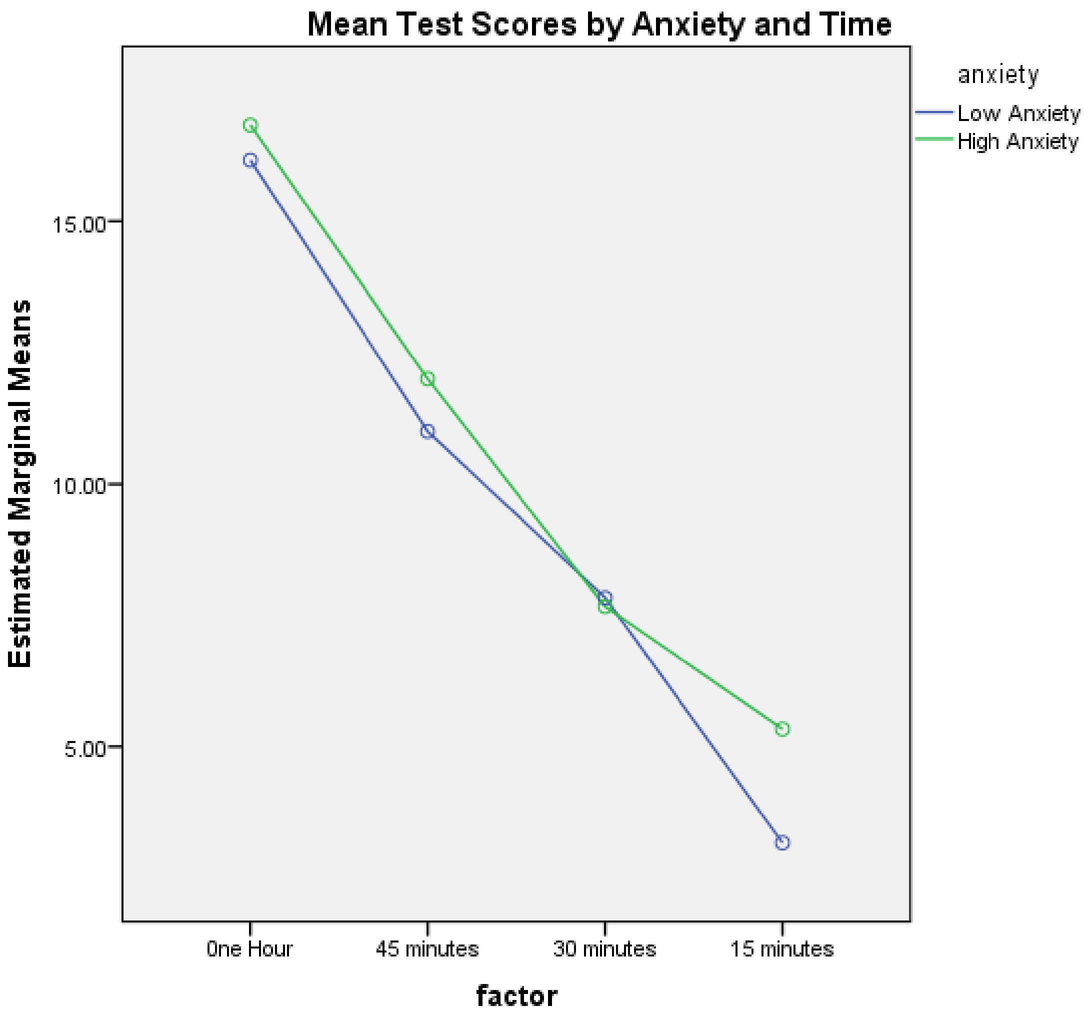
Measure: MEASURE_1

(I) factor1	(J) factor1	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
1	2	5.000*	.693	.000	2.728	7.272
	3	8.750*	.827	.000	6.038	11.462
	4	12.250*	.920	.000	9.236	15.264
2	1	-5.000*	.693	.000	-7.272	-2.728
	3	3.750*	.410	.000	2.407	5.093
	4	7.250*	.484	.000	5.662	8.838
3	1	-8.750*	.827	.000	-11.462	-6.038
	2	-3.750*	.410	.000	-5.093	-2.407
	4	3.500*	.394	.000	2.208	4.792
4	1	-12.250*	.920	.000	-15.264	-9.236
	2	-7.250*	.484	.000	-8.838	-5.662
	3	-3.500*	.394	.000	-4.792	-2.208

Based on estimated marginal means

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

b. Adjustment for multiple comparisons: Bonferroni.


Mean Test Scores by Anxiety and Time
anxiety
Low Anxiety
High Anxiety
Estimated Marginal Means
15.00
10.00
5.00
One Hour
45 minutes
30 minutes
15 minutes
factor

Example Results

A univariate repeated measure analysis of variance indicated a significant difference between the means of the four test trials, $F(3,30) = 128.63$, $p < .001 \eta_p^2$, = .928. The interaction between anxiety and test time was not significant, $F(3,30) = 2.81$, $p = .368$, $\eta_p^2 = .098$. The assumption of sphericity was found to be tenable according to the Mauchly's Teest of Sphericity ($\chi^2(5) = 11.011$, $p = .053$) . A Bonferroni post hoc analysis using revealed the mean difference was significant for all test times. Table 1 presents the means and standard deviations for the test times. Table 2 presents the repeated measure analysis of variance and the result of the between factor ANOVA. Figure 1 shows a graphical depiction of the mean test scores by anxiety level and test time.

Table 1

Means and Standard Deviations of Math Test Scores by Trial and anxiety level

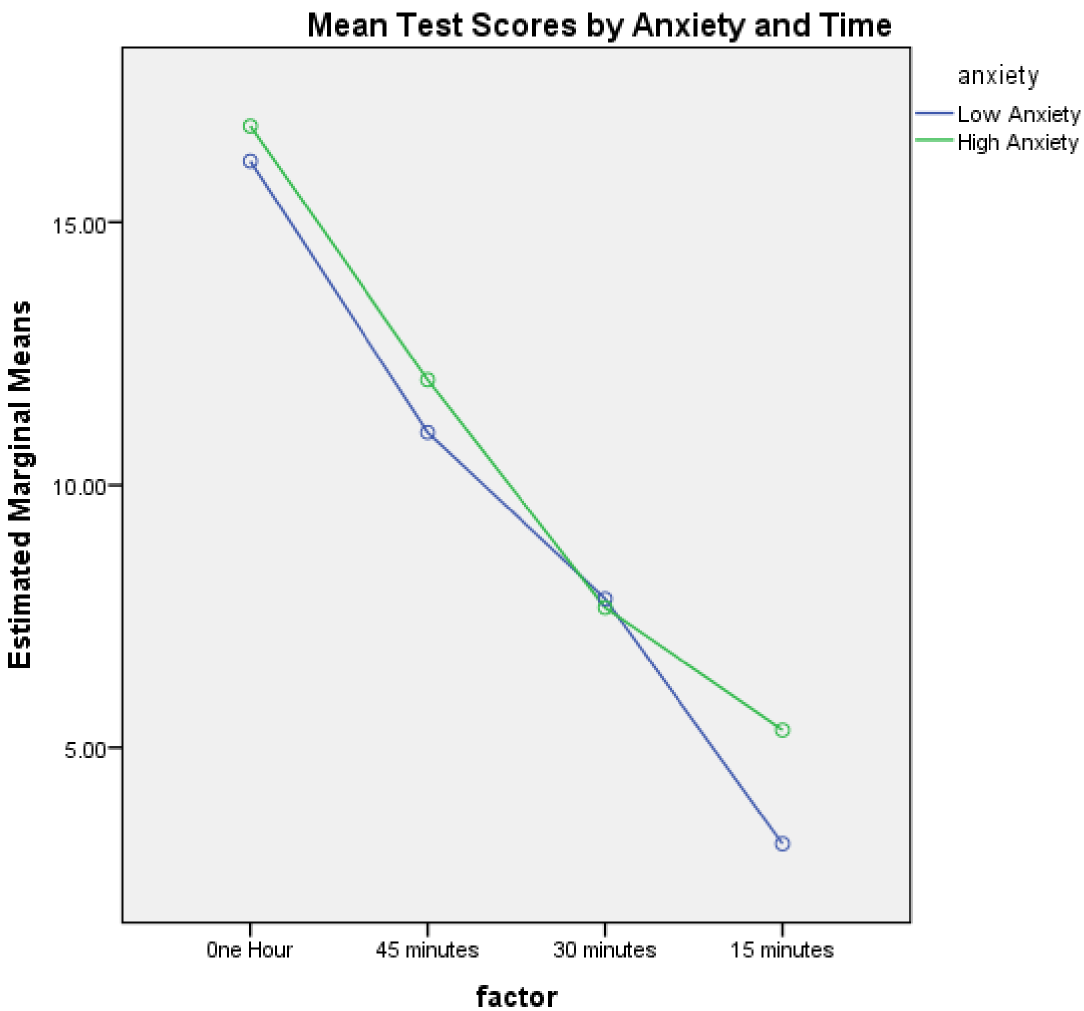
	Anxiety Level One			Anxiety Level Two			Total		
	N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Trial 1	6	16.17	2.71	6	16.17	2.71	6	16.17	2.71
Trial 2	6	11.00	2.10	6	11.00	2.10	6	11.00	2.10
Trial 3	6	7.83	2.71	6	7.83	2.71	6	7.83	2.71
Trial 4	6	3.17	1.83	6	3.17	1.83	6	3.17	1.83

Table 2

Univariate Repeated Measure Analysis of Variance Summary

Source	*Sum of Squares*	*DF*	*Mean Square*	*F value*	*p value*
Anxiety	10.08	1	10.08	.590	.460
Error	170.92	10	17.09		
Trial	991.50	3	330.5	128.63	<.001
Trial*Anxiety	8.42	3	2.81	1.09	.368
Error	77.08	30	2.57		

Figure 1.


Mean Test Scores by Anxiety and Time
anxiety
Low Anxiety
High Anxiety
Estimated Marginal Means
15.00
10.00
5.00
One Hour
45 minutes
30 minutes
15 minutes
factor

One Within and One Between REPEATED MEASURES

Example Discussion

The analysis indicated that there was a significant difference in test scores between test time conditions, however, there is not a significant difference in test scores between anxiety levels. In addition, the effect of test time did not depend on the anxiety level. In other words, this study showed that while the amount of time a student has to take a test affected the performance; it failed to reveal any effect of anxiety on the performance. The small sample size could have masked the effect of anxiety on test scores. Further study is suggested to see if there is indeed an effect of anxiety on test scores under different time constraints.