Department of Statistics and Operations Research

College of Science

King Saud University

Exercises

Non-parametric Statistics Methods

STAT 333

SPSS

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Course Description:

List of Topics:

1- Introduction, review of some parametric tests, the nonparametric statistical procedures.

2- **Testing data for normality**: Describing data and the normal distribution, computing and testing kurtosis and skewness for sample normality, Examining skewness and kurtosis for normality using statistical software packages.

3- The **Kolmogorov–Smirnov one-sample test**, performing the Kolmogorov–Smirnov one-sample test using statistical software packages.

4- **Comparing two related samples:** The **Wilcoxon signed rank and the sign test:** Confidence interval for the Wilcoxon signed rank test, performing the Wilcoxon Wilcoxon signed rank test and the sign test using statistical software packages.

5- **Comparing two unrelated samples:** The **Mann−Whitney U-test and the Kolmogorov−Smirnov two-sample test,** performing the Mann–Whitney U-Test and the Kolmogorov–Smirnov two-sample test using statistical software packages.

6- **Comparing more than two related samples:** The **Friedman test**, performing the Friedman test using statistical software packages.

7- **Comparing more than two unrelated samples:** the **Kruskal–Wallis H-test**, performing the Kruskal–Wallis H-test using statistical software packages.

8- **Comparing variables of ordinal or dichotomous scales**: Spearman rank-order, Point-Biserial, and Biserial correlations, performing the Spearman rank-order correlation, the Point-Biserial correlation and the Biserial correlation using statistical software packages.

9- The **χ2 Goodness-of-Fit Test (Category Frequencies not equal),** performing the χ2 goodness-of-Fit test using statistical software packages.

10- **The χ2 test for independence**, performing the χ2 test for independence using statistical software packages.

11- The Fisher exact test, computing the Fisher exact test for 2 × 2 tables, performing the Fisher exact test using statistical software packages.

12- Test for randomness: **The runs test**, performing the runs test using statistical packages, runs test referencing a custom value, performing the runs test for a custom value using statistical software packages.

Nonparametric Statistical Procedures
(RANKING DATA)

1. Male high school students completed the 1-mile run at the end of their 9th grade and the beginning of their 10th grade. The following values represent the differences between the recorded times. Notice that only one student's time improved (−2: 08). **Rank the values in Table 1** beginning with the student's time difference that displayed improvement.

TABLE 1

Participant	Value	Rank
1	0 : 36	
2	0 : 28	
3	1 : 41	
4	0 : 37	
5	1 : 01	
6	2 : 30	
7	0 : 44	
8	0 : 47	
9	0 : 13	
10	0 : 24	
11	0 : 51	
12	0 : 09	
13	−2 : 08	
14	0 : 12	
15	0 : 56	

The value ranks are listed in Table 1 Notice that there <u>are no ties</u>.

TABLE 1

Participant	Value	Rank
1	0 : 36	7
2	0 : 28	6
3	1 : 41	14
4	0 : 37	8
5	1 : 01	13
6	2 : 30	15
7	0 : 44	9
8	0 : 47	10
9	0 : 13	4
10	0 : 24	5
11	0 : 51	11
12	0 : 09	2
13	−2 : 08	1
14	0 : 12	3
15	0 : 56	12

2. The values in Table 2 represent weekly quiz scores on math. **Rank the quiz scores.**

TABLE 2

Participant	Score	Rank
1	100	
2	60	
3	70	
4	90	
5	80	
6	100	
7	80	
8	20	
9	100	
10	50	

The value ranks are listed in Table 2. Notice the tied values. The value of 80 occurred twice and required averaging the rank values of 5 and 6.

TABLE 2

Participant	Score	Rank
1	100	9
2	60	3
3	70	4
4	90	7
5	80	5.5
6	100	9
7	80	5.5
8	20	1
9	100	9
10	50	2

$$(5 + 6) \div 2 = 5.5$$

The value of 100 occurred three times and required averaging the rank values of 8, 9, and 10.

$$(8 + 9 + 10) \div 3 = 9$$

3. Using the data from the previous example, **what are the counts (or frequencies)** of passing scores and failing scores if a 70 is a passing score?

Table 3 shows the passing scores and failing scores using 70 as a passing score. The counts (or frequencies) of passing scores is $n_{\text{passing}} = 7$. The counts of failing scores is $n_{\text{failing}} = 3$.

TABLE 3

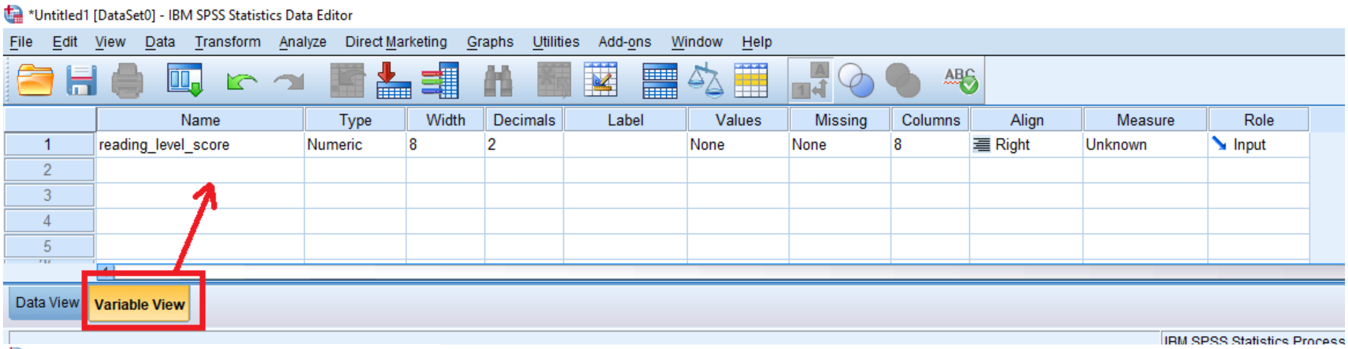
Participant	Score	Pass/Fail
1	100	Pass
2	60	Fail
3	70	Pass
4	90	Pass
5	80	Pass
6	100	Pass
7	80	Pass
8	20	Fail
9	100	Pass
10	50	Fail

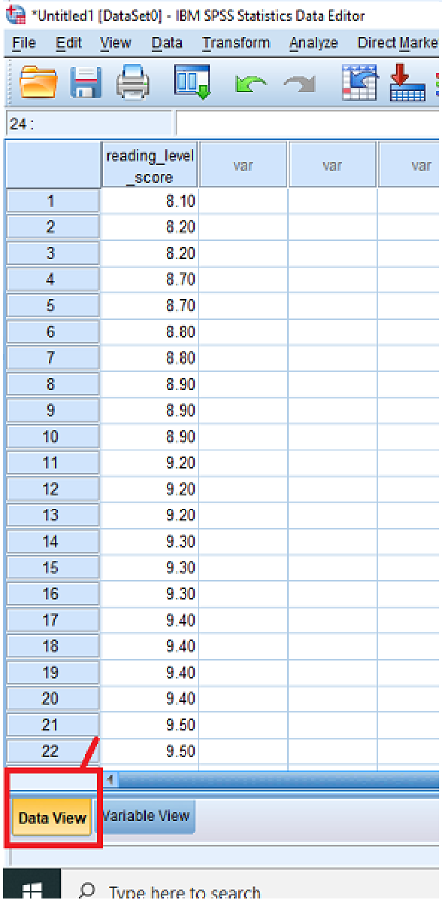
Testing Data For Normality

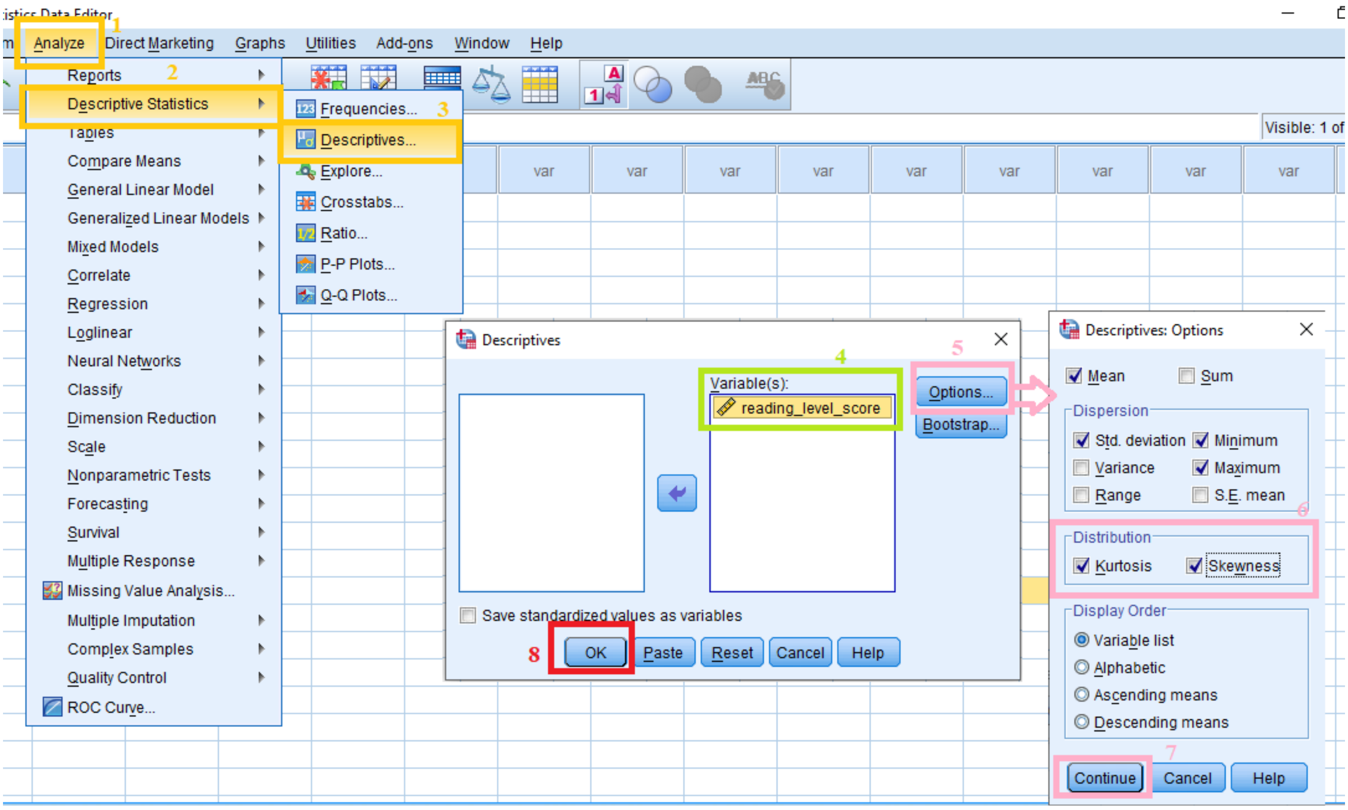
1. The values in Table 2.9 are a sample of reading-level score for a ninth-grade class. They are measured on a ratio scale. Examine the sample's **skewness and kurtosis for normality** for a = 0.05. Report your findings.

TABLE 2.9

Ninth-Grade Reading-Level Scores									
8.10	8.20	8.20	8.70	8.70	8.80	8.80	8.90	8.90	8.90
9.20	9.20	9.20	9.30	9.30	9.30	9.40	9.40	9.40	9.40
9.50	9.50	9.50	9.50	9.60	9.60	9.60	9.70	9.70	9.90







Descriptives

[DataSet0]

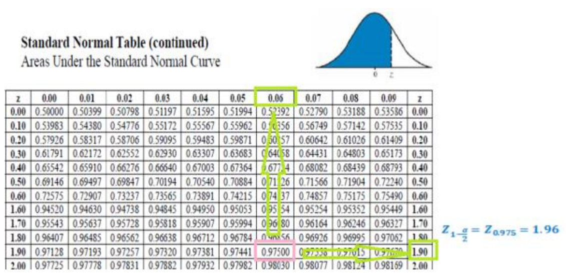
Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
reading_level_score	30	8.10	9.90	9.1800	.46639	-.904- S_K	.427 SE_{SK}	.188 K	.833 SE_K
Valid N (listwise)	30								

<u>**SPSS returned the following values:**</u>
Skewness = -0.904
Standard error of the skewness = 0.427

Kurtosis = 0.188
Standard error of the kurtosis = 0.833

For example: <u>alpha = 0.05,</u> then the calculated z-scores for an approximately normal distribution **must fall** between <u>−1.96 and +1.96.</u>



The computed Z-scores are below.

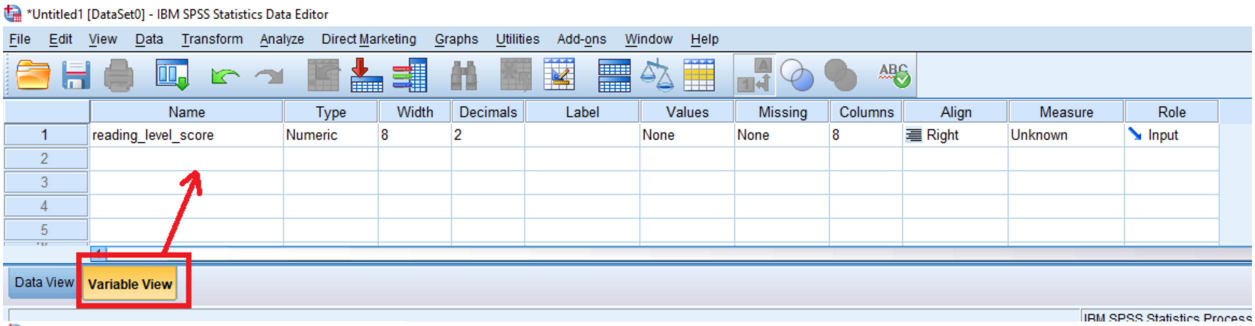
Kurtosis: $Z_K = \dfrac{K - 0}{SE_K} = \dfrac{0.188}{0.833} = 0.226$

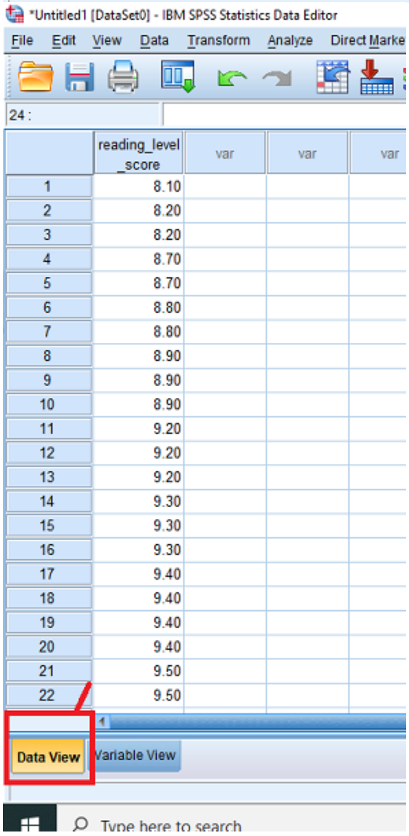
and

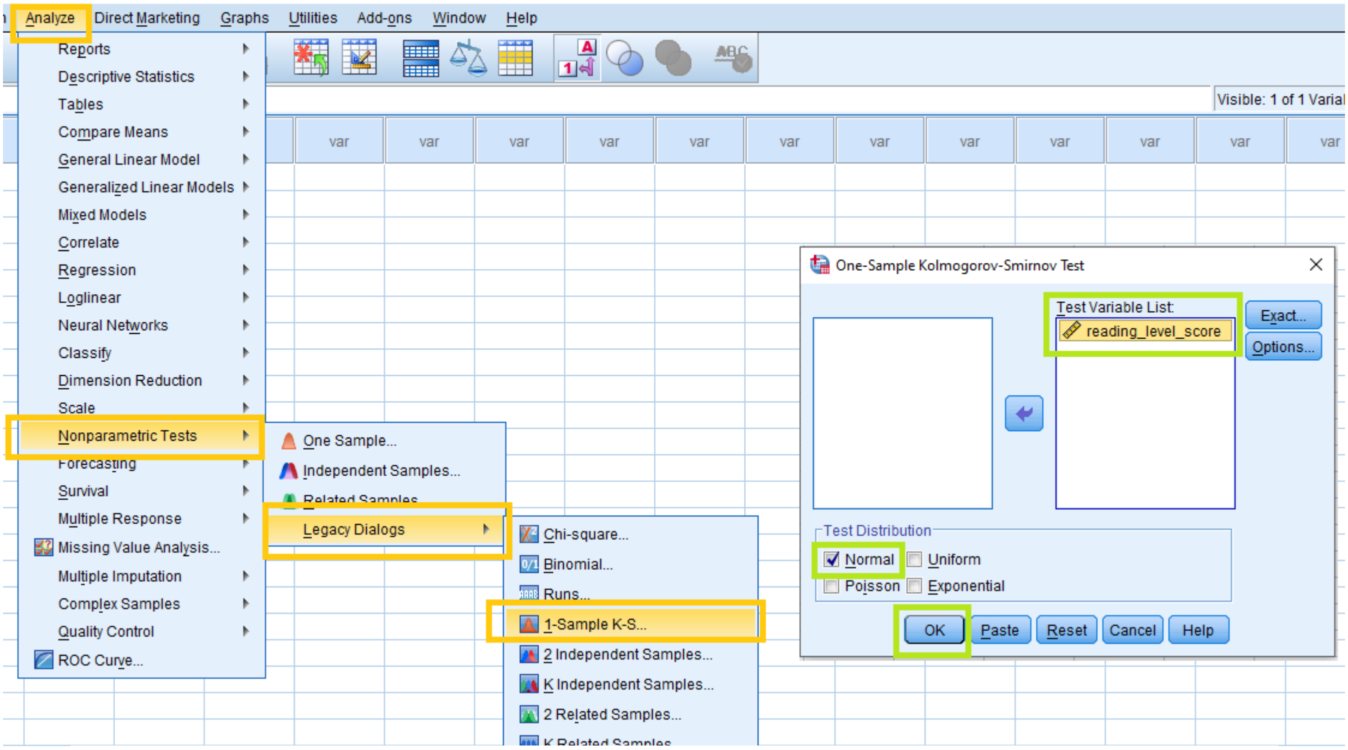
Skewness : $Z_{SK} = \dfrac{S_K - 0}{SE_{SK}} = \dfrac{-0.904}{0.427} = -2.117$

At $\alpha = 0.05$, the sample's skewness fails the normality test, while the kurtosis passes the normality test.
Based on our standard of $\alpha = 0.05$, this sample of reading levels for ninth-grade students is <u>not sufficiently normal</u>

2. Using a Kolmogorov-Smirnov one-sample test, examine the sample of values from Table 2.9. Report your findings.







NPar Tests

[DataSet0]

One-Sample Kolmogorov-Smirnov Test

		reading_level _score
N		30
Normal Parameters[a,b]	Mean	9.1800
	Std. Deviation	.46639
Most Extreme Differences	Absolute	.184
	Positive	.099
	Negative	-.184-
Kolmogorov-Smirnov Z		1.007
Asymp. Sig. (2-tailed)		.263

a. Test distribution is Normal.

b. Calculated from data.

the most extreme difference (D = 0.184)

Kolmogorov-Smirnov Z-test statistic

(*p-value* = 0.263).

Kolmogorov-Smirnov obtained value = 1.007
Two-tailed significance = 0.263
According to the Kolmogorov-Smirnov one-sample test with α= 0.05, this sample of reading levels for ninth-grade students is sufficiently normal.

Wilcoxon signed rank test + sign test

The Wilcoxon signed ranks test and sing test are a nonparametric statistical procedure for comparing two samples that are paired, or related.

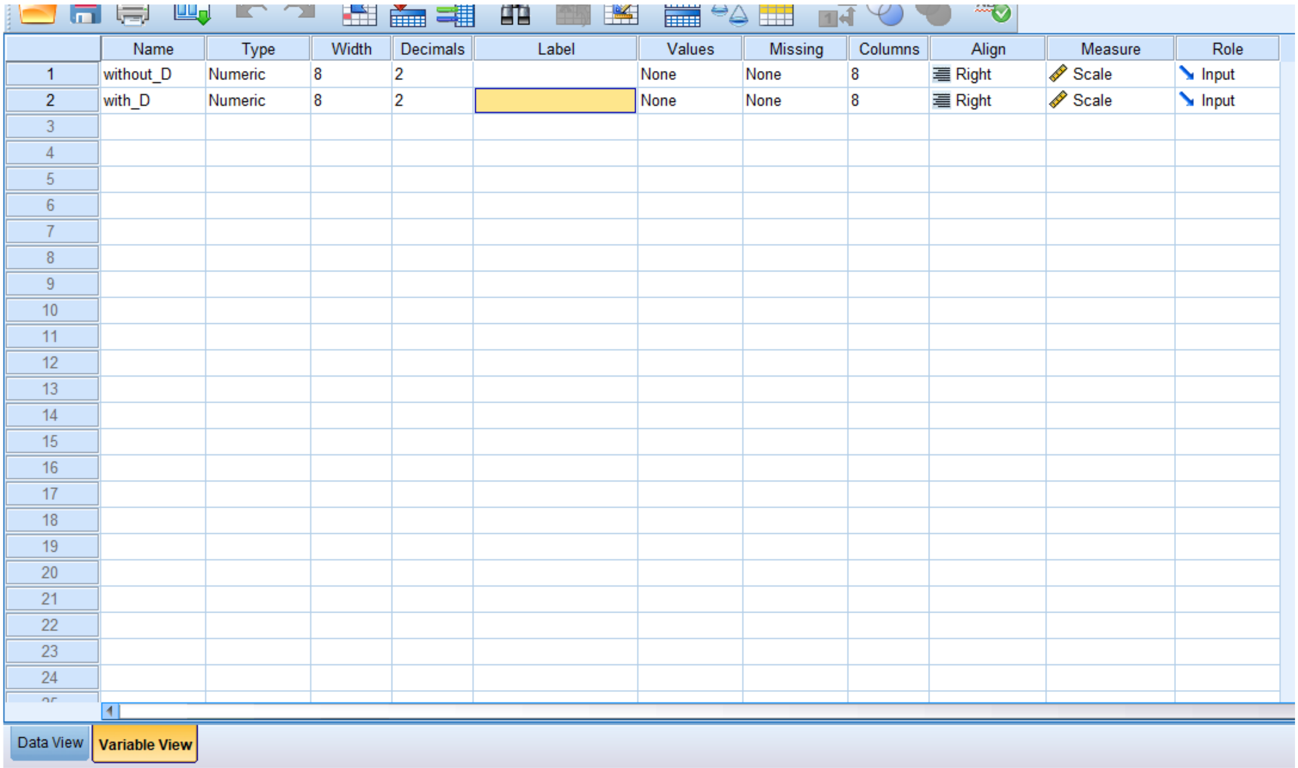
Q1: A teacher wished to determine if providing a bilingual dictionary to students with limited English proficiency improves math test scores. A small class of students (n = 10) was selected. Students were given two math tests. Each test covered the same type of math content; however, students were provided a bilingual dictionary on the second test. The data in Table 1 represent the students' performance on each math test.

TABLE 1.

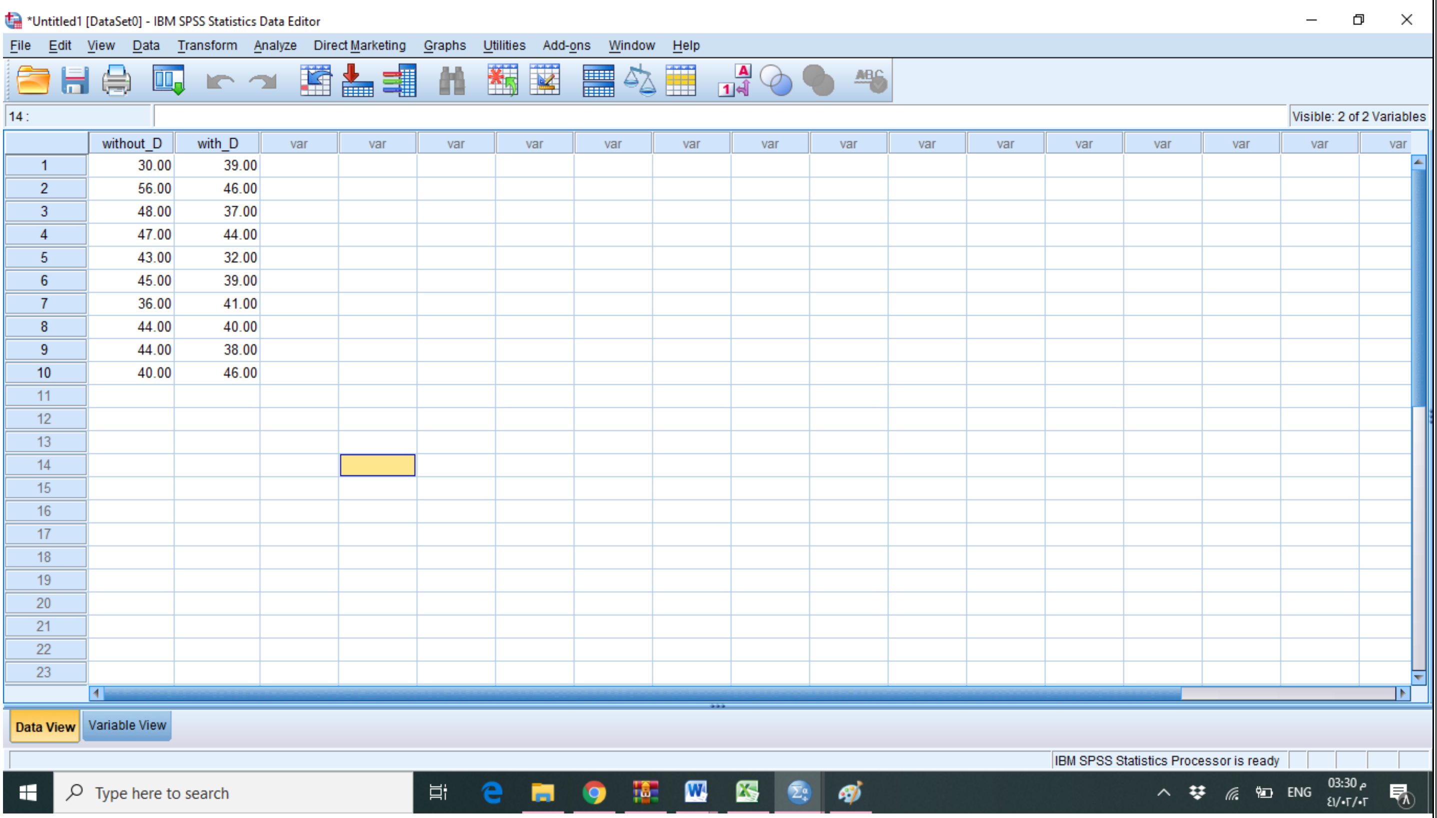
Student	Math test without a bilingual dictionary	Math test with a bilingual dictionary
1	30	39
2	56	46
3	48	37
4	47	44
5	43	32
6	45	39
7	36	41
8	44	40
9	44	38
10	40	46

Use a one-tailed Wilcoxon signed rank test and a one-tailed sign test to determine which testing condition resulted in higher scores. Use $\alpha = 0.05$. Report your findings.

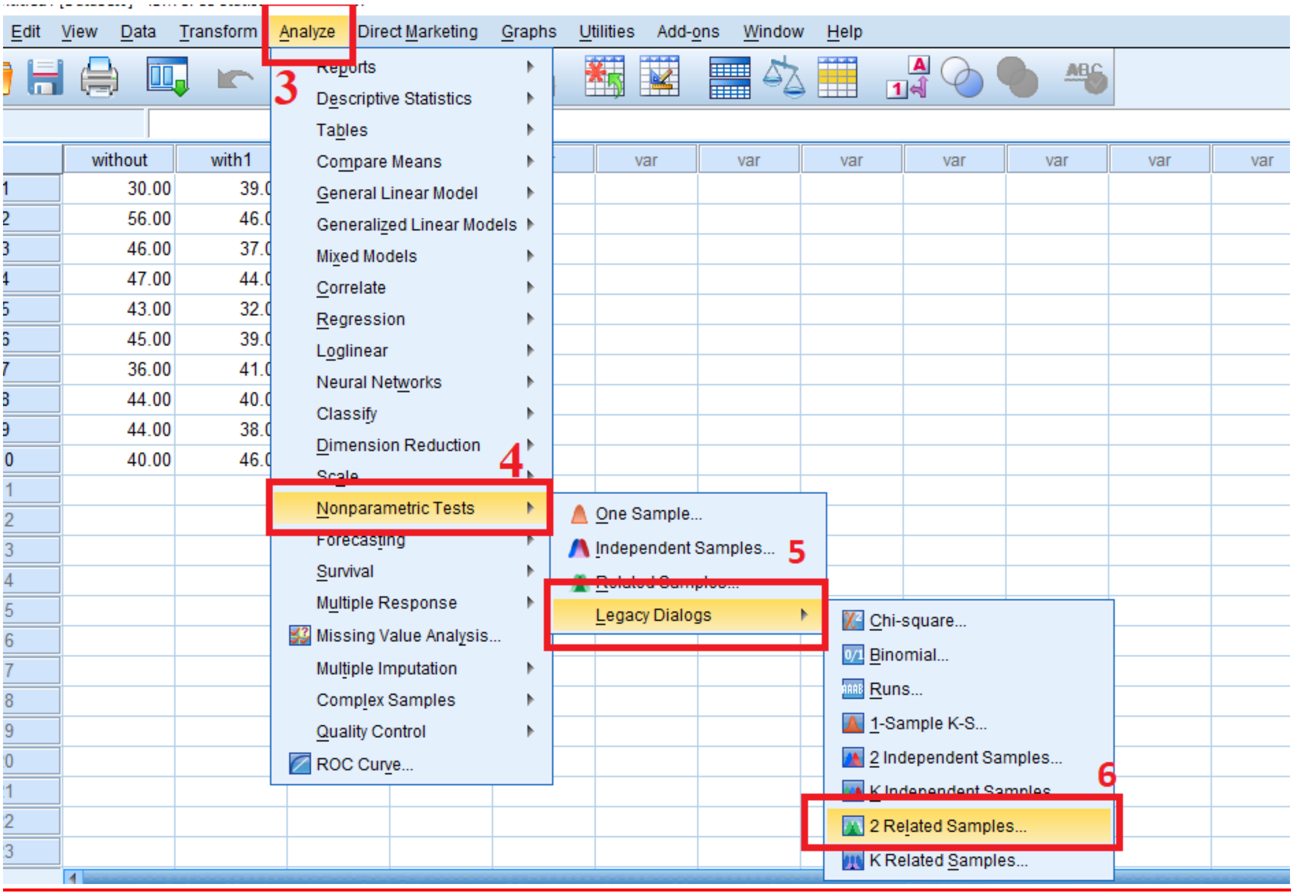
By using (SPSS):

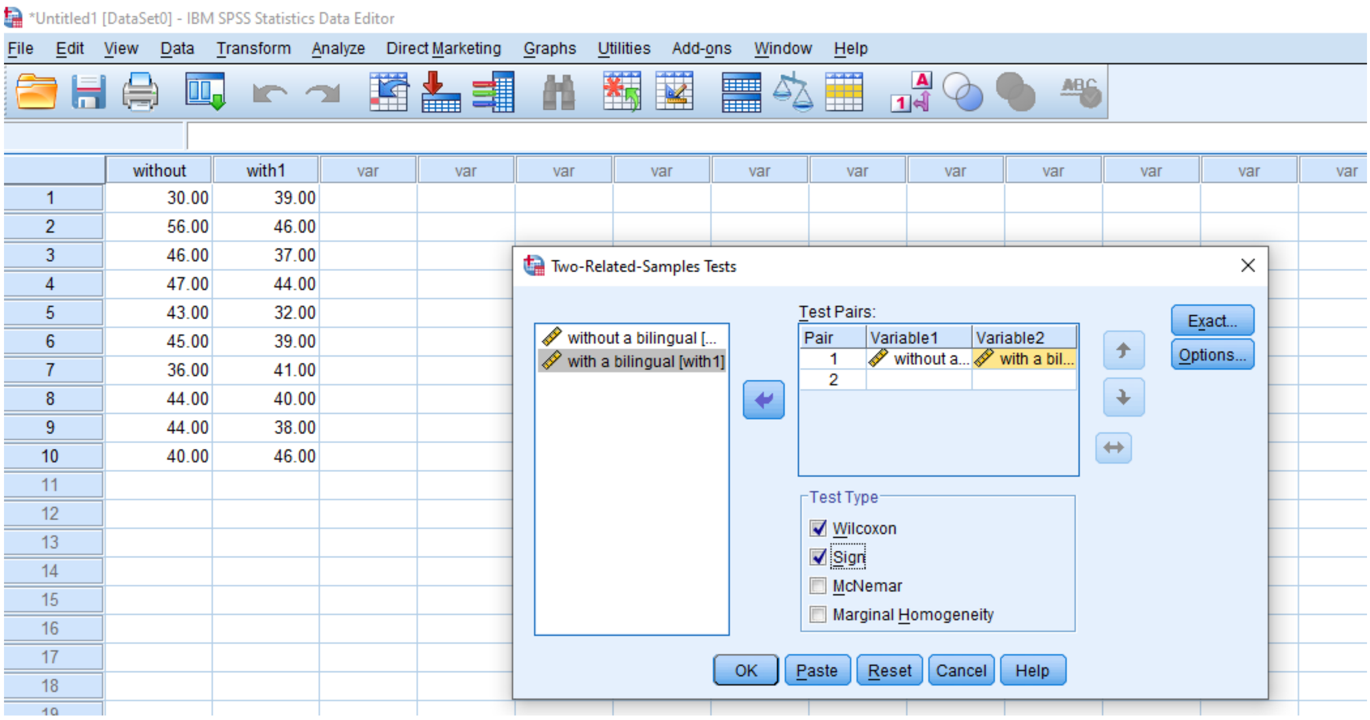


	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	without_D	Numeric	8	2		None	None	8	Right	Scale	Input
2	with_D	Numeric	8	2		None	None	8	Right	Scale	Input



	without_D	with_D
1	30.00	39.00
2	56.00	46.00
3	48.00	37.00
4	47.00	44.00
5	43.00	32.00
6	45.00	39.00
7	36.00	41.00
8	44.00	40.00
9	44.00	38.00
10	40.00	46.00


Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
3
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
4
Scale
Nonparametric Tests
Forecasting
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
One Sample...
Independent Samples...
5
Related Samples...
Legacy Dialogs
Chi-square...
Binomial...
Runs...
1-Sample K-S...
2 Independent Samples...
6
K Independent Samples...
2 Related Samples...
K Related Samples...
without
with1
var


*Untitled1 [DataSet0] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
without
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30.00 39.00
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44.00 40.00
44.00 38.00
40.00 46.00
Two-Related-Samples Tests
without a bilingual [...
with a bilingual [with1]
Test Pairs:
Pair
Variable1
Variable2
1
without a...
with a bil...
2
Exact...
Options...
Test Type
Wilcoxon
Sign
McNemar
Marginal Homogeneity
OK
Paste
Reset
Cancel
Help

The results from the analysis are displayed in SPSS Outputs 1 and 2. Both tests report the two-tailed significance, but the question asked for the one-tailed significance. Therefore, divide the two-tailed significance by 2 to find the one- tailed significance.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
with_D - without_D	Negative Ranks	7[a]	5.71	40.00
	Positive Ranks	3[b]	5.00	15.00
	Ties	0[c]		
	Total	10		

a. with_D < without_D

b. with_D > without_D

c. with_D = without_D

Test Statistics[a]

	with_D - without_D
Z	-1.278[b]
Asymp. Sig. (2-tailed)	.201

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

SPSS OUTPUT 1.

Sign Test

Frequencies

		N
with_D - without_D	Negative Differences[a]	7
	Positive Differences[b]	3
	Ties[c]	0
	Total	10

a. with_D < without_D

b. with_D > without_D

c. with_D = without_D

Test Statistics[a]

	with_D - without_D
Exact Sig. (2-tailed)	.344[b]

a. Sign Test

b. Binomial distribution used.

SPSS OUTPUT 2.

The results from the Wilcoxon signed rank test reported a one-tailed significance of $p = 0.201/2 = 0.101$. The test results ($T = 15.0$, $n = 10$, $p > 0.05$) indicated that the two testing conditions were not significantly different.

The results from the sign test reported a one-tailed significance of $p = 0.344/2 = 0.172$. These test results ($p > 0.05$) also indicated that the two testing conditions were not significantly different.

Therefore, based on this study, the use of bilingual dictionaries on a math test did not significantly improve scores among limited English proficient students.

Q2: A research study was done to investigate the influence of being alone at night on the human male heart rate. Ten men were sent into a wooded area, one at a time, at night, for 20 min. They had a heart monitor to record their pulse rate. The second night, the same men were sent into a similar wooded area accompanied by a companion. Their pulse rate was recorded again. The researcher wanted to see if having a companion would change their pulse rate. The median rates are reported in Table 2. Use a two-tailed Wilcoxon signed rank test and a two-tailed sign test to determine which condition produced a higher pulse rate. Use $\alpha = 0.05$. Report your findings.

TABLE 2.

Participant	Median rate alone	Median rate with companion
A	88	72
B	77	74
C	91	80
D	70	77
E	80	71
F	85	83
G	90	80
H	82	91
I	93	86
J	75	69

By using (SPSS):

The results from the analysis are displayed in SPSS Outputs 3 and 4.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
companion - alone	Negative Ranks	8[a]	5.50	44.00
	Positive Ranks	2[b]	5.50	11.00
	Ties	0[c]		
	Total	10		

a. companion < alone

b. companion > alone

c. companion = alone

Test Statistics[a]

	companion - alone
Z	-1.684[b]
Asymp. Sig. (2-tailed)	.092

a. Wilcoxon Signed Ranks Test

b. Based on positive ranks.

SPSS OUTPUT 3.

Sign Test

Frequencies

		N
companion - alone	Negative Differences[a]	8
	Positive Differences[b]	2
	Ties[c]	0
	Total	10

a. companion < alone

b. companion > alone

c. companion = alone

Test Statistics[a]

	companion - alone
Exact Sig. (2-tailed)	.109[b]

a. Sign Test

b. Binomial distribution used.

SPSS OUTPUT 4

The results from the Wilcoxon signed rank test reported a two-tailed significance of $p = 0.092$. The test results ($T = 11.0$, $n = 10$, $p > 0.05$) indicated that the two conditions were not significantly different.

The results from the sign test reported a two-tailed significance of $p = 0.109$. These test results ($p > 0.05$) also indicated that the two testing conditions were not significantly different.

Therefore, based on this study, the presence of a companion in the woods at night did not significantly influence the males' pulse rates.

Q3: A researcher conducts a pilot study to compare two treatments to help obese female teenagers lose weight. She tests each individual in two different treatment conditions. The data in Table 3 provide the number of pounds that each participant lost.

TABLE 3.

	Pounds lost	
Participant	Treatment 1	Treatment 2
1	10	18
2	20	12
3	15	16
4	9	7
5	18	21
6	11	17
7	6	13
8	12	14

Use a two-tailed Wilcoxon signed rank test and a two-tailed sign test to determine which treatment resulted in greater weight loss. Use $\alpha = 0.05$. Report your findings.

The results from the analysis are displayed in SPSS Outputs 6 and 7. The results from the Wilcoxon signed rank test ($T = 10.0$, $n = 8$, $p > 0.05$) indicated that the two treatments were not significantly different.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
Treatment2 - Treatment1	Negative Ranks	2[a]	5.00	10.00
	Positive Ranks	6[b]	4.33	26.00
	Ties	0[c]		
	Total	8		

a. Treatment2 < Treatment1

b. Treatment2 > Treatment1

c. Treatment2 = Treatment1

Test Statistics[a]

	Treatment2 - Treatment1
Z	-1.123[b]
Asymp. Sig. (2-tailed)	.261

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

SPSS OUTPUT 6.

Sign Test

Frequencies

		N
Treatment2 - Treatment1	Negative Differences[a]	2
	Positive Differences[b]	6
	Ties[c]	0
	Total	8

a. Treatment2 < Treatment1

b. Treatment2 > Treatment1

c. Treatment2 = Treatment1

Test Statistics[a]

	Treatment2 - Treatment1
Exact Sig. (2-tailed)	.289[b]

a. Sign Test

b. Binomial distribution used.

SPSS OUTPUT 7.

The results from the sign test ($p > 0.05$) also indicated that the two testing conditions were not significantly different.

Therefore, based on this study, neither treatment program resulted in a significantly higher weight loss among obese female teenagers.

Q4: Twenty participants in an exercise program were measured on the number of sit-ups they could do before other physical exercise (first count) and the number they could do after they had done at least 45 min of other physical exercise (second count). Table 4 shows the results for 20 participants obtained during two separate physical exercise sessions. Determine the ES for a calculated z-score.

TABLE 4.

Participant	First count	Second count
1	18	28
2	19	18
3	20	28
4	29	20
5	15	30
6	22	25
7	21	28
8	30	18
9	22	27
10	11	30
11	20	24
12	21	27
13	21	10
14	20	40
15	18	20
16	27	14
17	24	29
18	13	30
19	10	24
20	10	36

First	Second	D	|D|	Rank |D|	sign
18	28	10	10	11	+
19	18	-1	1	1	-
20	28	8	8	9	+
29	20	-9	9	10	-
15	30	15	15	16	+
22	25	3	3	3	+
21	28	7	7	8	+
30	18	-12	12	13	-
22	27	5	5	6	+
11	30	19	19	18	+
20	24	4	4	4	+
21	27	6	6	7	+
21	10	-11	11	12	-
20	40	20	20	19	+
18	20	2	2	2	+
27	14	-13	13	14	-
24	29	5	5	5	+
13	30	17	17	17	+
10	24	14	14	15	+
10	36	26	26	20	+

N=20

$$\sum R_+ = 160 \qquad , \sum R_- = 50$$

$$T = min\left(\sum R_+ \ , \sum R_- \ \right) = 50$$

$$\bar{x}_T = \frac{n(n+1)}{4} = \frac{20(20+1)}{4} = 105$$

$$S_T = \sqrt{\frac{n(n+1)(2n+1)}{24}} = \sqrt{\frac{20(20+1)(2*20+1)}{24}} = 26.786$$

$$Z = \frac{T - \bar{x}_T}{s_T} = \frac{50 - 105}{26.786} = -2.0533$$

Effect Size :

$$ES = \frac{|Z|}{\sqrt{n}} = \frac{2.0533}{\sqrt{20}} = 0.459 \approx 0.46$$

This is a reasonably high ES which indicates a strong measure of association.

Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
sss - fff	Negative Ranks	5[a]	10.00	50.00
	Positive Ranks	15[b]	10.67	160.00
	Ties	0[c]		
	Total	20		

a. sss < fff

b. sss > fff

c. sss = fff

Test Statistics[a]

	sss - fff
Z	-2.053-[b]
Asymp. Sig. (2-tailed)	.040

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Sign Test

Q5: A school is trying to get more students to participate in activities that will make learning more desirable. Table 6 shows the number of activities that each of the 10 students in one class participated in last year before a new activity program was implemented and this year after it was implemented. Construct a 95% median confidence interval based on the Wilcoxon signed rank test to determine whether the new activity program had a significant positive effect on the student participation.

TABLE 6.

Participants	Last year	This year
1	18	20
2	22	28
3	10	18
4	25	23
5	16	20
6	14	21
7	21	17
8	13	18
9	28	22
10	12	21

Last year	This year	D
18	20	2
22	28	6
10	18	8
25	23	-2
16	20	4
14	21	7
21	17	-4
13	18	5
28	22	-6
12	21	9

For our example, n = 10 and p = $\frac{\alpha}{2} = \frac{0.05}{2} = 0.025$. Thus, T = 8 (from table B.3) and

$K = T + 1 = 8 + 1 = 9$. The ninth value from the bottom is -1.0 and the ninth value from the top is 7.0. Based on these findings, it is estimated with 95% confidence that the difference in students' number of activities before and after the new program lies between -1.0 and 7.0

$$U_{i,j} = \frac{D_i + D_j}{2} \quad , \qquad 1 \le i \le j \le n{=}10$$

	2	6	8	-2	4	7	-4	5	-6	9
2	2	4	5	0	3	4.5	-1	3.5	-2	5.5
6		6	7	2	5	6.5	1	5.5	0	7.5
8			8	3	6	7.5	2	6.5	1	8.5
-2				-2	1	2.5	-3	1.5	-4	3.5
4					4	5.5	0	4.5	-1	6.5
7						7	1.5	6	0.5	8
-4							-4	0.5	-5	2.5
5								5	-0.5	7
-6									-6	1.5
9										9

9th from the bottom

1	-6	12	0	23	2	34	4.5	45	6.5
2	-5	13	0	24	2	35	5	46	6.5
3	-4	14	0.5	25	2.5	36	5	474	7
4	-4	15	0.5	26	2.5	37	5	48	7
5	-3	16	1	27	3	38	5.5	49	7
6	-2	17	1	28	3	39	5.5	50	7.5
7	-2	18	1	29	3.5	40	5.5	51	7.5
8	-1	19	1.5	30	3.5	41	6	52	8
9	-1	20	1.5	31	4	42	6	53	8
10	-0.5	21	1.5	32	4	43	6	54	8.8
11	0	22	2	33	4.5	44	6.5	55	9

9th from the top

Mann–Whitney U-test +Kolmogorov–Smirnov two-sample test

The Mann–Whitney U-test and the Kolmogorov–Smirnov two-sample test

are nonparametric statistical procedures for comparing two samples that are independent, or not related.

1.The data in Table 1 were obtained from a reading-level test for 1st-grade children. Compare the performance gains of the two different methods for teaching reading.

TABLE 1.

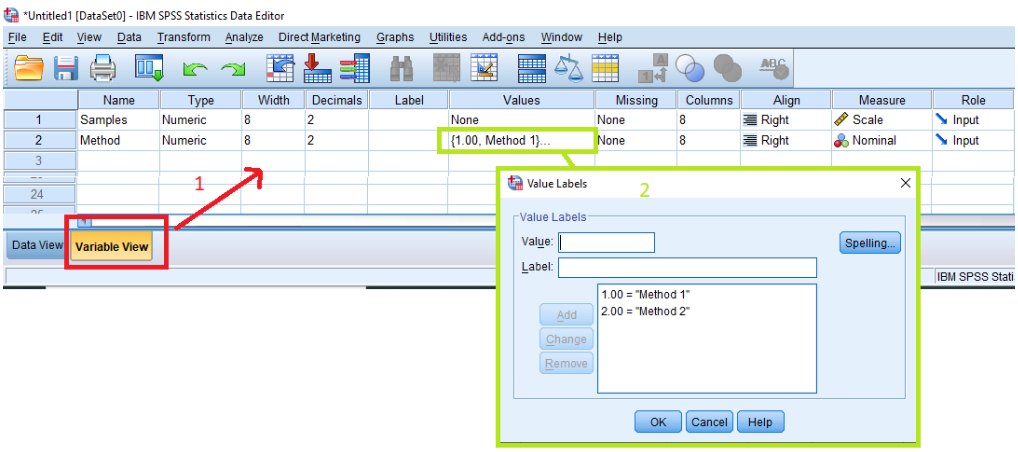
Method	Gain score	Method	Gain score
One on one	16	Small group	11
One on one	13	Small group	2
One on one	16	Small group	10
One on one	16	Small group	4
One on one	13	Small group	9
One on one	9	Small group	8
One on one	12	Small group	5
One on one	12	Small group	6
One on one	20	Small group	4
One on one	17	Small group	16

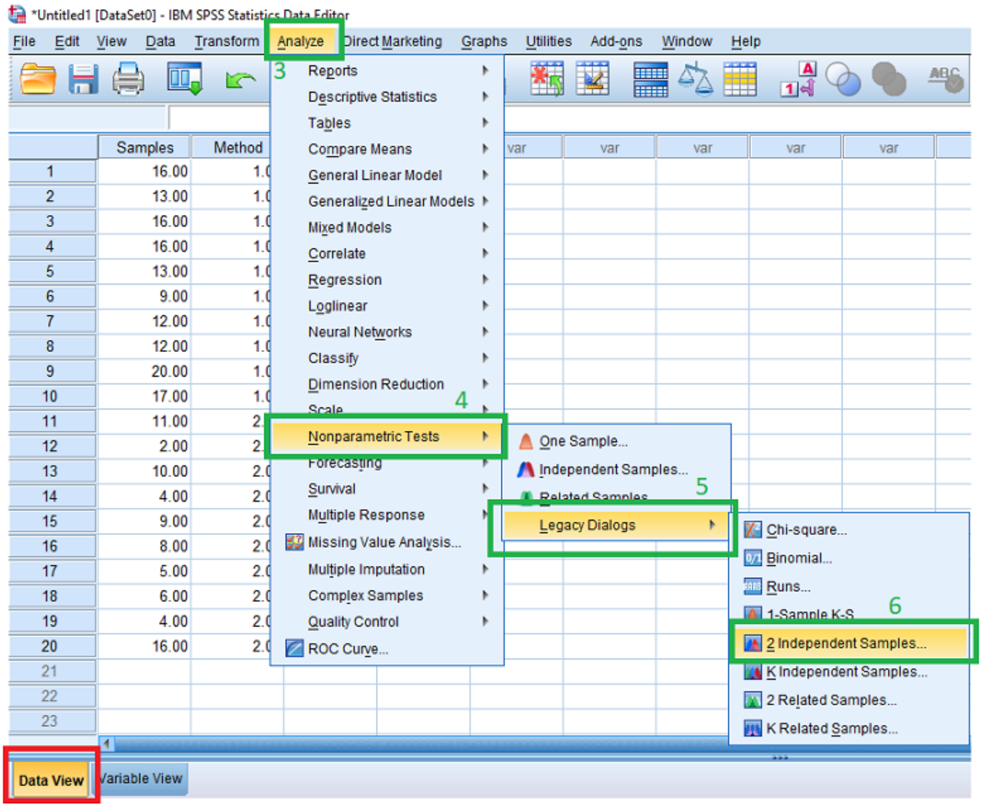
Use two-tailed Mann–Whitney U and Kolmogorov–Smirnov two-sample tests to determine which method was better for teaching reading. Set α = 0.05. Report your findings.

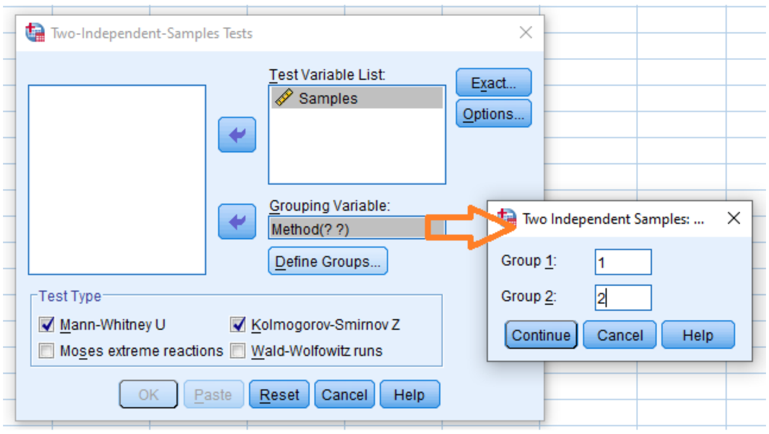
H0: no tendency of the ranks of one method to be significantly higher (or lower) than the other

H1:The ranks of one method are systematically higher (or lower) than the other

By using (SPSS):




*Untitled1 [DataSet0] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
3
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
4
Scale
Nonparametric Tests
Forecasting
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
One Sample...
Independent Samples...
5
Related Samples...
Legacy Dialogs
Chi-square...
Binomial...
Runs...
1-Sample K-S...
6
2 Independent Samples...
K Independent Samples...
2 Related Samples...
K Related Samples...
Samples
Method
Data View
Variable View


Two-Independent-Samples Tests
Test Variable List:
Samples
Exact...
Options...
Grouping Variable:
Method(? ?)
Define Groups...
Test Type
Mann-Whitney U
Kolmogorov-Smirnov Z
Moses extreme reactions
Wald-Wolfowitz runs
OK
Paste
Reset
Cancel
Help
Two Independent Samples: ...
Group 1:
1
Group 2:
2
Continue
Cancel
Help

Mann-Whitney Test

Ranks

	Method	N	Mean Rank	Sum of Ranks
Samples	Method 1	10	14.60	146.00
	Method 2	10	6.40	64.00
	Total	20		

146.00 → $\sum R_1$

64.00 → $\sum R_2$

Test Statistics[a]

	Samples
Mann-Whitney U	9.000
Wilcoxon W	64.000
Z	-3.116-
Asymp. Sig. (2-tailed)	.002
Exact Sig. [2*(1-tailed Sig.)]	.001[b]

a. Grouping Variable: Method

b. Not corrected for ties.

Mann-Whitney U → Test statistic U=9

Asymp. Sig. (2-tailed) → p-value

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	Method	N
Samples	Method 1	10
	Method 2	10
	Total	20

Test Statistics[a]

		Samples
Most Extreme Differences	Absolute	.800
	Positive	.000
	Negative	-.800-
Kolmogorov-Smirnov Z		1.789
Asymp. Sig. (2-tailed)		.003

a. Grouping Variable: Method

Asymp. Sig. (2-tailed) → p-value =0.003

The results from the **Mann Whitney U-test** ($U = 9$, $n_1 = 10$, $n_2 = 10$, p=0.002 < 0.05) indicated that the two methods were significantly different. Moreover, the one-on-one method produced a higher sum of ranks (ΣR_1= 146) than the small group method (ΣR_2= 64). We see that method 1 had significantly higher.

The results from the **Kolmogorov–Smirnov two-sample test** (Z= 1.789,$D_{max} = 0.8$, p=0.003 < 0.05) also suggested that the two methods were significantly different.

Therefore, based on both statistical tests, 1st-grade children displayed significantly higher reading levels when taught with a one-on-one method.

Q2: A research study was conducted to see if an active involvement in a hobby had a positive effect on the health of a person who retires after age 65. The data in Table 2 describe the health (number of doctor visits in 1 year) for participants who are involved in a hobby almost daily and those who are not.

TABLE 2

No hobby group	Hobby group
12	9
15	5
8	10
11	3
9	4
17	2

Use one-tailed Mann–Whitney U and Kolmogorov–Smirnov two-sample tests to determine whether the hobby tends to reduce the need for doctor visits. Set $\alpha = 0.05$. Report your findings.

Mann-Whitney Test

Ranks

	method	N	Mean Rank	Sum of Ranks
samples	No Hobby	n1= 6	8.92	53.50 (ΣR_1)
	Hobby	n2= 6	4.08	24.50 (ΣR_1)
	Total	12		

Test Statistics[a]

	samples
Mann-Whitney U	3.500
Wilcoxon W	24.500
Z	-2.326-
Asymp. Sig. (2-tailed)	.020
Exact Sig. [2*(1-tailed Sig.)]	.015[b]

a. Grouping Variable: method

b. Not corrected for ties.

Mann–Whitney U-test statistic (U=3.5)

p-value (.020)

Two-Sample Kolmogorov-Smirnov Test

Frequencies

	method	N
samples	No Hobby	m= 6
	Hobby	n= 6
	Total	12

Test Statistics[a]

		samples
Most Extreme Differences	Absolute	.667
	Positive	.000
	Negative	-.667-
Kolmogorov-Smirnov Z		1.155
Asymp. Sig. (2-tailed)		.139

a. Grouping Variable: method

Kolmogorov–Smirnov test statistic Z (Z=1.155)

p-value (.139)

The results from the **Mann–Whitney *U*-test** ($U = 3.5$, $n_1 = 6$, $n_2 = 6$, $p = \frac{0.02}{2} = 0.01 < \alpha = 0.05$) indicated that the two samples were **significantly different**. Moreover, the sample with no hobby produced a higher sum of ranks ($\Sigma R_1 = 53.5$) than the sample with a hobby ($\Sigma R_2 = 24.5$).

The results from **the Kolmogorov–Smirnov two-sample test** ($Z = 1.155$, $p = \frac{0.139}{2} = 0.0695 > \alpha = 0.05$) suggested, however, that the two methods were **not significantly different**.

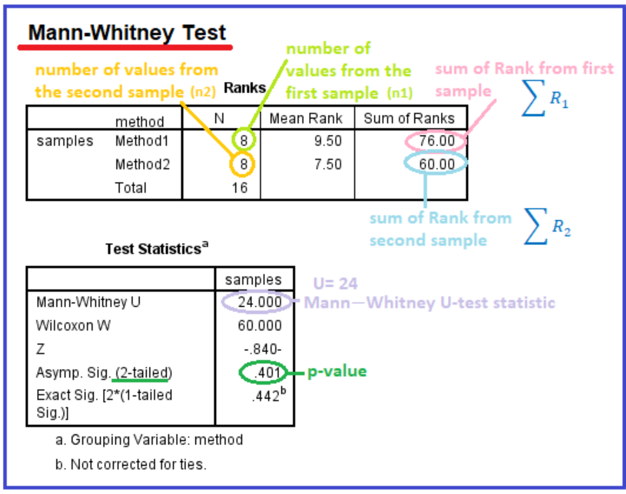
The conflicting results from the two statistical tests prevent us from making a conclusive statement about this study. Study replication with larger sample sizes is recommended.

Q3: Table 3 shows assessment scores of two different classes who are being taught computer skills using two different methods.

TABLE 3

Method 1	Method 2
53	91
41	18
17	14
45	21
44	23
12	99
49	16
50	10

Use two-tailed Mann–Whitney U and Kolmogorov–Smirnov two-sample tests to determine which method was better for teaching computer skills. Set α = 0.05. Report your findings.



Mann-Whitney Test

Ranks

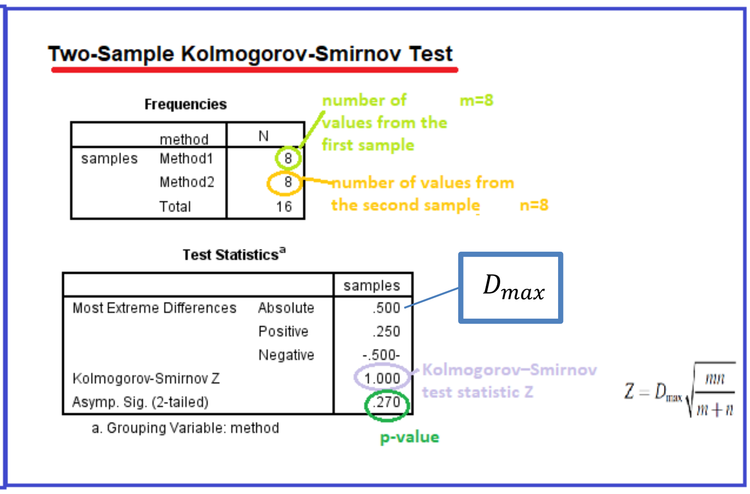
	method	N	Mean Rank	Sum of Ranks
samples	Method1	8	9.50	76.00
	Method2	8	7.50	60.00
	Total	16		

Test Statistics[a]

	samples
Mann-Whitney U	24.000
Wilcoxon W	60.000
Z	-.840-
Asymp. Sig. (2-tailed)	.401
Exact Sig. [2*(1-tailed Sig.)]	.442[b]

a. Grouping Variable: method

b. Not corrected for ties.



Two-Sample Kolmogorov-Smirnov Test

Frequencies

	method	N
samples	Method1	8
	Method2	8
	Total	16

Test Statistics[a]

		samples
Most Extreme Differences	Absolute	.500
	Positive	.250
	Negative	-.500-
Kolmogorov-Smirnov Z		1.000
Asymp. Sig. (2-tailed)		.270

a. Grouping Variable: method

The results from the **Mann–Whitney U-test** (U = 24, n1 = 8, n2 = 8, p=0.401 > 0.05) and the results from the **Kolmogorov–Smirnov two-sample test** (Z = 1.000, p=0.270 > 0.05) indicated that the two samples were **not significantly different.**

Therefore, based on this study, neither method resulted in significantly different assessment scores for computer skills.

Q4: Two methods were used to provide instruction in science for 7th grade. Method 1 included a laboratory each week and method 2 had only classroom work with lecture and worksheets. Table 4 shows end-of-course test performance for the two methods. Construct a 95% median confidence interval based on the difference between two independent samples to compare the two methods.

TABLE 4.

Method 1	Method 2
15	8
23	15
9	10
12	13
18	17
22	5
17	18
20	7

For our example, n1 = 8 and n2 = 8. For 0.05/2 = 0.025, $w_{\alpha/2}$ = 14. Based on these results, we are 95% certain that the median difference between the two methods is between 0 and 11.

Friedman test

The Friedman test is a nonparametric statistical procedure for comparing more than two samples that are <u>related</u>.

Q1: A graduate student performed a pilot study for his dissertation. He wanted to examine the effects of animal companionship on elderly males. He selected 10 male participants from a nursing home. Then he used an ABAB research design, where A represented a week with the absence of a cat and B represented a week with the presence of a cat. At the end of each week, he administered a 20-point survey to measure quality of life satisfaction. The survey results are presented in Table 1

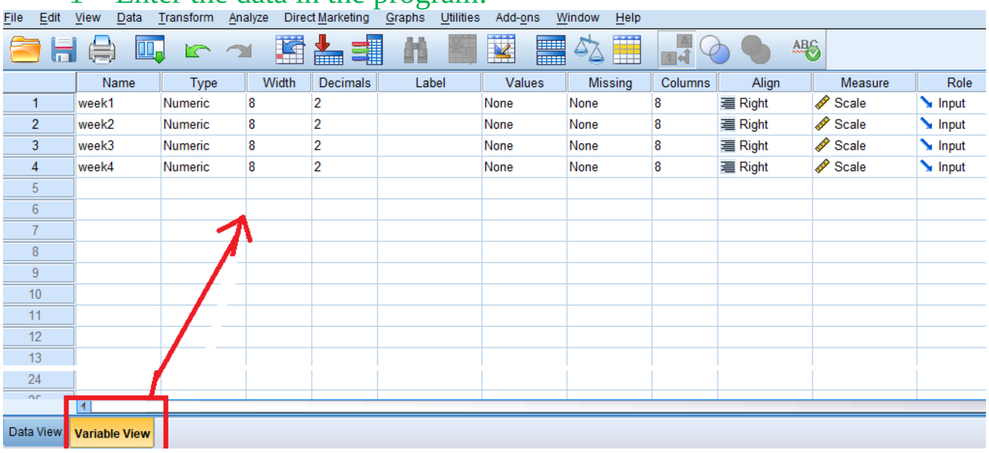
TABLE 1

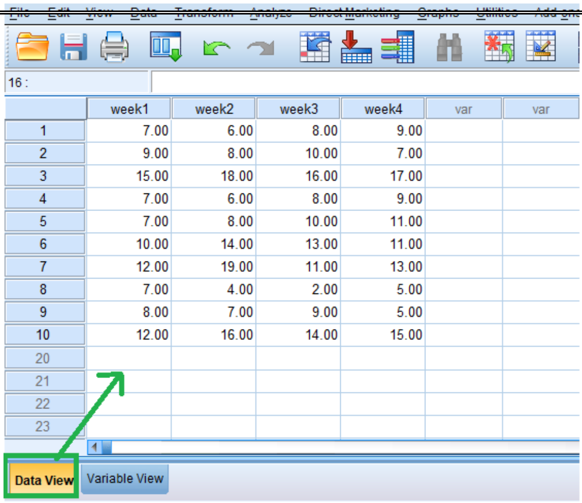
Participants	Week 1	Week 2	Week 3	Week 4
1	7	6	8	9
2	9	8	10	7
3	15	18	16	17
4	7	6	8	9
5	7	8	10	11
6	10	14	13	11
7	12	19	11	13
8	7	4	2	5
9	8	7	9	5
10	12	16	14	15

<u>**Use a Friedman test to determine if one or more of the groups are significantly different**</u>. Since this is pilot study, use <u>$\alpha = 0.10$</u>. If a significant difference exists, use Wilcoxon signed rank tests to identify which groups are significantly different. Use the Bonferroni procedure to limit the type I error rate. Report your findings.

<u>By using SPSS :</u>

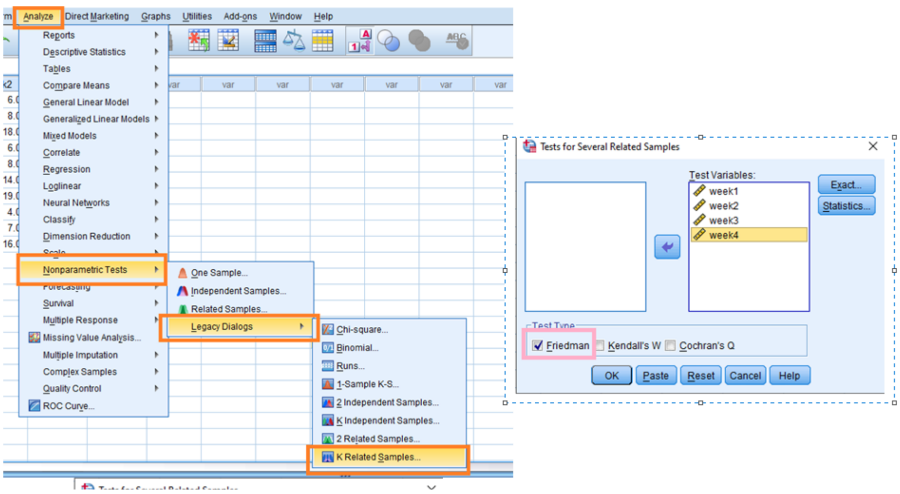
1- Enter the data in the program:





	week1	week2	week3	week4	var	var
1	7.00	6.00	8.00	9.00		
2	9.00	8.00	10.00	7.00		
3	15.00	18.00	16.00	17.00		
4	7.00	6.00	8.00	9.00		
5	7.00	8.00	10.00	11.00		
6	10.00	14.00	13.00	11.00		
7	12.00	19.00	11.00	13.00		
8	7.00	4.00	2.00	5.00		
9	8.00	7.00	9.00	5.00		
10	12.00	16.00	14.00	15.00		

2- calculate the Friedman test from (Analysis - nonparametric test -legacy Dialogs - K related samples):



3-test result:

Friedman Test

Ranks

	Mean Rank
week1	2.00
week2	2.60
week3	2.60
week4	2.80

$\frac{\sum R_1}{n}$ = (20/10) =2

$\frac{\sum R_2}{n}$ =26/10=2.6

$\frac{\sum R_3}{n}$ = 26 /10 =2.6

$\frac{\sum R_4}{n}$ = 28 /10 =2.8

Test Statistics[a]

N	10	number of values in each group
Chi-Square	2.160	Friedman test statistic $F_{r=2.16}$
df	3	degrees of freedom df=k-1
Asymp. Sig.	.540	p-value

a. Friedman Test

name of test

According to the data, the results from the Friedman test indicated that the four conditions were <u>not significantly different</u> ($F_{r(3)}$ = 2.160, $p=0.54$ > 0.10). Therefore, no follow-up contrasts are needed.

Remember

If $p-value \leq \propto$ $Reject\ H_0$

And

If $p-value > \propto$ $not\ reject\ H_0$

Q2: A physical education teacher conducted an action research project to examine a strength and conditioning program. Using 12 male participants, she measures the number of curl ups they could do in 1 min. She measured their performance before the programs. Then, she measured their performance at 1 month intervals. Table 2 presents the performance results.

TABLE 2

Number of curl ups in one minute

Participants	Baseline	Month 1	Month 2
1	66	67	69
2	49	50	56
3	51	52	49
4	65	65	69
5	42	43	46
6	38	39	40
7	33	31	39
8	41	41	44
9	46	47	48
10	45	46	46
11	36	33	34
12	51	55	67

Use a Friedman test with $\alpha = 0.05$ to determine if one or more of the groups are significantly different. The teacher is expecting performance gains, so if a significant difference exists, use Wilcoxon signed rank tests to identify which groups are significantly different. Use the Bonferroni procedure to limit the type I error rate. Report your findings.

By using SPSS :

1- Enter the data in the program.
2- calculate the Friedman test from (Analysis - nonparametric test -legacy Dialogs - K related samples).
3- Test result:

Friedman Test

Ranks

	Mean Rank
Baseline	1.42
month1	1.88
month2	2.71

$\frac{\sum R_1}{n}$ = 17/12

$\frac{\sum R_2}{n}$ = 22.5/12

$\frac{\sum R_3}{n}$ = 32.5/12

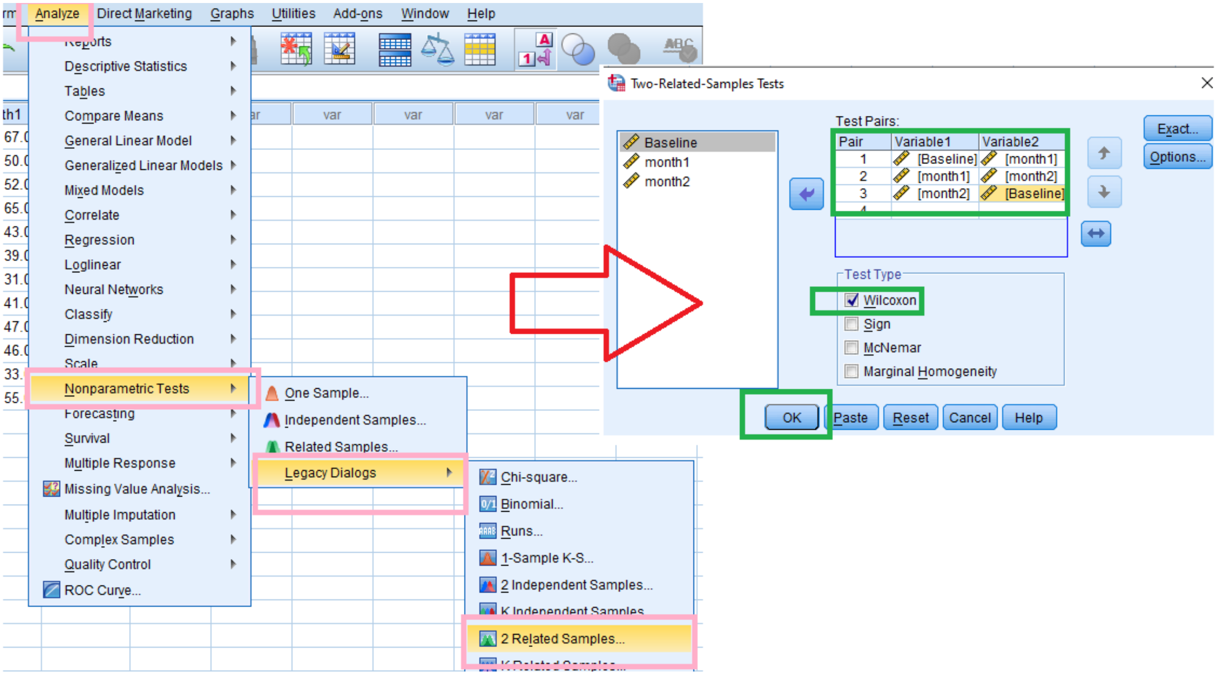
Test Statistics[a]

N	12	number of values in each groups
Chi-Square	10.978	Friedman test statistic Fr=10.978
df	2	degrees of freedom df=k-1
Asymp. Sig.	.004	p-value

a. Friedman Test — name of test

According to the data, the results from the Friedman test indicated that **one or more of the three groups are significantly different** (Fr(2) = 10.978, p=0.004 < 0.05). Therefore, we must examine each set of samples with follow-up contrasts to find the differences between groups.

We compare the samples with Wilcoxon signed rank tests. Since there are k = 3 groups, use $\propto_B = \frac{\propto}{k} = \frac{0.05}{3} = 0.0167$ to avoid type I error rate inflation. The results from the Wilcoxon signed rank tests are displayed in SPSS outputs



Wilcoxon Signed Ranks Test

Ranks

		N	Mean Rank	Sum of Ranks
month1 - Baseline	Negative Ranks	2[a]	8.50	17.00
	Positive Ranks	8[b]	4.75	38.00
	Ties	2[c]		
	Total	12		
month2 - month1	Negative Ranks	1[d]	6.00	6.00
	Positive Ranks	10[e]	6.00	60.00
	Ties	1[f]		
	Total	12		
Baseline - month2	Negative Ranks	10[g]	7.10	71.00
	Positive Ranks	2[h]	3.50	7.00
	Ties	0[i]		
	Total	12		

a. month1 < Baseline
b. month1 > Baseline
c. month1 = Baseline
d. month2 < month1
e. month2 > month1
f. month2 = month1
g. Baseline < month2
h. Baseline > month2
i. Baseline = month2

$$T = \text{smaller of } \Sigma R_+ \text{ and } \Sigma R_-$$

Test Statistics[a]

	month1 - Baseline	month2 - month1	Baseline - month2
Z	-1.111-[b]	-2.410-[b]	-2.522-[c]
Asymp. Sig. (2-tailed)	.266	.016	.012

p-value

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

c. Based on positive ranks.

a. **Baseline–Month 1 Comparison.** The results from the Wilcoxon signed rank test (T = 17.0, n = 12, p=0.266 > 0.0167) indicated that the two samples were not significantly different.

b. **Month 1–Month 2 Comparison.** The results from the Wilcoxon signed rank test (T = 6.0, n = 12, p=0.016 < 0.0167) indicated that the two samples were significantly different.

c. **Baseline–Month 2 Comparison.** The results from the Wilcoxon signed rank test (T = 7.0, n = 12, p=0.012 < 0.0167) indicated that the two samples were significantly different.

THE KRUSKAL–WALLIS H-TEST

The Kruskal–Wallis H-test is used to compare more than two independent samples.

1. A researcher conducted a study with $n = 15$ participants to investigate strength gains from exercise. The participants were divided into three groups and given one of three treatments. Participants' strength gains were measured and ranked. The rankings are presented in Table 1.

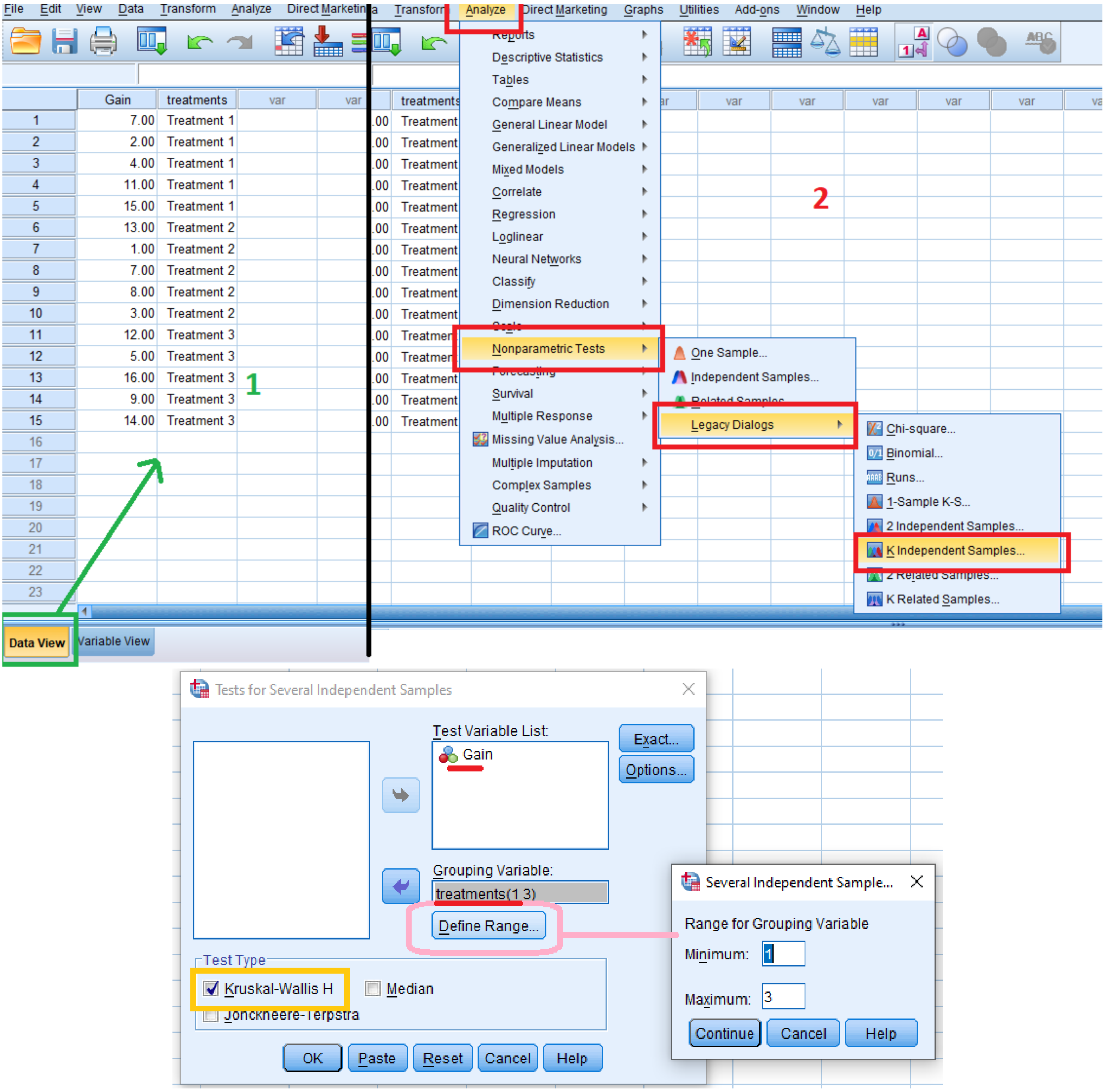
TABLE 1

Treatments		
I	II	III
7	13	12
2	1	5
4	7	16
11	8	9
15	3	14

Use a Kruskal–Wallis *H*-test with $\alpha = 0.05$ to determine if one or more of the groups are significantly different. If a significant difference exists, use a two- tailed Mann–Whitney *U*-tests or two-sample Kolmogorov–Smirnov tests to identify which groups are significantly different. Use the Bonferroni procedure to limit the Type I error rate. Report your findings.

Test hypothesis:

$H_0: \theta_{T1} = \theta_{T2} = \theta_{T3}$ vs H_1: At least one of the θ is different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Gain
treatments
1
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Reports
Descriptive Statistics
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Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
Nonparametric Tests
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
One Sample...
Independent Samples...
Legacy Dialogs
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2 Independent Samples...
K Independent Samples...
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Variable View
Tests for Several Independent Samples
Test Variable List:
Gain
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Options...
Grouping Variable:
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OK
Paste
Reset
Cancel
Help
Several Independent Sample...
Range for Grouping Variable
Minimum:
1
Maximum:
3
Continue
Cancel
Help

Kruskal-Wallis Test

number of values in treatments

Ranks

	treatments	N	Mean Rank
Gain	Treatment 1	5	7.30
	Treatment 2	5	6.10
	Treatment 3	5	10.60
	Total	15	

Test Statistics[a,b]

	Gain
Chi-Square	2.720
df	2
Asymp. Sig.	.257

a. Kruskal Wallis Test

b. Grouping Variable: treatments

H-test statistic

df=k-1 =3-1=2 (degrees of freedom)

p-value

According to the data, the results from the Kruskal–Wallis H-test indicated that the three groups are not significantly different (H(2) = 2.720, p=0.257 > 0.05). Therefore, no follow-up contrasts are needed.

Remember

If $p-value \leq \propto$ $Reject\ H_0$

And

If $p-value > \propto$ $not\ reject\ H_0$

2. A researcher investigated how physical attraction influences the perception among others of a person's effectiveness with difficult tasks. The photographs of 24 people were shown to a focus group. The group was asked to classify the photos into three groups: very attractive, average, and very unattractive. Then, the group ranked the photographs according to their impression of how capable they were of solving difficult problems. Table 2shows the classification and rankings of the people in the photos (1 = most effective, 24 = least effective).

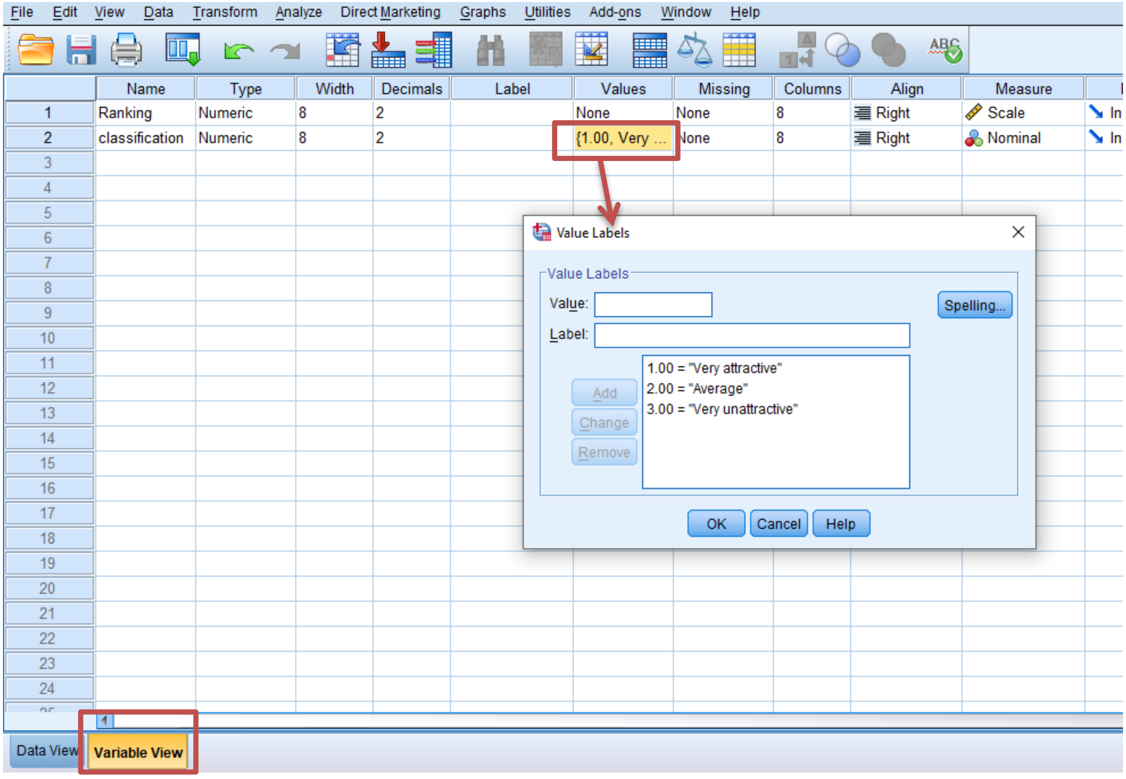
TABLE 2

Very attractive	Average	Very unattractive
1	3	11
2	4	15
5	8	16
6	9	18
7	13	20
10	14	21
12	19	23
17	22	24

Use a Kruskal–Wallis H-test with α = 0.05 to determine if one or more of the groups are significantly different. If a significant difference exists, use two- tailed Mann–Whitney U-tests to identify which groups are significantly different. Use the Bonferroni procedure to limit the type I error rate. Report your findings.

Test hypothesis:

$$H_0: \theta_1 = \theta_2 = \theta_3 \qquad \text{vs} \qquad H_1:$$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Spelling...
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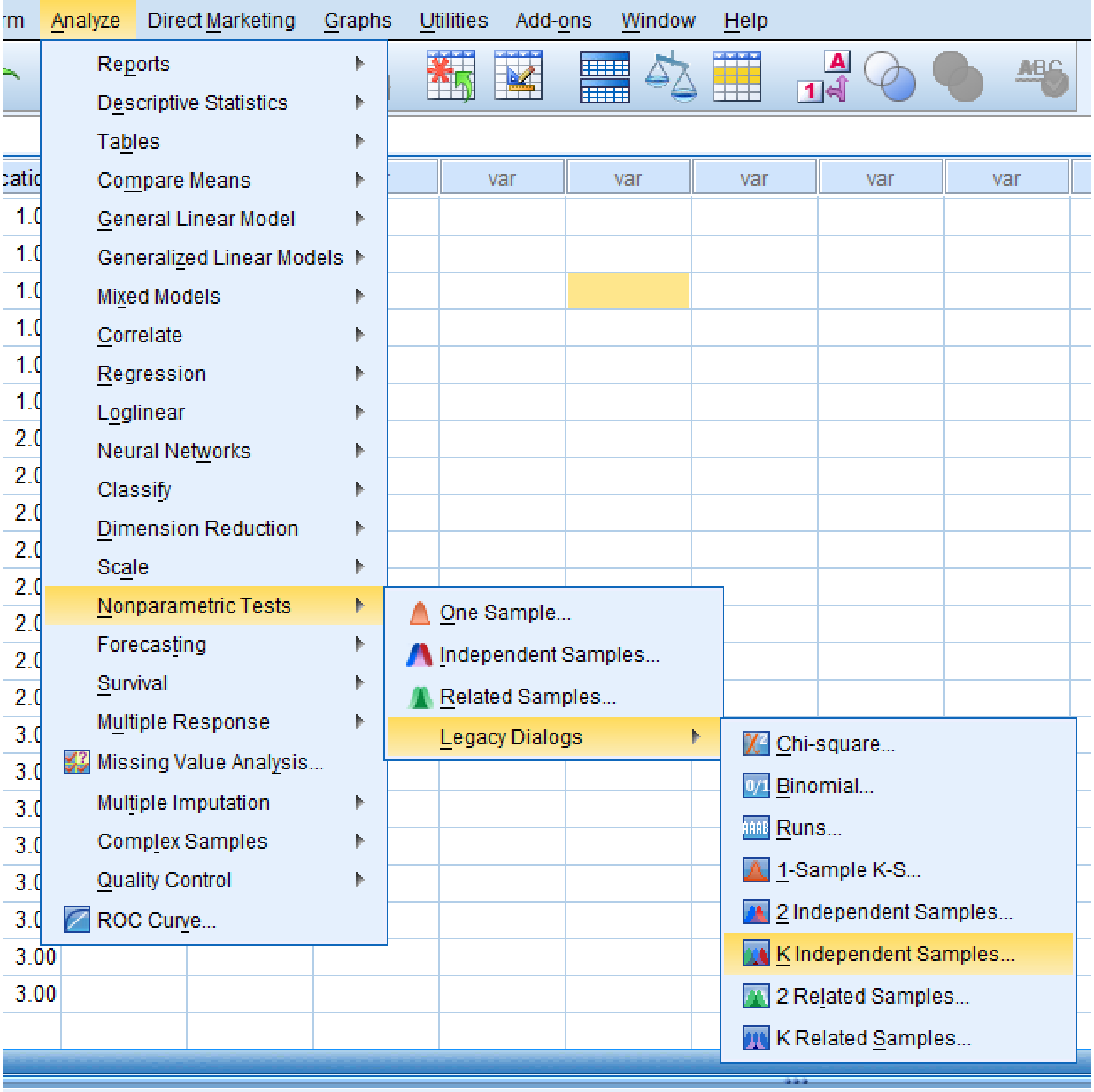
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Mixed Models
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Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
Scale
Nonparametric Tests
Forecasting
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
One Sample...
Independent Samples...
Related Samples...
Legacy Dialogs
Chi-square...
Binomial...
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1-Sample K-S...
2 Independent Samples...
K Independent Samples...
2 Related Samples...
K Related Samples...
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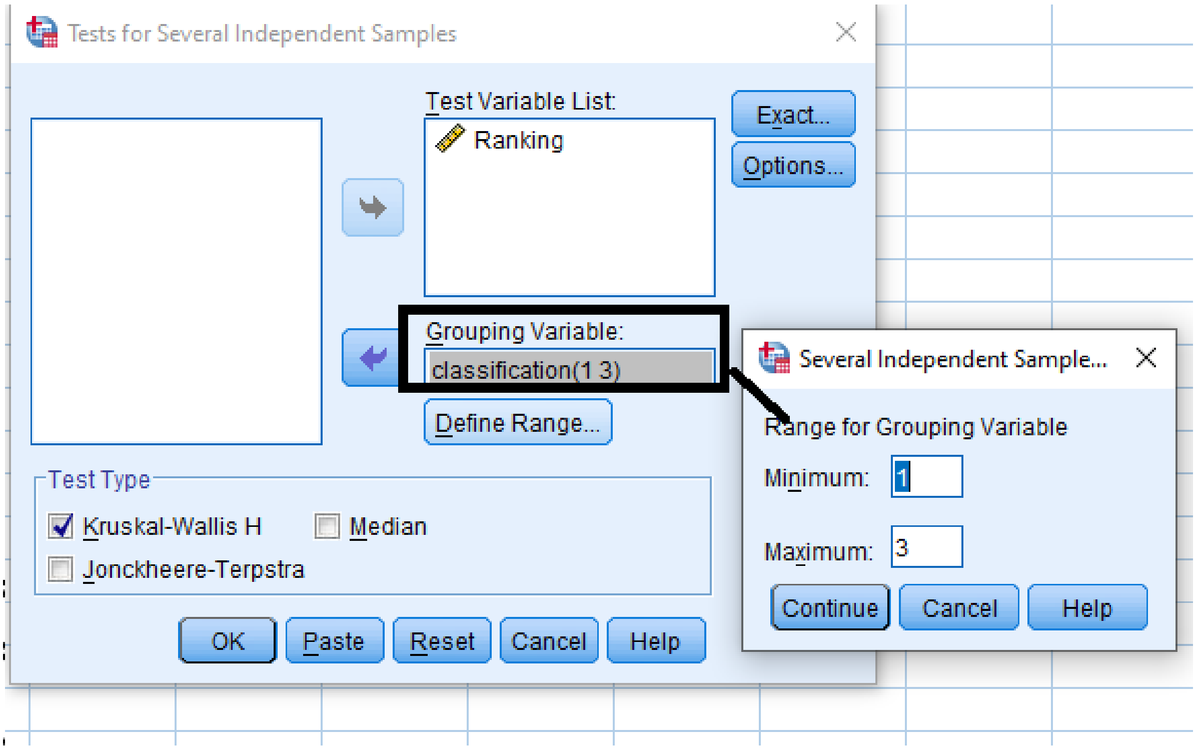


Kruskal-Wallis Test

Ranks the number of values from each group

	classification	N	Mean Rank
Ranking	Very attractive	8	7.50
	Average	8	11.50
	Very unattractive	8	18.50
	Total	24	

Test Statistics[a,b]

	Ranking
Chi-Square	9.920
df	2
Asymp. Sig.	.007

H-test statistic

p-value

a. Kruskal Wallis Test

b. Grouping Variable: classification

According to the data, the results from the Kruskal-Wallis H-test indicated that one or more of the **three groups are significantly different** (H(2) = 9.920, $p < 0.05$). Therefore, we must examine each set of samples with follow-up contrasts to find the differences between groups.

Based on the significance from the Kruskal-Wallis H-test, **we compare the samples with Mann-Whitney U-tests. Since there are k = 3 groups, use $\alpha_B = \frac{\alpha}{k} = 0.0167$** to avoid Type I error rate inflation. The results from the Mann-Whitney U-tests are displayed in the SPSS Outputs below

a. Very attractive-Avarege comparison:

Mann-Whitney Test

Ranks

	chassif	N	Mean Rank	Sum of Ranks
Ranks	Very attractive	8	7.00	56.00
	Average	8	10.00	80.00
	Total	16		

Test Statistics[a]

	Ranks
Mann-Whitney U	20.000
Wilcoxon W	56.000
Z	-1.260-
Asymp. Sig. (2-tailed)	.208
Exact Sig. [2*(1-tailed Sig.)]	.234[b]

a. Grouping Variable: chassif

b. Not corrected for ties.

Mann–Whitney U-test statistic

The results from the Mann-Whitney U-test (U = 20.0, n_1=8 , n_2 = 8, **p=0.208** > 0.0167) indicated that the two samples were **not significantly different**,

b. Very Attractive-very unattractive comparison:

Mann-Whitney Test

Ranks

	chassif	N	Mean Rank	Sum of Ranks
Ranks	Very attractive	8	5.00	40.00
	Very unattractive	8	12.00	96.00
	Total	16		

Test Statistics[a]

	Ranks
Mann-Whitney U	4.000
Wilcoxon W	40.000
Z	-2.941-
Asymp. Sig. (2-tailed)	.003
Exact Sig. [2*(1-tailed Sig.)]	.002[b]

a. Grouping Variable: chassif

b. Not corrected for ties.

The results from the Mann-Whitney U test (U = 12.0, n_1=8 , n_2= S, p=0.003< 0.0167) indicated that the two samples were **significantly different**,

c. Average -very unattractive comparison:

Mann-Whitney Test

Ranks

	chassif	N	Mean Rank	Sum of Ranks
Ranks	Average	8	6.00	48.00
	Very unattractive	8	11.00	88.00
	Total	16		

Test Statistics[a]

	Ranks
Mann-Whitney U	12.000
Wilcoxon W	48.000
Z	-2.100-
Asymp. Sig. (2-tailed)	.036
Exact Sig. [2*(1-tailed Sig.)]	.038[b]

a. Grouping Variable: chassif

b. Not corrected for ties.

The results from the Mann-Whitney U-test (U = 4.0, n_1=8 , n_2 = 8, p=0.036 >0.0167) indicated that the two samples were **not significantly different**.

Comparing Variables Of Ordinal Or Dichotomous Scales:

Spearman Rank- Order, Point-Biserial, and Biserial Correlations

The Spearman rank-order correlation, also called the Spearman's ρ, is used to compare the relationship between ordinal, or rank-ordered, variables

The point-biserial and biserial correlations are used to compare the relationship between two variables if one of the variables is dichotomous

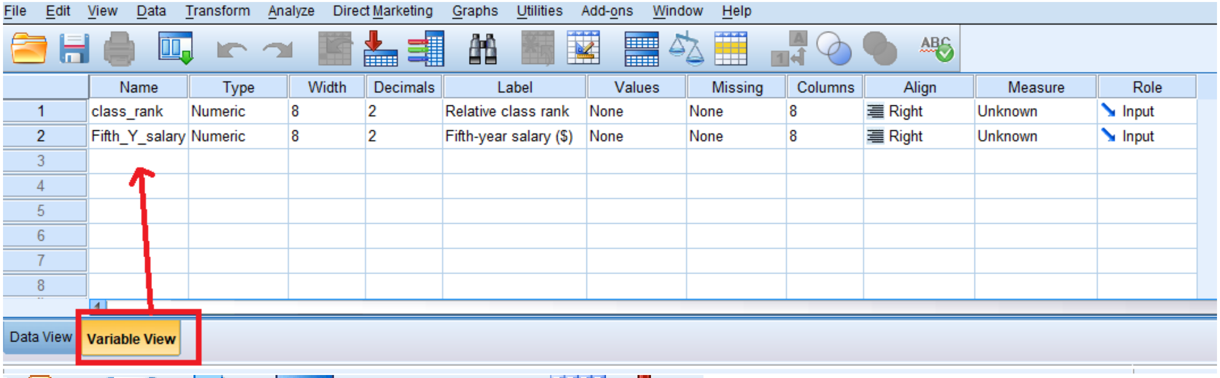
1. The business department at a small college wanted to compare the relative class rank of its MBA graduates with their fifth-year salaries. The data collected by the department are presented in Table 1. Compare the graduates' class rank with their fifth-year salaries.

TABLE 1

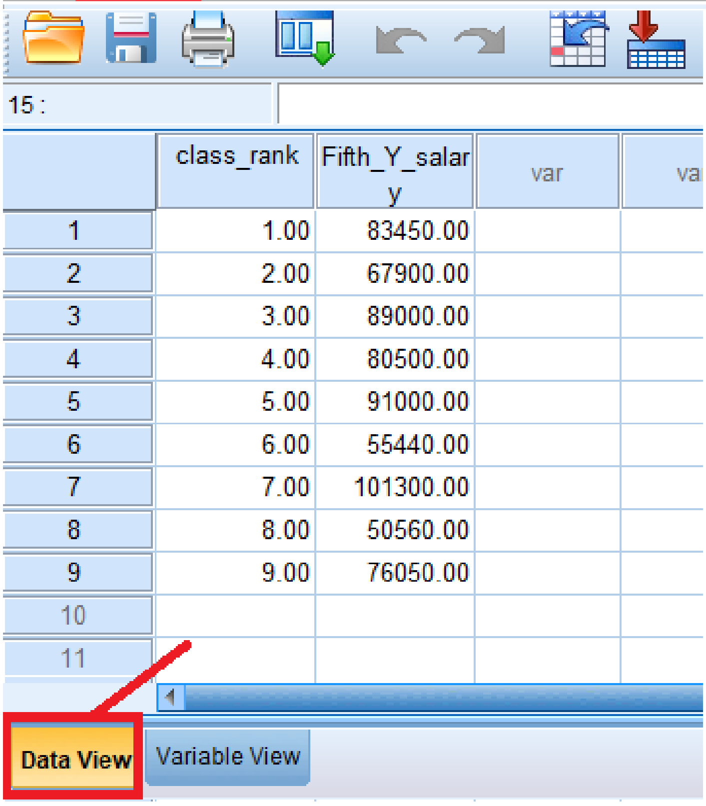
Relative class rank	Fifth-year salary ($)
1	83,450
2	67,900
3	89,000
4	80,500
5	91,000
6	55,440
7	101,300
8	50,560
9	76,050

Use a two-tailed Spearman rank-order correlation with $\alpha = 0.05$ to deter- mine if a relationship exists between the two variables. Report your findings.

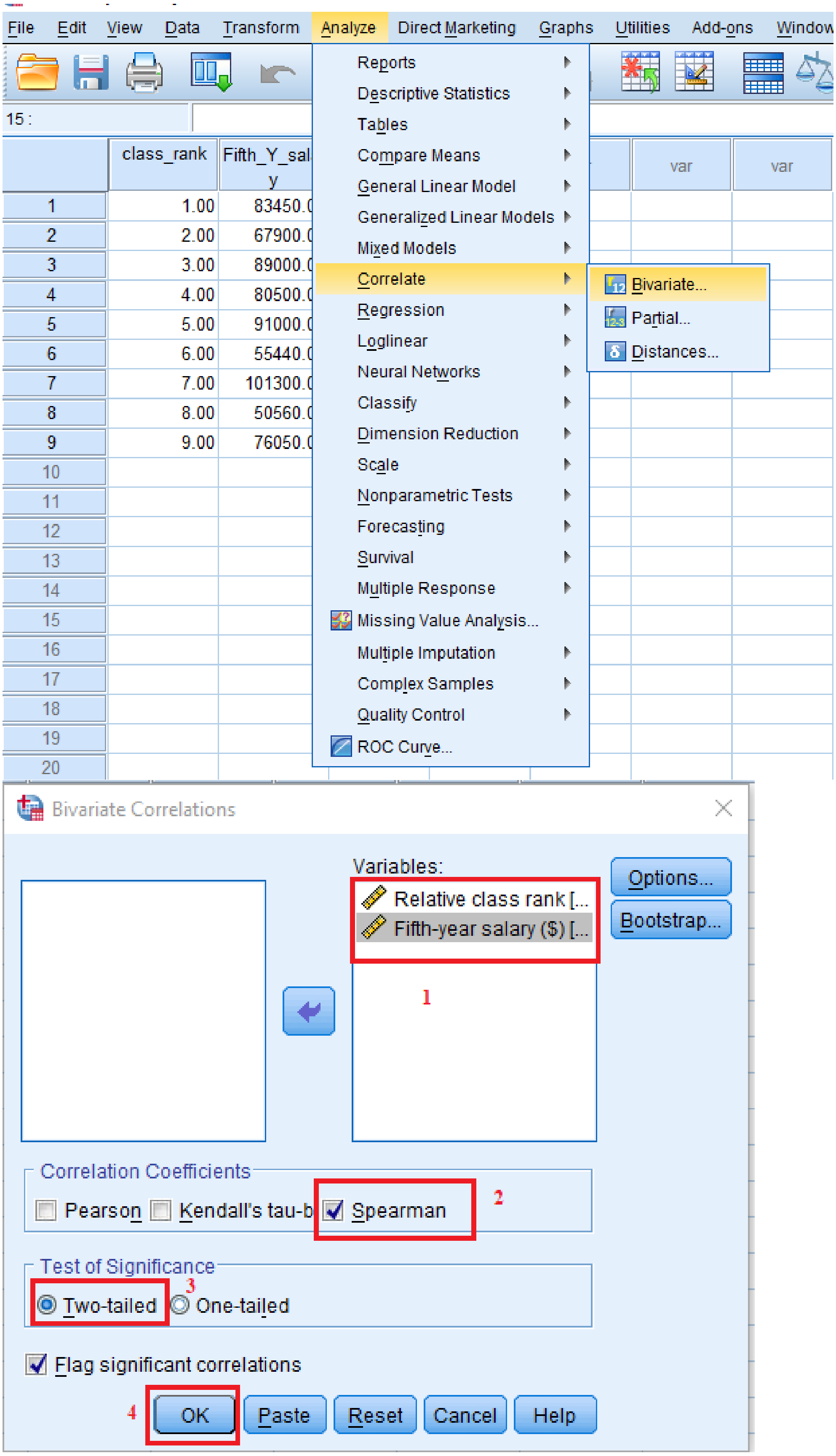
BY SPSS:



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	class_rank	Numeric	8	2	Relative class rank	None	None	8	Right	Unknown	Input
2	Fifth_Y_salary	Numeric	8	2	Fifth-year salary ($)	None	None	8	Right	Unknown	Input



	class_rank	Fifth_Y_salary
1	1.00	83450.00
2	2.00	67900.00
3	3.00	89000.00
4	4.00	80500.00
5	5.00	91000.00
6	6.00	55440.00
7	7.00	101300.00
8	8.00	50560.00
9	9.00	76050.00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Multiple Response
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Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
Bivariate...
Partial...
Distances...
Bivariate Correlations
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Fifth-year salary ($) [...
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Pearson
Kendall's tau-b
Spearman
2
Test of Significance
Two-tailed
3
One-tailed
Flag significant correlations
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Nonparametric Correlations

[DataSet0]

Correlations

			Relative class rank	Fifth-year salary ($)
Spearman's rho	Relative class rank	Correlation Coefficient	1.000	-.217-
		Sig. (2-tailed)	.	.576
		N	9	9
	Fifth-year salary ($)	Correlation Coefficient	-.217-	1.000
		Sig. (2-tailed)	.576	.
		N	9	9

Spearman rank-order correlation coefficient (r_s= -0.217)

p-value = 0.576

number of pairs (n = 9)
number in class rank =9
number in salary =9

The results from the Spearman rank-order correlation (r_s= −0.217, p=0.576 > 0.05) **did not produce significant results**. Based on these data, we can state that there is **no clear relationship between graduates' relative class rank and fifth-year salary.**

Remember

If $p-value \leq \propto$ $\quad$ $Reject\ H_0$

And

If $p-value > \propto$ $\quad$ $not\ reject\ H_0$

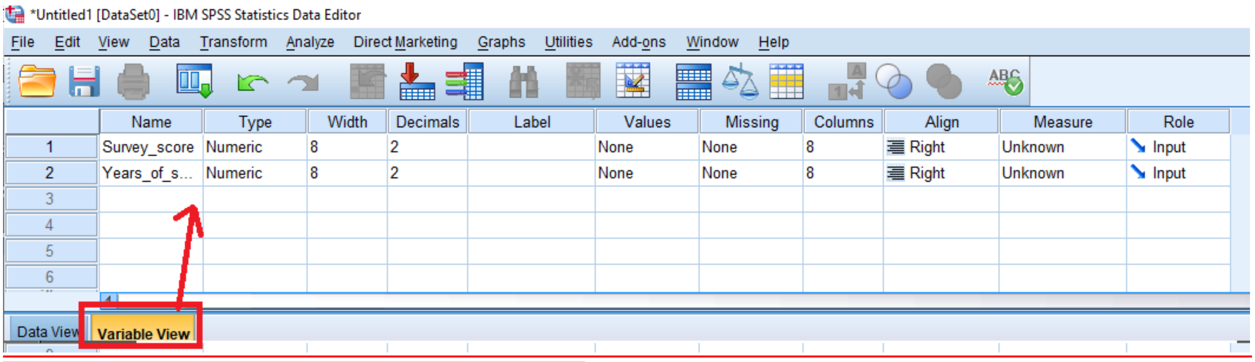
2. A researcher was contracted by the military to assess soldiers' perception of a new training program's effectiveness. Fifteen soldiers participated in the program. The researcher used a survey to measure the soldiers' perceptions of the pro- gram's effectiveness. The survey used a Likert-type scale that ranged from 5 = *strongly agree* to 1 = *strongly disagree*. Using the data presented in Table 2, compare the soldiers' average survey scores with the total number of years the soldiers had been serving.

TABLE 2

Average survey score	Years of service
4.0	18
4.0	15
2.4	2
4.2	13
3.4	4
4.0	10
5.0	24
1.8	4
3.2	9
2.5	5
2.5	3
3.0	8
3.6	16
4.6	14
4.8	12

Use a two-tailed Spearman rank-order correlation with $\alpha = 0.05$ to deter- mine if a relationship exists between the two variables. Report your findings.

BY SPSS:



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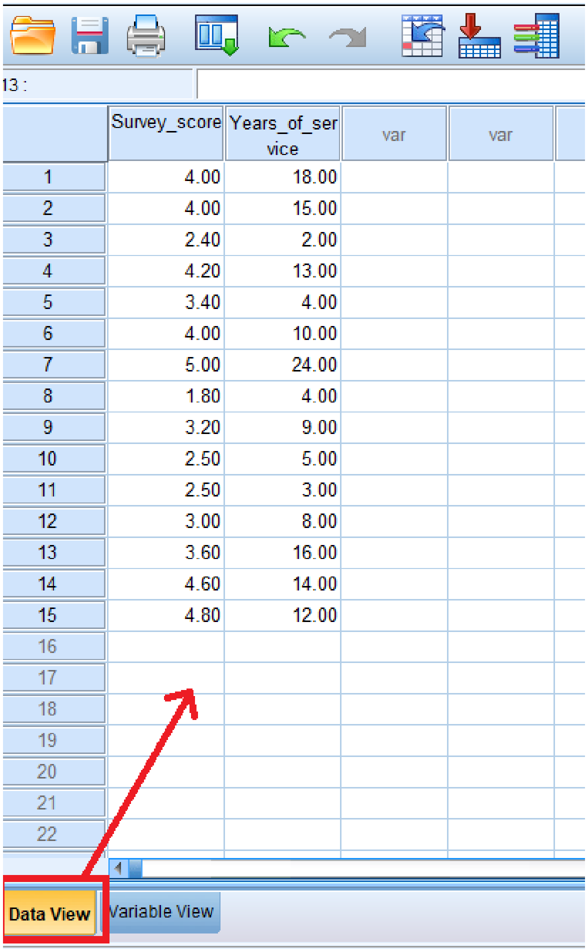
	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	Survey_score	Numeric	8	2		None	None	8	Right	Unknown	Input
2	Years_of_s...	Numeric	8	2		None	None	8	Right	Unknown	Input
3											
4											
5											
6											

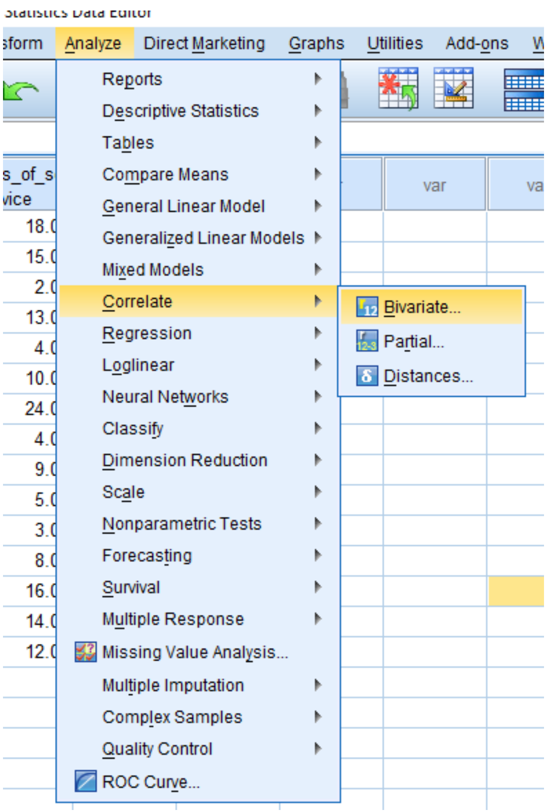
Data View | Variable View



13 :

	Survey_score	Years_of_service	var	var
1	4.00	18.00		
2	4.00	15.00		
3	2.40	2.00		
4	4.20	13.00		
5	3.40	4.00		
6	4.00	10.00		
7	5.00	24.00		
8	1.80	4.00		
9	3.20	9.00		
10	2.50	5.00		
11	2.50	3.00		
12	3.00	8.00		
13	3.60	16.00		
14	4.60	14.00		
15	4.80	12.00		
16				
17				
18				
19				
20				
21				
22				

Data View | Variable View


Statistics Data Editor
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Classify
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Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
Bivariate...
Partial...
Distances...
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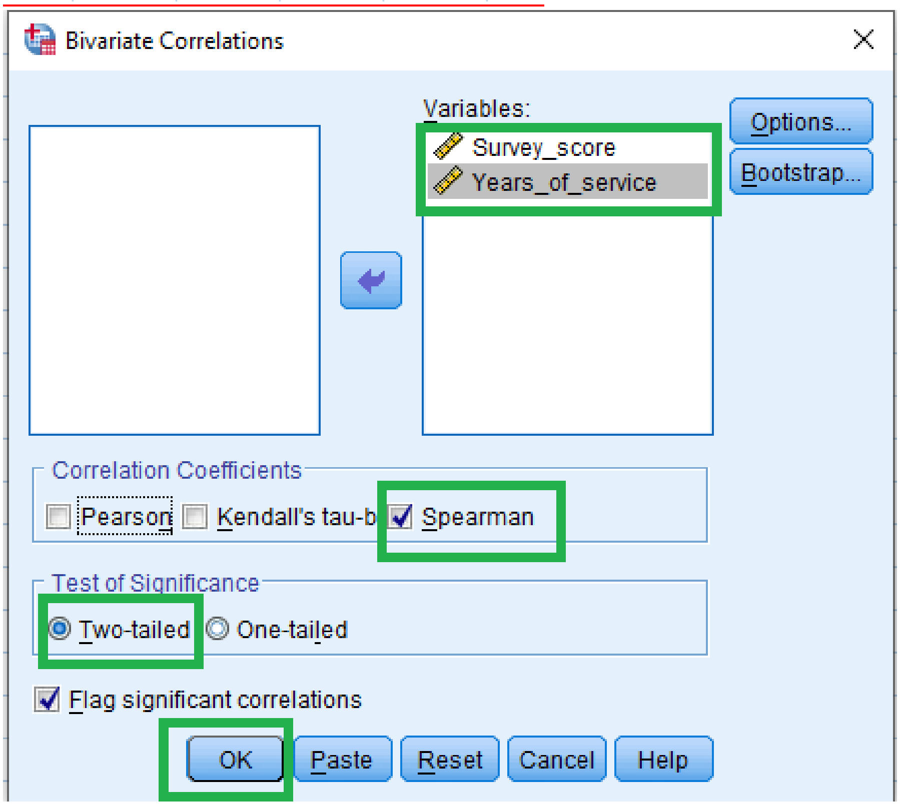

Bivariate Correlations
Variables:
Survey_score
Years_of_service
Options...
Bootstrap...
Correlation Coefficients
Pearson
Kendall's tau-b
Spearman
Test of Significance
Two-tailed
One-tailed
Flag significant correlations
OK
Paste
Reset
Cancel
Help

Nonparametric Correlations

[DataSet0]

Correlations

			Survey_score	Years_of_service
Spearman's rho	Survey_score	Correlation Coefficient	1.000	.806**
		Sig. (2-tailed)	.	.000
		N	15	15
	Years_of_service	Correlation Coefficient	.806**	1.000
		Sig. (2-tailed)	.000	.
		N	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

r_s=0.806

p-value=0

number of pairs =15

The results from the Spearman rank-order correlation (r_s = = 0.806, p=0.000 < 0.05) produced **significant results**. Based on these data, **we can state that there is a very strong correlation between soldiers' survey scores concerning the new program's effectiveness and their total years of military service**.

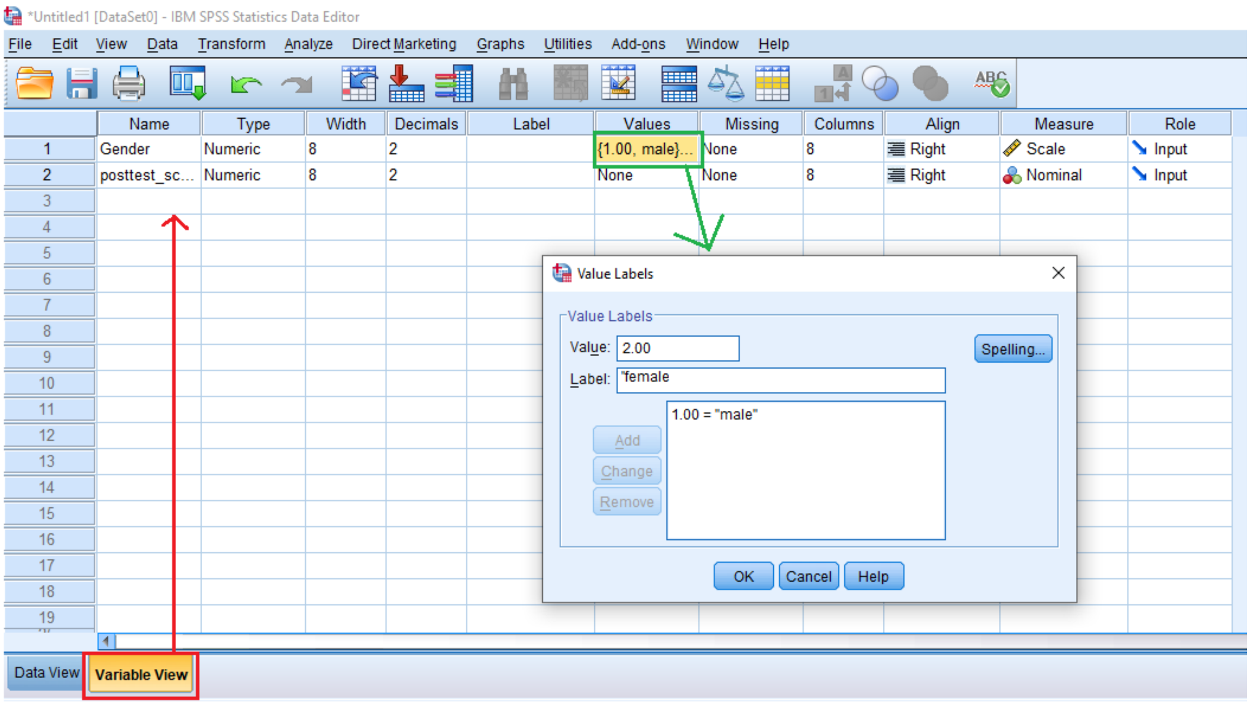
3. A middle school history teacher wished to determine if there is a connection between gender and history knowledge among 8th-grade gifted students. The teacher administered a 50 item test at the beginning of the school year to 16 gifted 8th-grade students. The scores from the test are presented in Table 3.

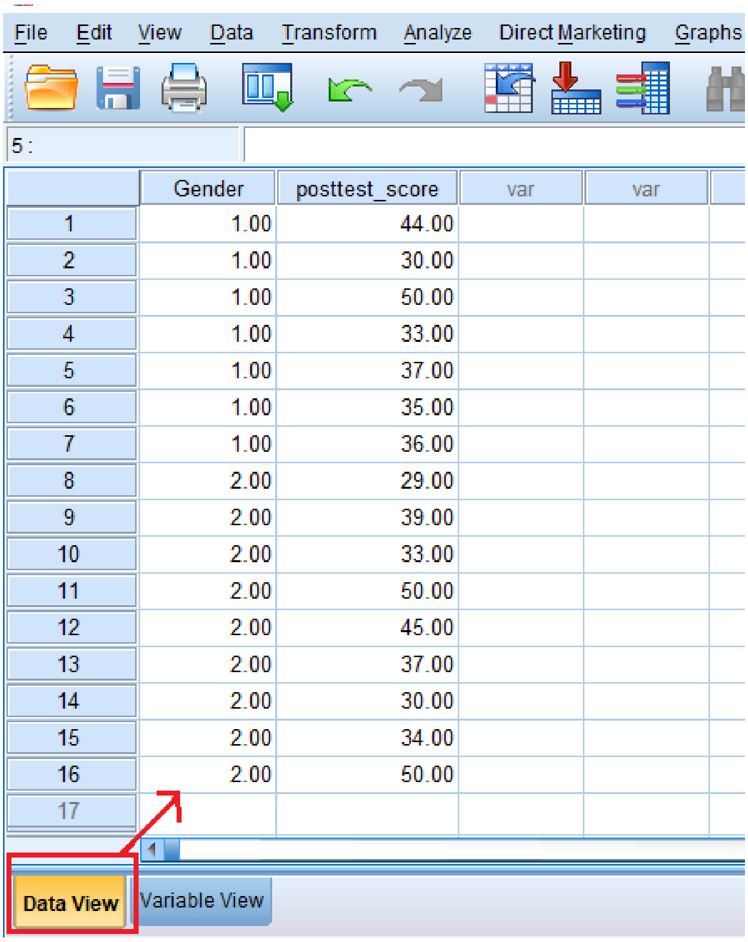
TABLE 3

Participant	Gender	Posttest score
1	M	44
2	M	30
3	M	50
4	M	33
5	M	37
6	M	35
7	M	36
8	F	29
9	F	39
10	F	33
11	F	50
12	F	45
13	F	37
14	F	30
15	F	34
16	F	50

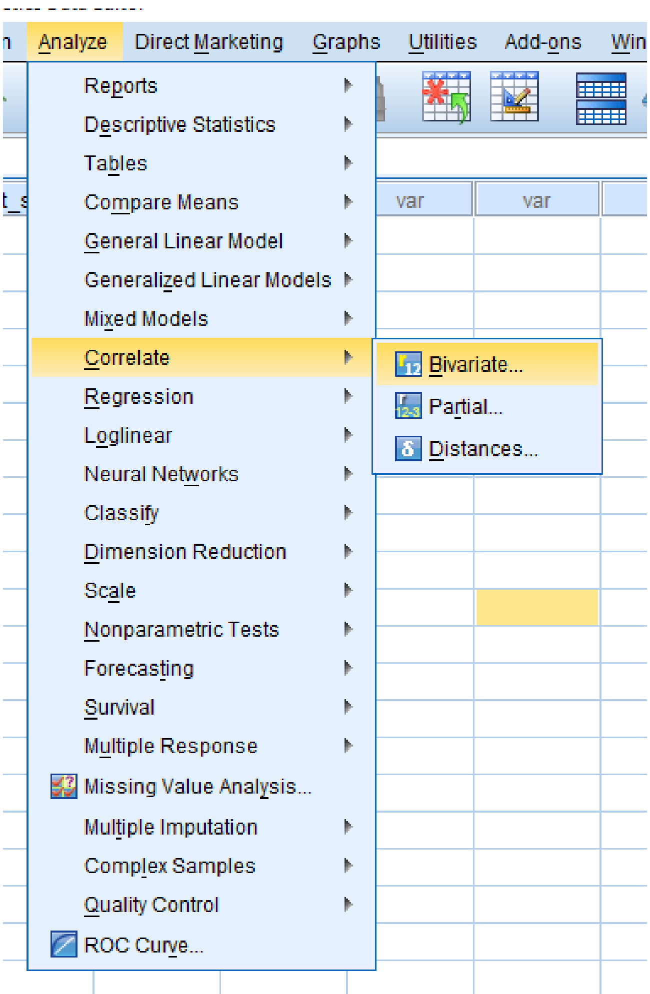
Use a two-tailed point-biserial correlation with α = 0.05 to determine if a relationship exists between the two variables. Report your findings.

Test hypothesis: $H_0: \rho_{pb} = 0 \quad vs \quad H_A: \rho_{pb} \neq 0$





	Gender	posttest_score	var	var
1	1.00	44.00		
2	1.00	30.00		
3	1.00	50.00		
4	1.00	33.00		
5	1.00	37.00		
6	1.00	35.00		
7	1.00	36.00		
8	2.00	29.00		
9	2.00	39.00		
10	2.00	33.00		
11	2.00	50.00		
12	2.00	45.00		
13	2.00	37.00		
14	2.00	30.00		
15	2.00	34.00		
16	2.00	50.00		
17				


Analyze
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Dimension Reduction
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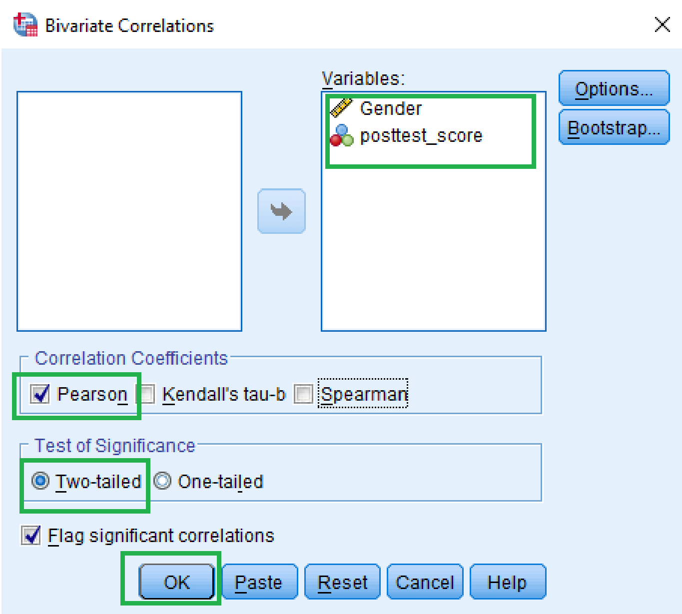
Bivariate Correlations
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Gender
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Pearson
Kendall's tau-b
Spearman
Test of Significance
Two-tailed
One-tailed
Flag significant correlations
OK
Paste
Reset
Cancel
Help

Correlations

[DataSet0]

Correlations

		Gender	posttest_score
Gender	Pearson Correlation	1	.049
	Sig. (2-tailed)		.858
	N	16	16
posttest_score	Pearson Correlation	.049	1
	Sig. (2-tailed)	.858	
	N	16	16

r_{pb}=0.049

p-value =0.858

number of Participant=16

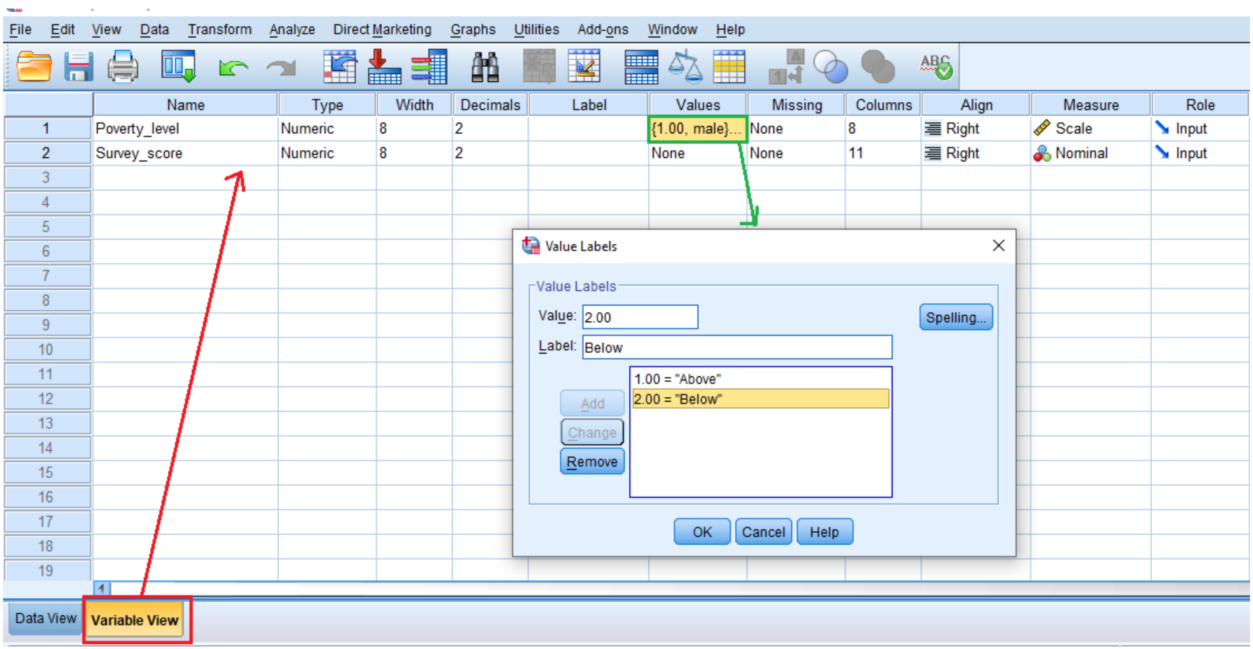
The results from the point-biserial correlation (r_{pb} = 0.049, p=0.858 > α= 0.05) **did not produce significant results**. Based on these data, we can state that there is **no clear relationship between eight-grade gifted students' gender and their score on the history knowledge test administered by the teacher**.

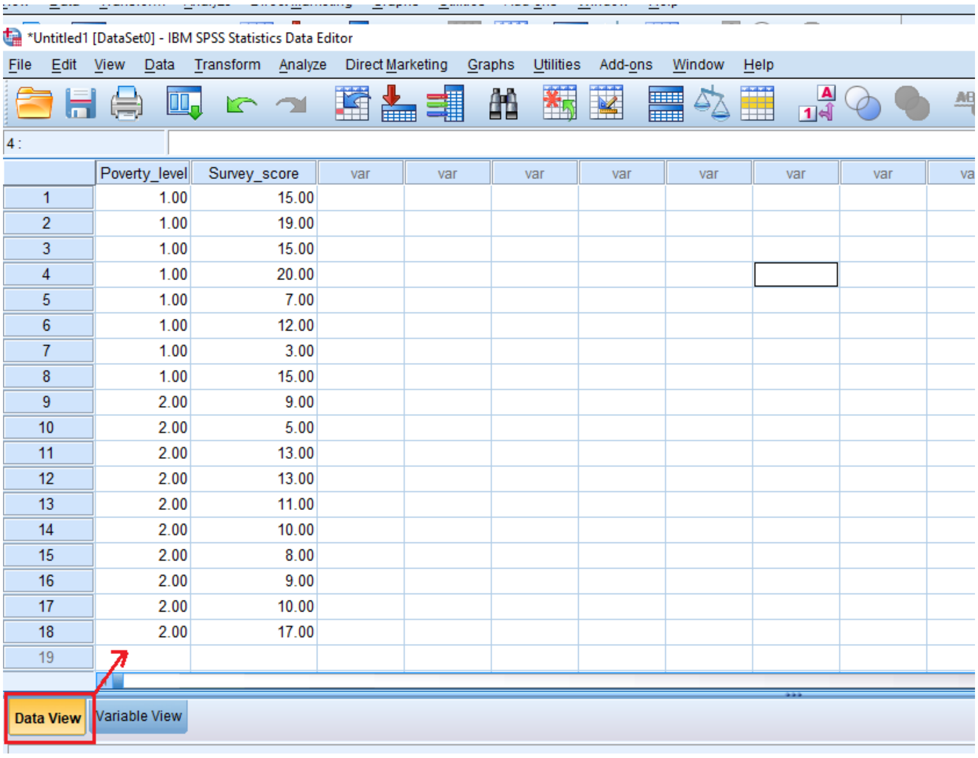
4. A researcher wished to determine if there is a connection between poverty and self-esteem. Income level was used to classify 18 participants as either below poverty or above poverty. Participants completed a 20 item survey to measure self-esteem. The scores from the survey are reported in Table 4

TABLE 4

Participant	Poverty level	Survey score
1	Above	15
2	Above	19
3	Above	15
4	Above	20
5	Above	7
6	Above	12
7	Above	3
8	Above	15
9	Below	9
10	Below	5
11	Below	13
12	Below	13
13	Below	11
14	Below	10
15	Below	8
16	Below	9
17	Below	10
18	Below	17

Use a two-tailed biserial correlation with α = 0.05 to determine if a relationship exists between the two variables. Report your findings.

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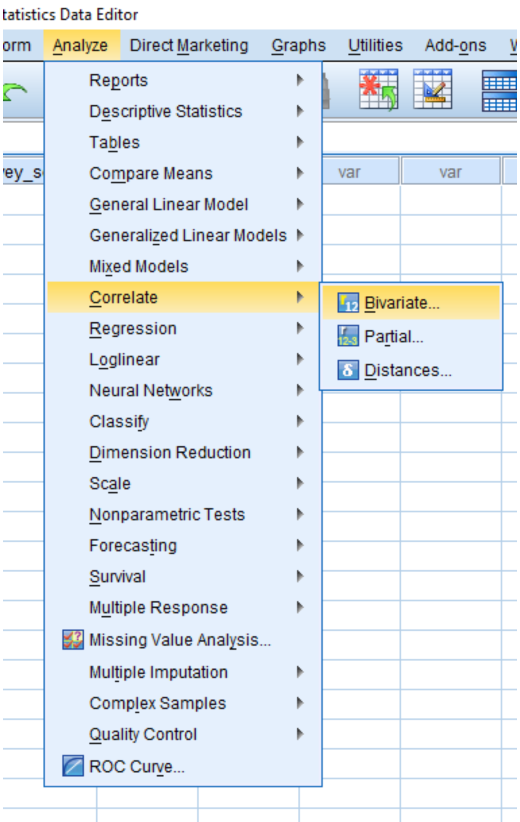
Poverty_level Survey_score var var var var var var var
1 1.00 15.00
2 1.00 19.00
3 1.00 15.00
4 1.00 20.00
5 1.00 7.00
6 1.00 12.00
7 1.00 3.00
8 1.00 15.00
9 2.00 9.00
10 2.00 5.00
11 2.00 13.00
12 2.00 13.00
13 2.00 11.00
14 2.00 10.00
15 2.00 8.00
16 2.00 9.00
17 2.00 10.00
18 2.00 17.00
19
Data View
Variable View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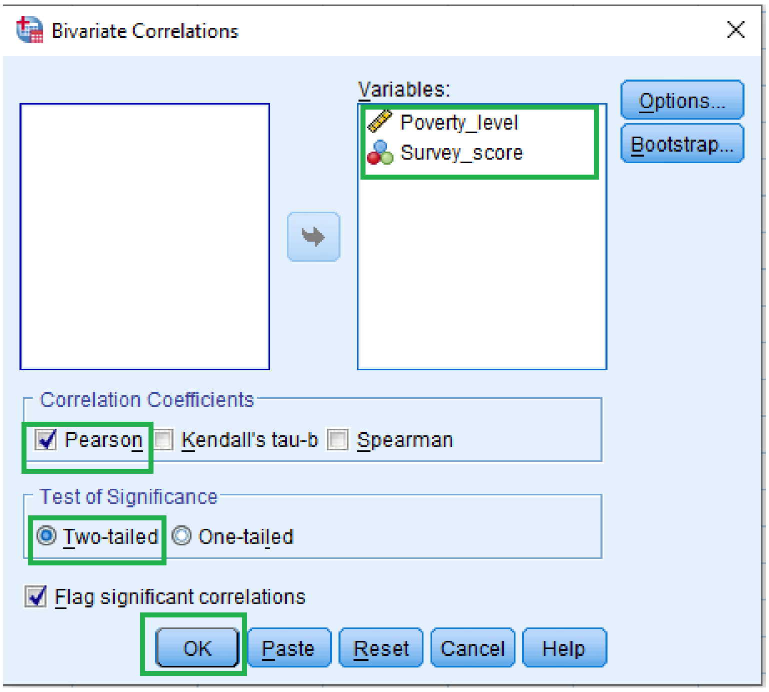


Correlations

[DataSet0]

Correlations

		Survey scor	Poverty
Survey scor	Pearson Correlation	1	-.304-
	Sig. (2-tailed)		.220
	N	18	18
Poverty	Pearson Correlation	-.304-	1
	Sig. (2-tailed)	.220	
	N	18	18

The results from the biserial correlation (r_b = -0.304, $p > 0.05$) **did not produce significant results**. Based on these data, we can state that there is **no clear relationship between poverty level and self-esteem.**

Chi-square Test

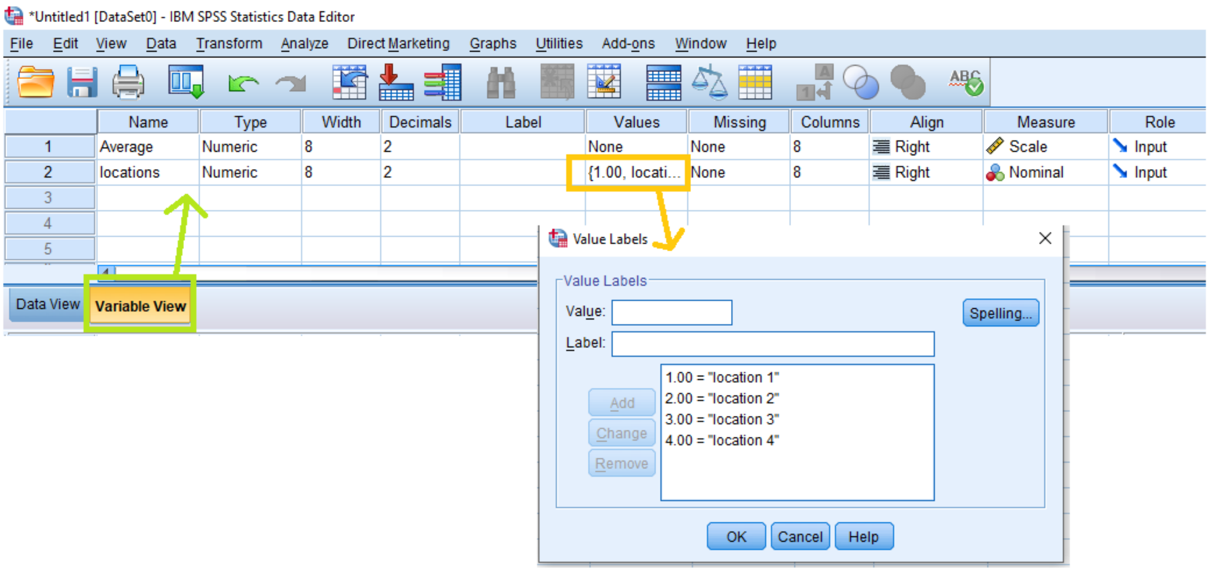
1. A police department wishes to compare the average number of monthly robberies at four locations in their town. Use equal categories in order to identify one or more concentrations of robberies. The data are presented in Table 1.

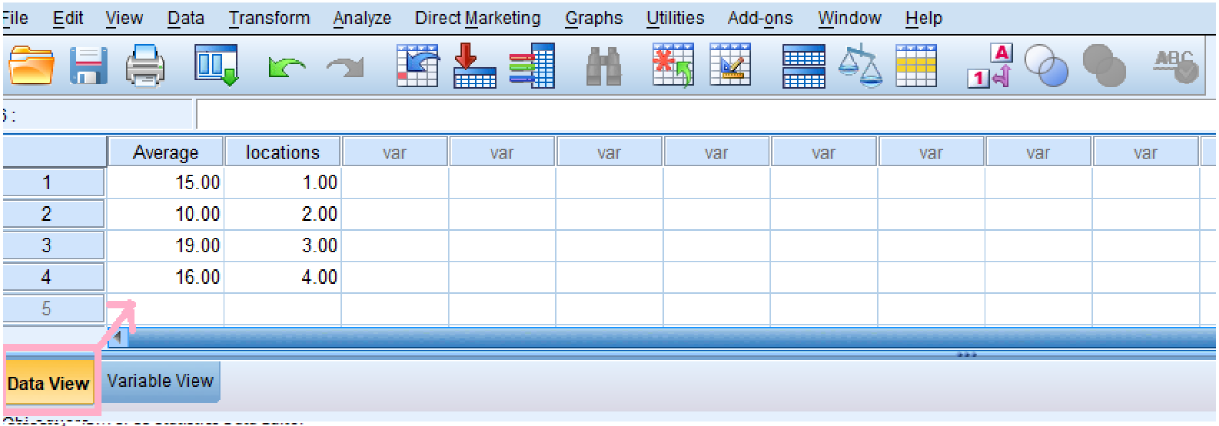
TABLE 1

	Average monthly robberies
Location 1	15
Location 2	10
Location 3	19
Location 4	16

Use a χ^2 goodness-of-it test with $\alpha = 0.05$ to determine if the robberies are concentrated in one or more of the locations. Report your findings.

By SPSS:

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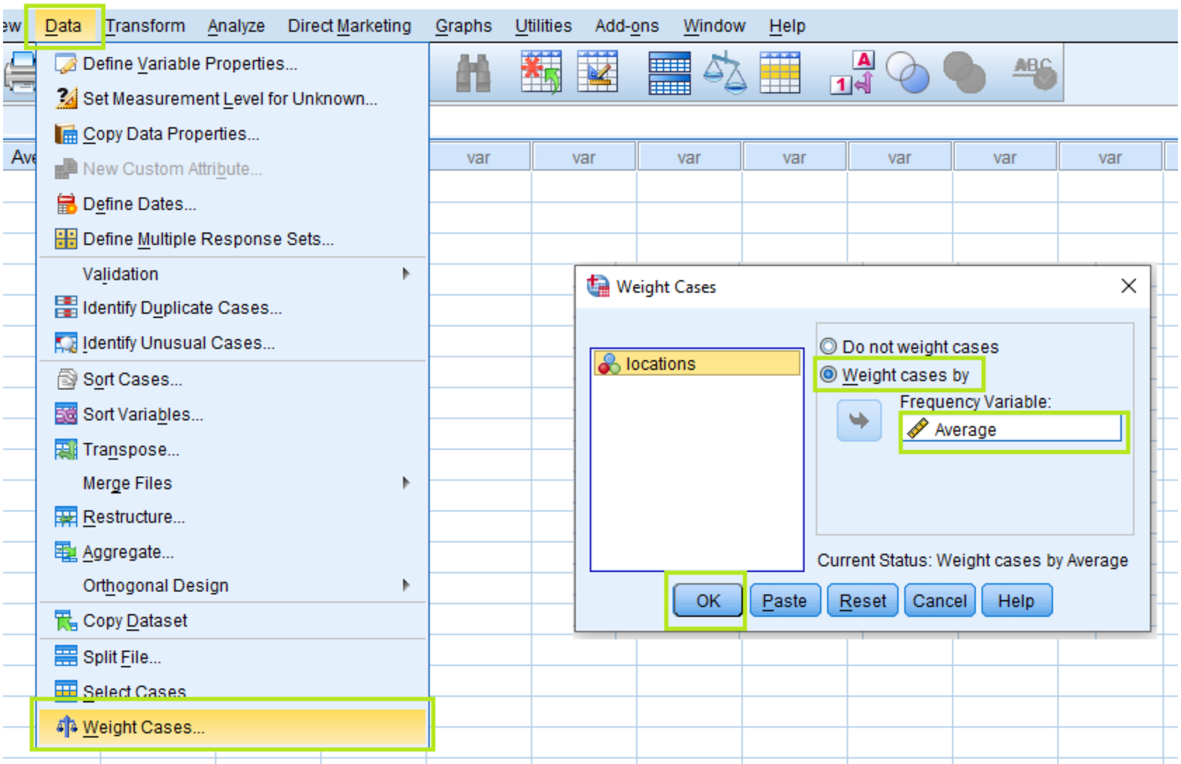
Average locations var var var var var var var var
1 15.00 1.00
2 10.00 2.00
3 19.00 3.00
4 16.00 4.00
5
Data View
Variable View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Set Measurement Level for Unknown...
Copy Data Properties...
New Custom Attribute...
Define Dates...
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Validation
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Identify Unusual Cases...
Sort Cases...
Sort Variables...
Transpose...
Merge Files
Restructure...
Aggregate...
Orthogonal Design
Copy Dataset
Split File...
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Current Status: Weight cases by Average
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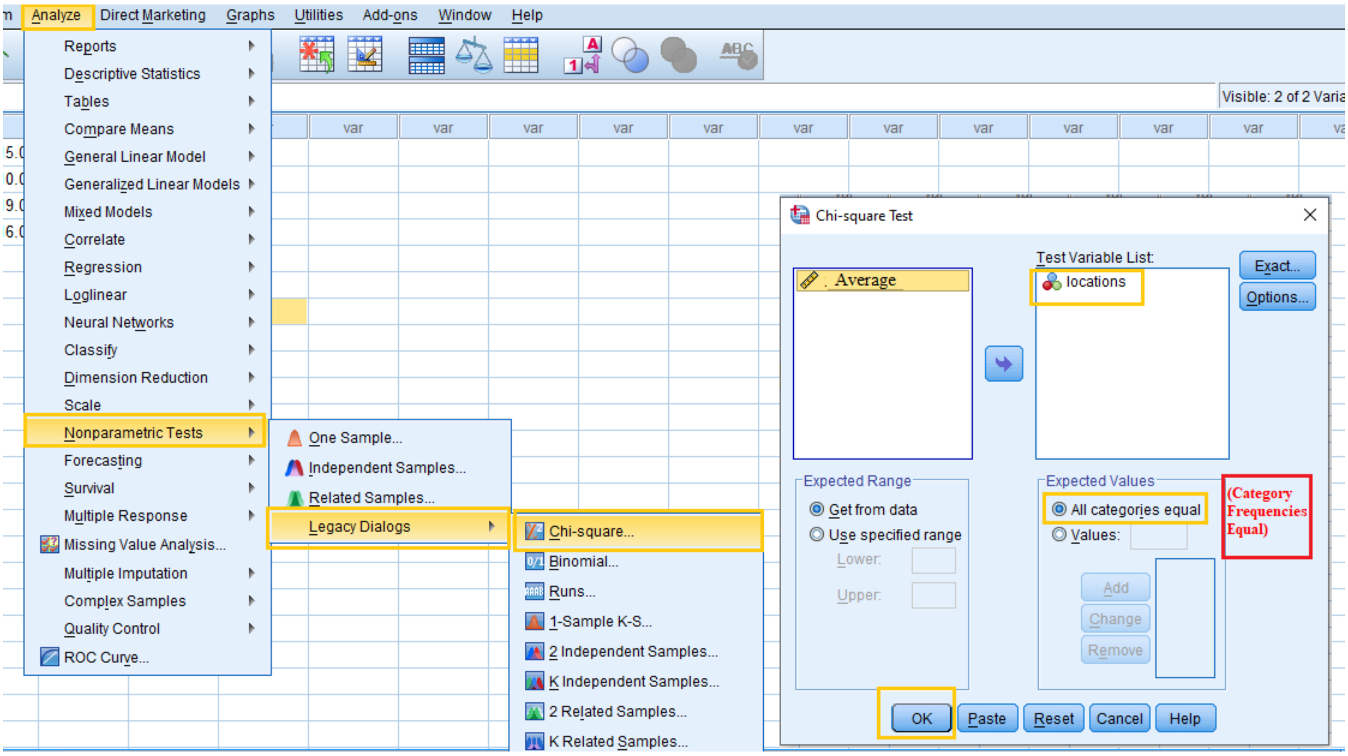
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Multiple Imputation
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Quality Control
ROC Curve...
One Sample...
Independent Samples...
Related Samples...
Legacy Dialogs
Chi-square...
Binomial...
Runs...
1-Sample K-S...
2 Independent Samples...
K Independent Samples...
2 Related Samples...
K Related Samples...
Visible: 2 of 2 Varia
Chi-square Test
Average
Test Variable List:
locations
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Options...
Expected Range
Get from data
Use specified range
Lower:
Upper:
Expected Values
All categories equal
Values:
Add
Change
Remove
(Category Frequencies Equal)
OK
Paste
Reset
Cancel
Help

Chi-Square Test

Frequencies

locations

	Observed N	Expected N	Residual
location 1	15	15.0	.0
location 2	10	15.0	-5.0-
location 3	19	15.0	4.0
location 4	16	15.0	1.0
Total	60		

Test Statistics

	locations
Chi-Square	2.800[a]
df	3
Asymp. Sig.	.423

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.0.

The χ^2 statistic $\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$

the degrees of freedom df=C-1

p-value (p-value =0.423 > α =0.05 not reject H0)

According to the data, the results from the chi-square goodness-of-fit test were **not significant** ($\chi^2_{(3)} = 2.800$, $p = 0.423 > \alpha = 0.05$)

Therefore, no particular location displayed a significantly higher or lower number of robberies.

2. The χ^2 goodness-of-it test serves as a useful tool to ensure that statistical samples approximately match the desired stratification proportions of the population from which they are drawn.

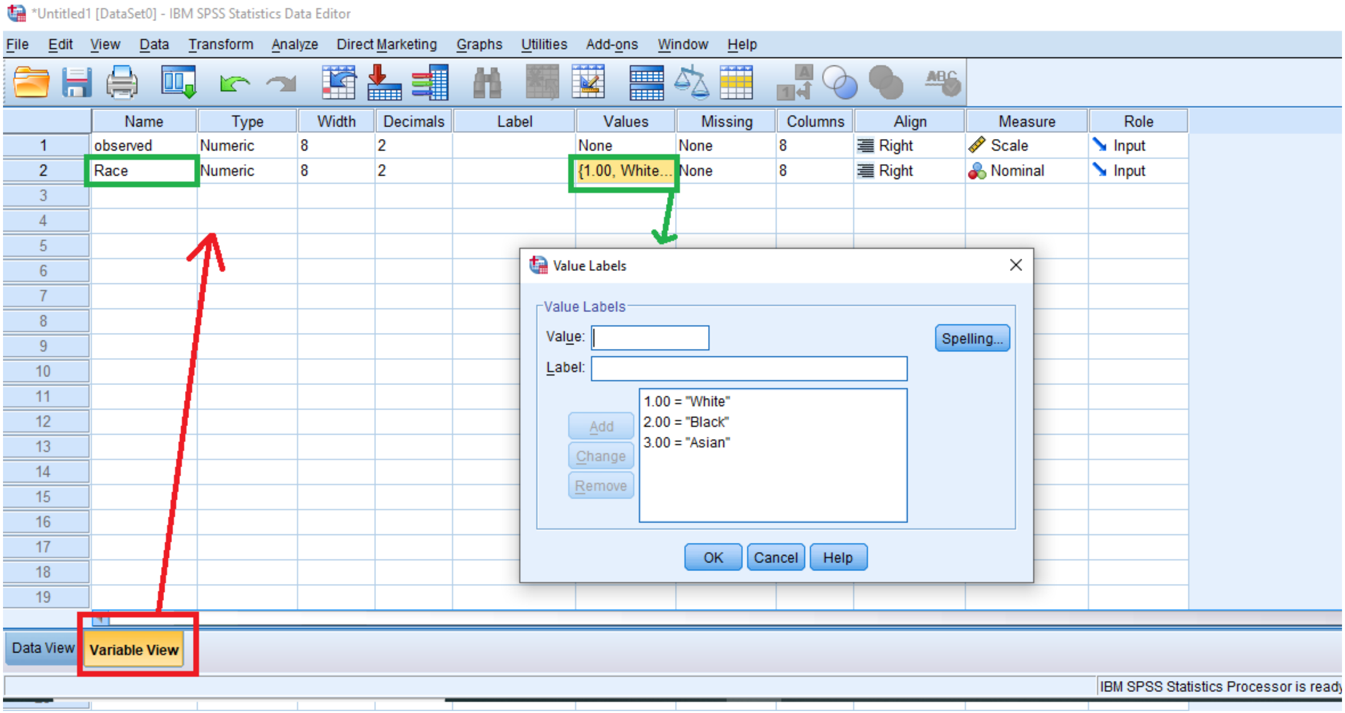
A researcher wishes to determine if her randomly drawn sample matches the racial stratification of school age children. She used the most recent U.S. Census data, which was from 2001. The racial composition of her sample and the 2001 U.S. Census proportions are displayed in Table 2.

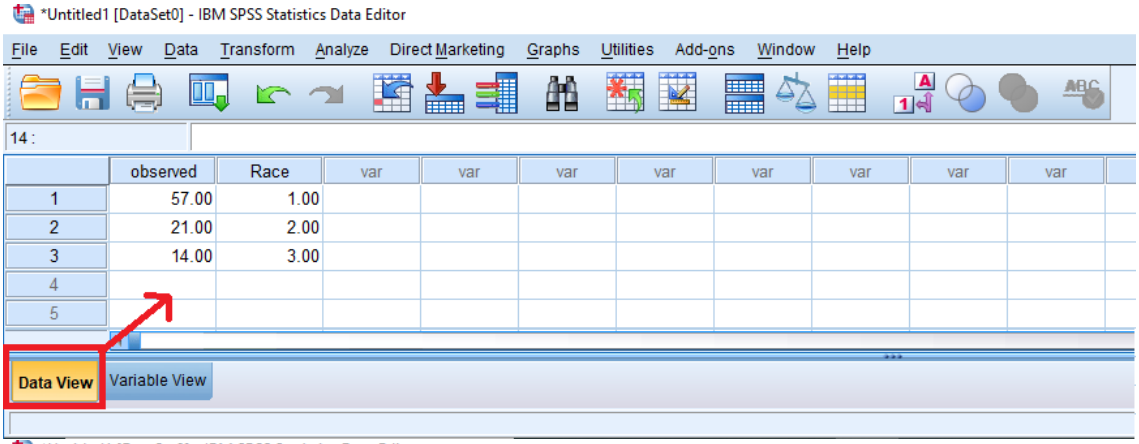
TABLE 2

Race	Frequency of race from the researcher's randomly drawn sample	Racial percentage of U.S. school children based on the 2001 U.S. Census (%)
White	57	72
Black	21	20
Asian, Hispanic, or Pacific Islander	14	8

Use a χ^2 goodness-of-it test with $\alpha = 0.05$ to determine if the researcher's sample matches the proportions reported by the U.S. Census. Report your findings.

By SPSS:

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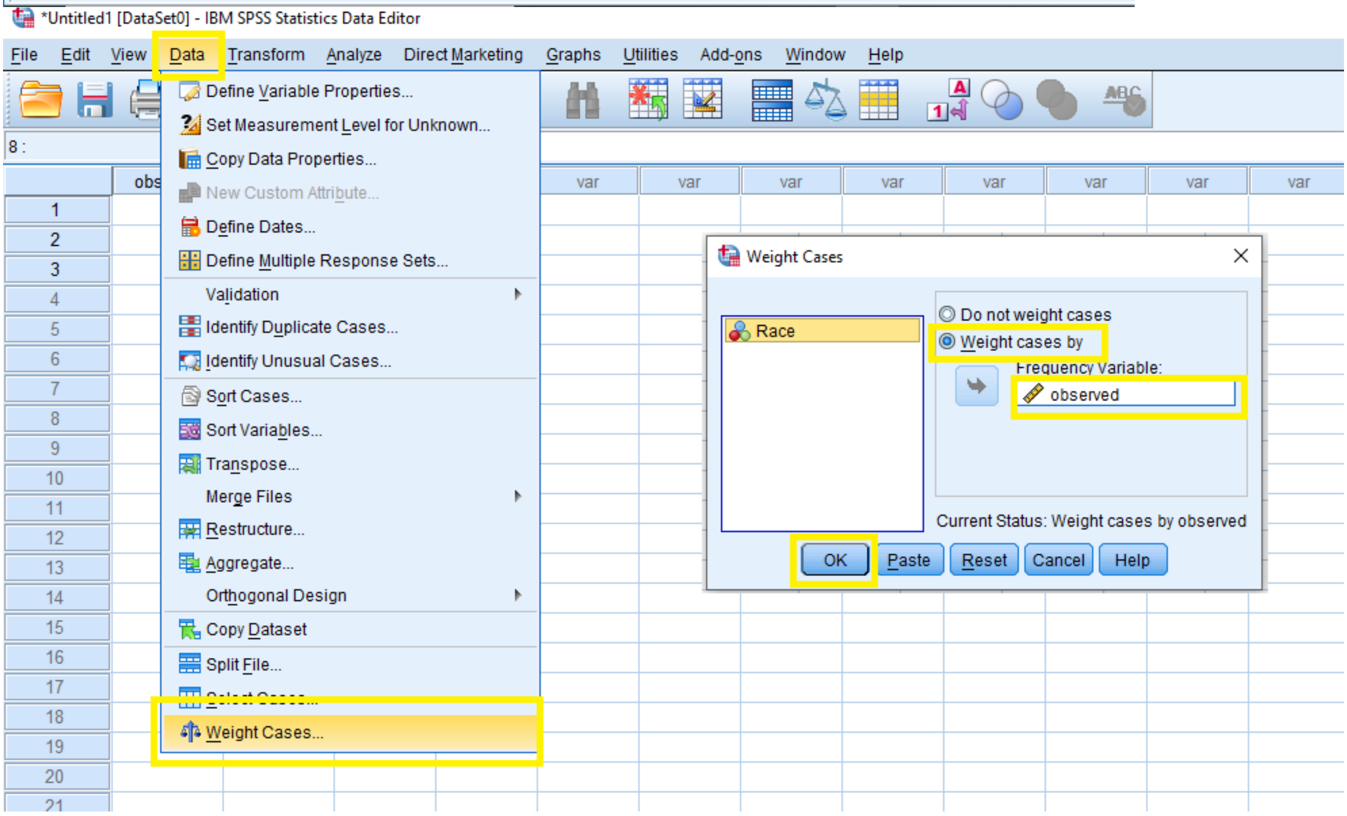
2 21.00 2.00
3 14.00 3.00
4
5
Data View
Variable View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8 :
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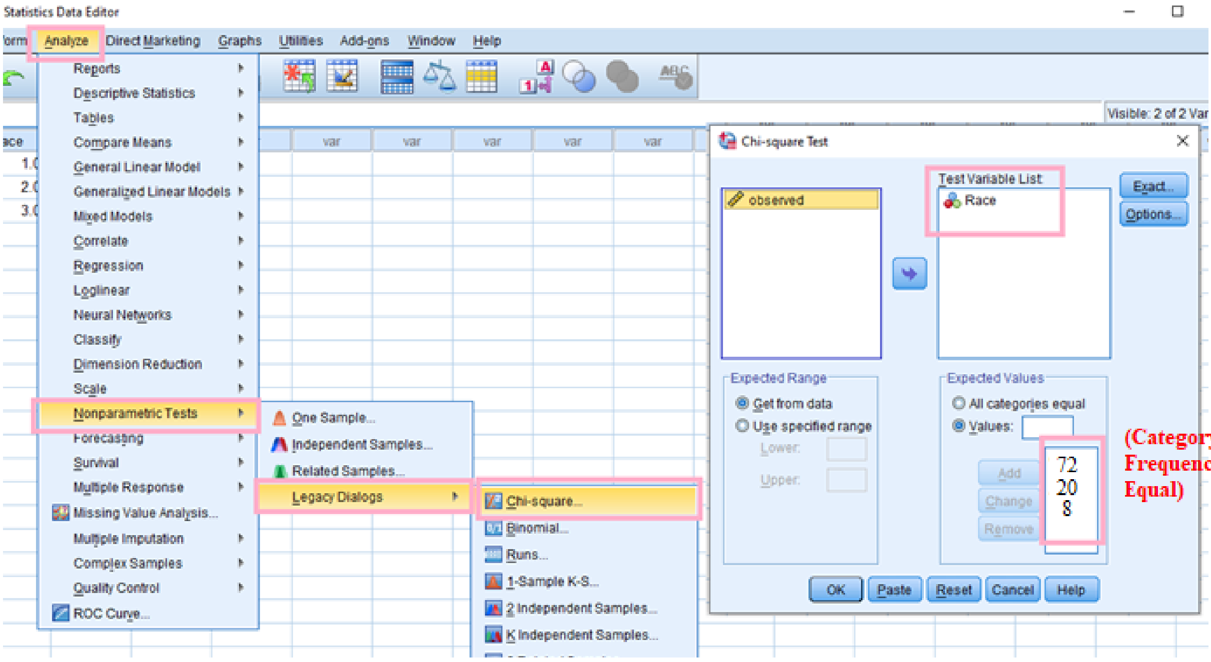
Set Measurement Level for Unknown...
Copy Data Properties...
New Custom Attribute...
Define Dates...
Define Multiple Response Sets...
Validation
Identify Duplicate Cases...
Identify Unusual Cases...
Sort Cases...
Sort Variables...
Transpose...
Merge Files
Restructure...
Aggregate...
Orthogonal Design
Copy Dataset
Split File...
Weight Cases...
Weight Cases
Race
Do not weight cases
Weight cases by
Frequency Variable:
observed
Current Status: Weight cases by observed
OK
Paste
Reset
Cancel
Help



(Category Frequencies Not Equal)

Chi-Square Test

Frequencies

cat

	Observed N	Expected N	Residual
whit	57	66.2	-9.2-
black	21	18.4	2.6
as	14	7.4	6.6
Total	92		

Test Statistics

	cat
Chi-Square	7.647[a]
df	2
Asymp. Sig.	.022

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.4.

$\chi^2_{(2)}$ **test statistic =7.647**

degrees of freedom =2

p-value =0.022

According to the data, the results from the chi-square goodness-of-fit test were significant (χ^2_2) = 7.647, p=0.022 <α= 0.05).

Therefore, the sample's racial stratification approximately matches the U.S. Census racial composition of school aged children in 2001

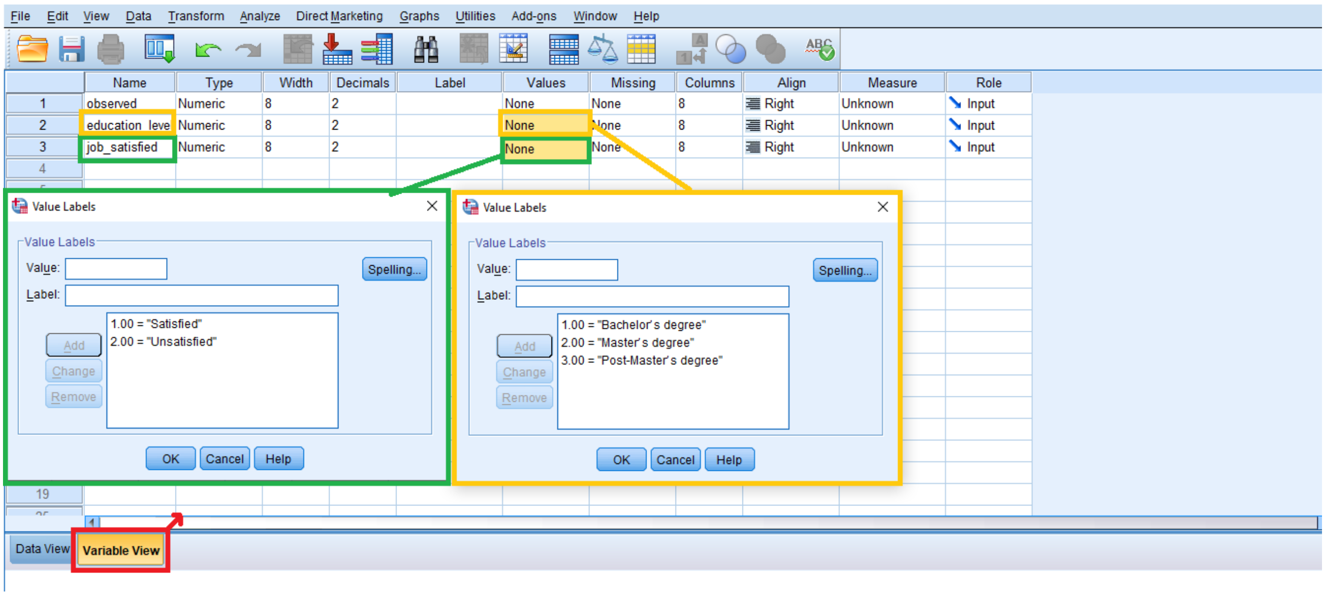
3. A researcher wishes to determine if there is an association between the level of a teacher's education and his/her job satisfaction. He surveyed 158 teachers. The frequencies of the corresponding results are displayed in Table 3.

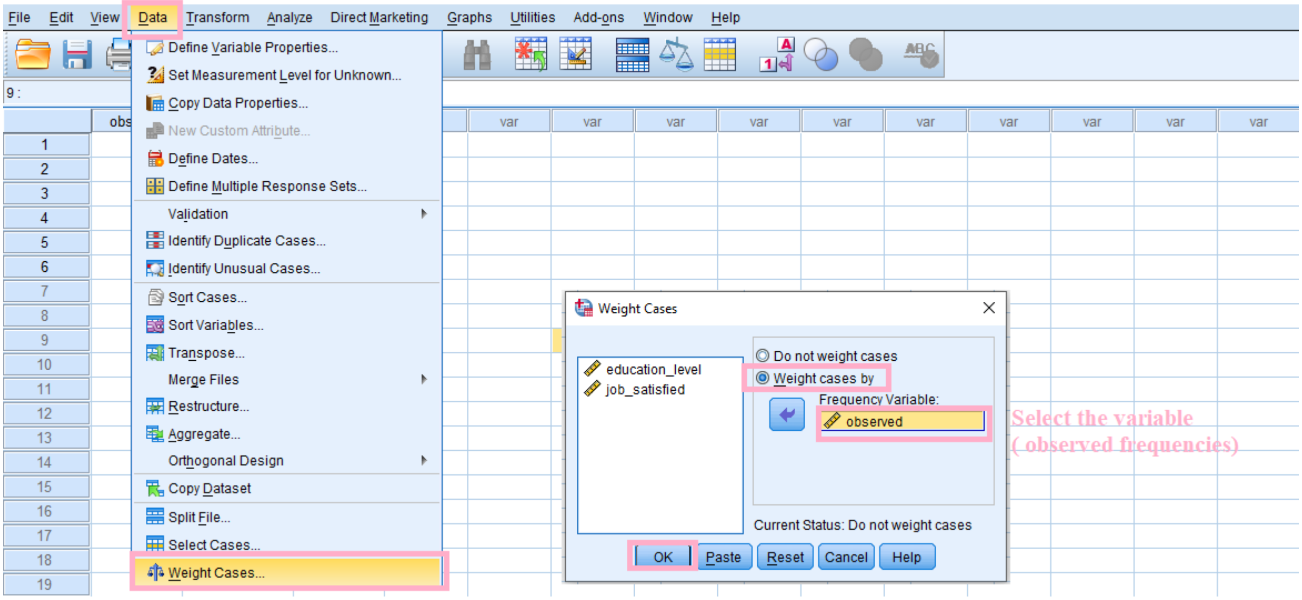
TABLE 3

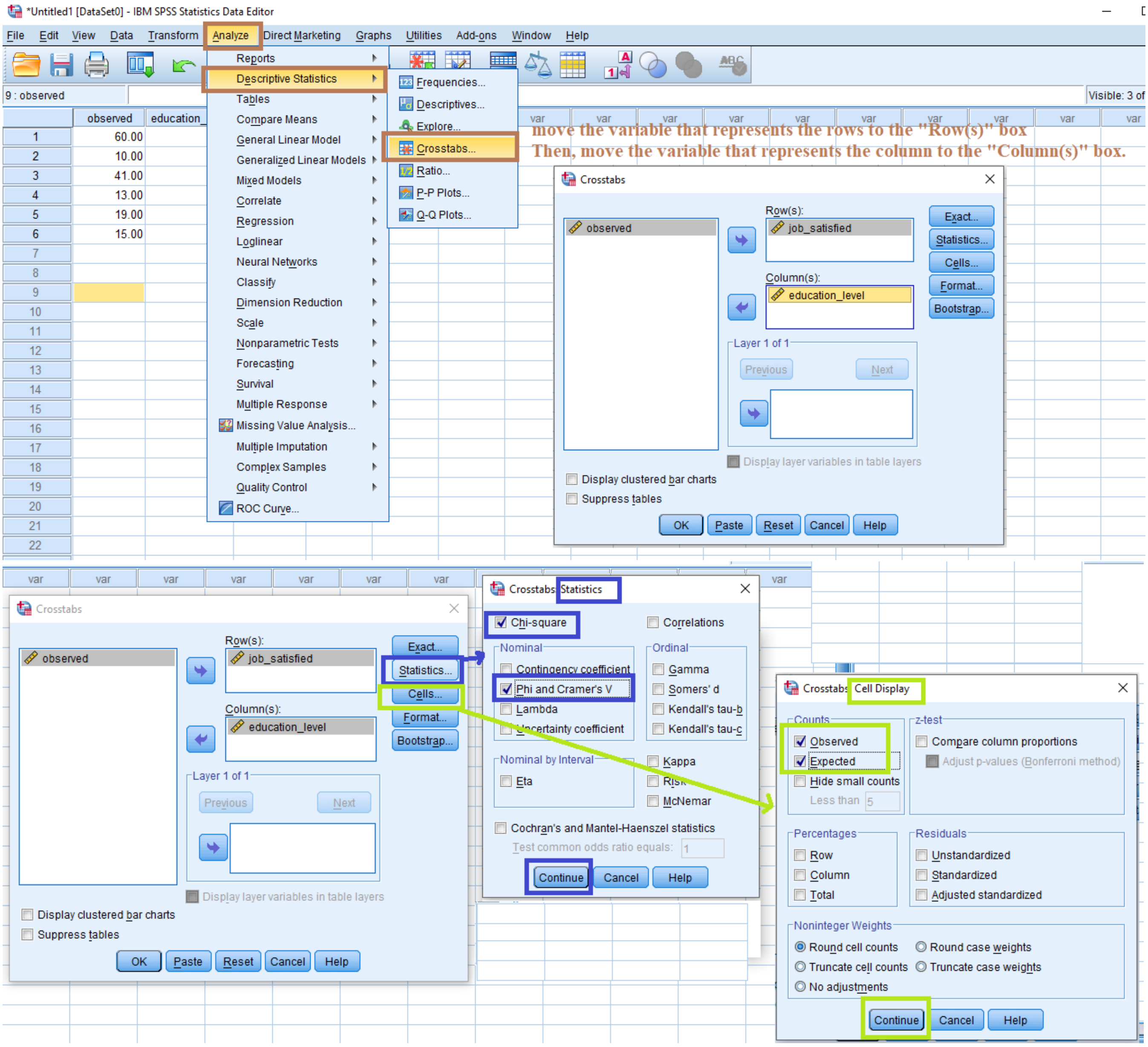
	Teacher education level (observed)			
	Bachelor's degree	Master's degree	Post-Master's degree	Row totals
Satisfied	60	41	19	120
Unsatisfied	10	13	15	38
Column totals	70	54	34	158

First, use a χ^2-test for independence with $\alpha = 0.05$ to determine if there is an association between level of education and job satisfaction. Then, determine the effect size for the association. Report your findings.

By SPSS:




File
Edit
View
Data
Transform
Analyze
Direct Marketing
Graphs
Utilities
Add-ons
Window
Help
Define Variable Properties...
Set Measurement Level for Unknown...
Copy Data Properties...
New Custom Attribute...
Define Dates...
Define Multiple Response Sets...
Validation
Identify Duplicate Cases...
Identify Unusual Cases...
Sort Cases...
Sort Variables...
Transpose...
Merge Files
Restructure...
Aggregate...
Orthogonal Design
Copy Dataset
Split File...
Select Cases...
Weight Cases...
Weight Cases
education_level
job_satisfied
Do not weight cases
Weight cases by
Frequency Variable:
observed
Current Status: Do not weight cases
OK
Paste
Reset
Cancel
Help
Select the variable
(observed frequencies)


*Untitled1 [DataSet0] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
Scale
Nonparametric Tests
Forecasting
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
Frequencies...
Descriptives...
Explore...
Crosstabs...
Ratio...
P-P Plots...
Q-Q Plots...
observed
education
60.00
10.00
41.00
13.00
19.00
15.00
move the variable that represents the rows to the "Row(s)" box
Then, move the variable that represents the column to the "Column(s)" box.
Crosstabs
Row(s):
job_satisfied
Column(s):
education_level
Layer 1 of 1
Previous
Next
Exact...
Statistics...
Cells...
Format...
Bootstrap...
Display layer variables in table layers
Display clustered bar charts
Suppress tables
OK
Paste
Reset
Cancel
Help
Crosstabs: Statistics
Chi-square
Correlations
Nominal
Contingency coefficient
Phi and Cramer's V
Lambda
Uncertainty coefficient
Ordinal
Gamma
Somers' d
Kendall's tau-b
Kendall's tau-c
Nominal by Interval
Eta
Kappa
Risk
McNemar
Cochran's and Mantel-Haenszel statistics
Test common odds ratio equals:
Continue
Crosstabs: Cell Display
Counts
Observed
Expected
Hide small counts
Less than
z-test
Compare column proportions
Adjust p-values (Bonferroni method)
Percentages
Row
Column
Total
Residuals
Unstandardized
Standardized
Adjusted standardized
Noninteger Weights
Round cell counts
Round case weights
Truncate cell counts
Truncate case weights
No adjustments

4. *Interpret the results from the SPSS Output window.*

The second, third, and fourth output tables from SPSS are of interest in this procedure.

The second SPSS output table provides the observed and expected frequencies for each category and the total counts.

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
job_satisfied * education_level	158	100.0%	0	0.0%	158	100.0%

job_satisfied * education_level Crosstabulation

			education_level			
			Bachelor's degree	Master's degree	Post-Master's degree	Total
job_satisfied	Satisfied	Count	60	41	19	120
		Expected Count	53.2	41.0	25.8	120.0
	Unsatisfied	Count	10	13	15	38
		Expected Count	16.8	13.0	8.2	38.0
Total		Count	70	54	34	158
		Expected Count	70.0	54.0	34.0	158.0

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	11.150[a]	2	.004
Likelihood Ratio	10.638	2	.005
Linear-by-Linear Association	10.593	1	.001
N of Valid Cases	158		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 8.18.

the significance (p-value) ($p = 0.004$)

chi-square statistic ($\chi^2 = 11.150$)

the degrees of freedom (df = 2)

Symmetric Measures

		Value	Approx. Sig.
Nominal by Nominal	Phi	.266	.004
	Cramer's V	.266	.004
N of Valid Cases		158	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

the Cramer's V statistic (V= 0.266) to determine the level of association, or effect size.

As seen in the first SPSS Output, none of the cells had an expected count of less than 5. Therefore, the chi-square test was indeed an appropriate analysis. Concerning effect size, the size of the contingency table was larger than 2 x 2 . Therefore, a Cramer's V was appropriate.

According to the data, the results from the chi-square test for independence were significant ($\chi_2{}^2 = 11.150$, $p < 0.05$).

Therefore, the analysis provides evidence that teacher education level differentiates between individuals based on job satisfaction.

In addition, the effect size (V= 0.266) indicated a medium level of association between the variables.

THE RUNS TEST

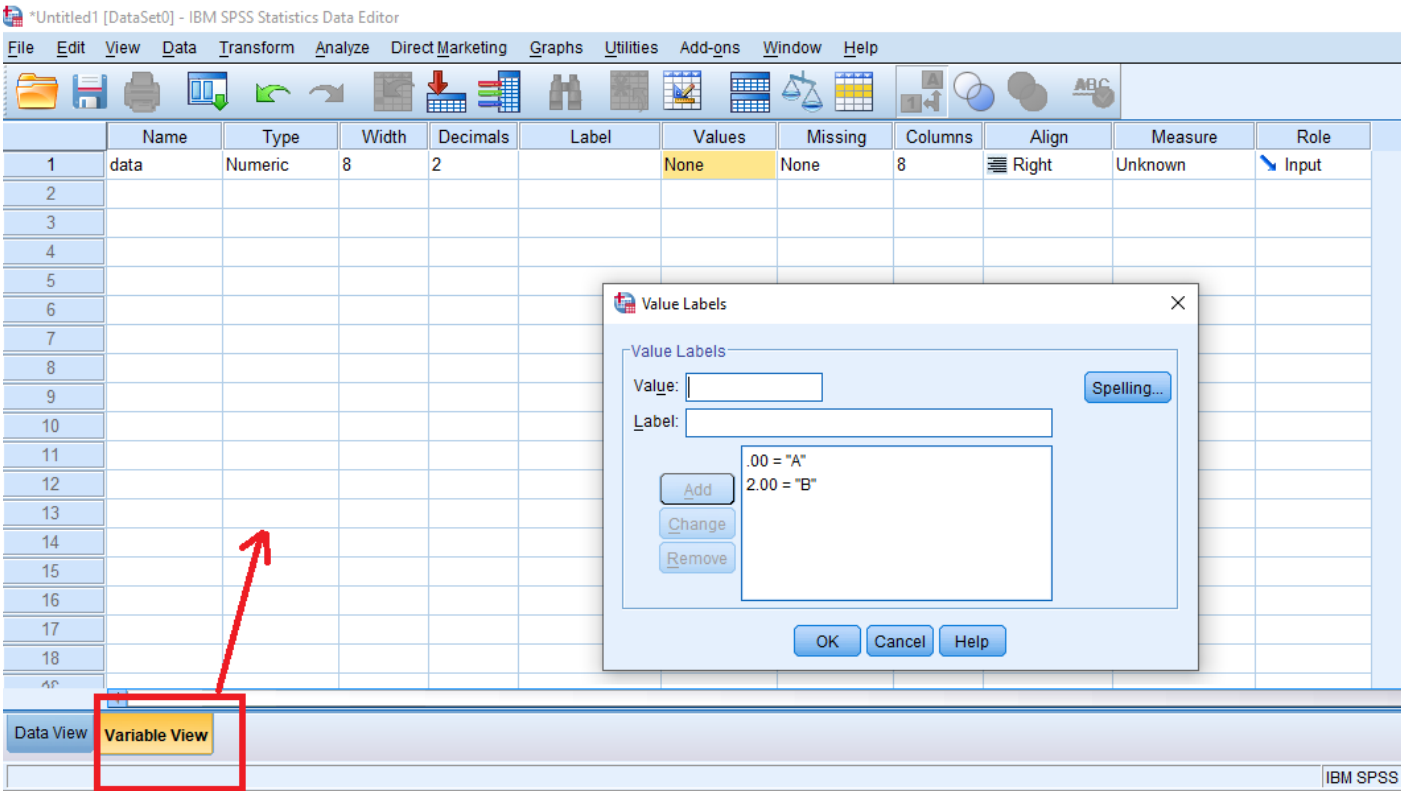
The runs test is a statistical procedure for examining a series of events for randomness.

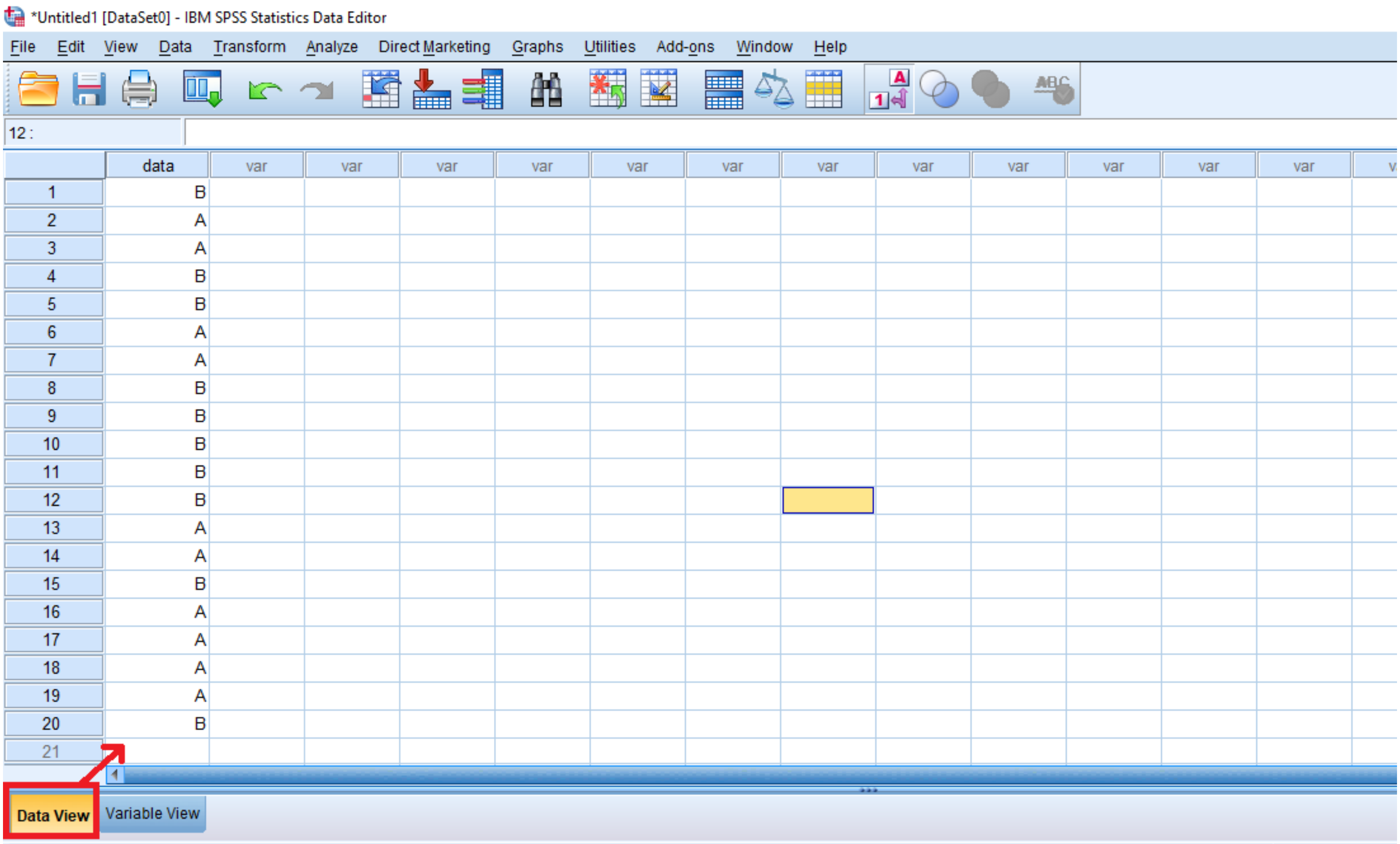
1- Represented in the data is the daily performance of a popular stock. Letter A represents a gain and letter B represents a loss. Use a runs test to analyze the stock's performance for randomness. Set $\alpha = 0.05$. Report the results.

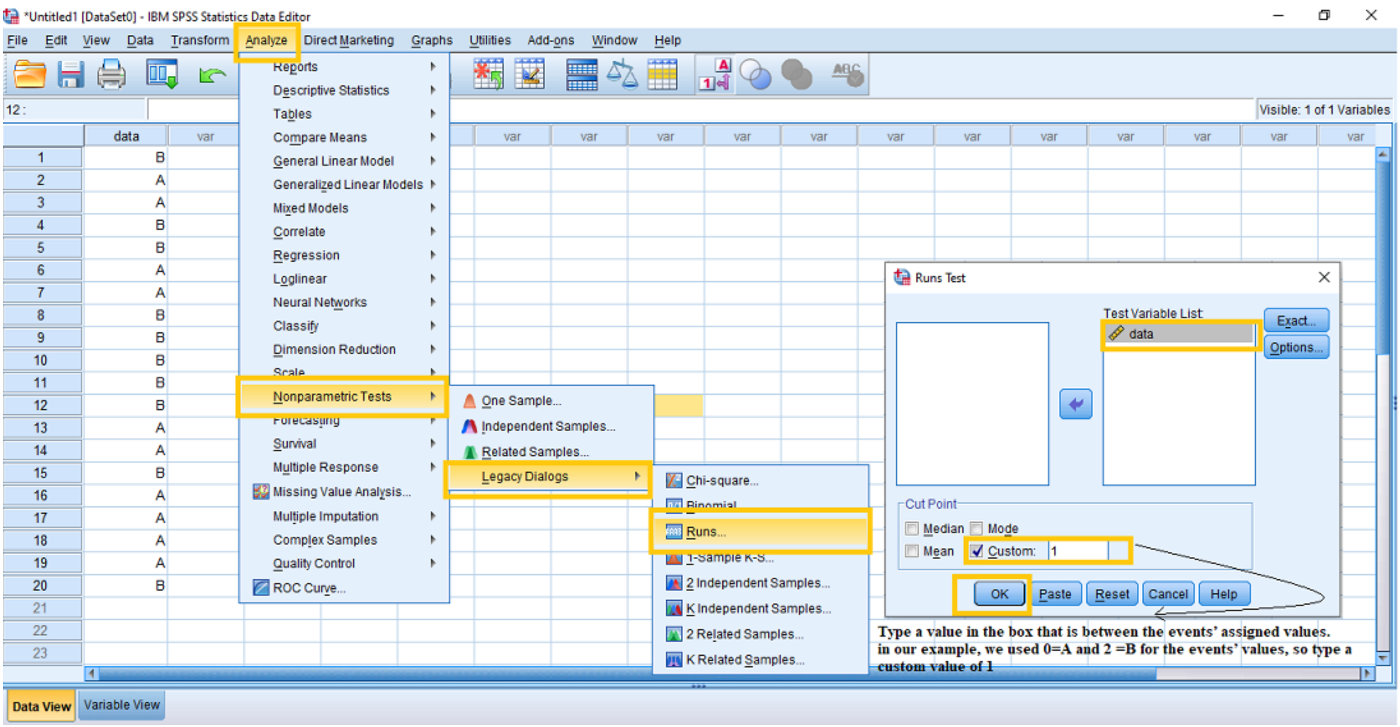
BAABBAABBBBBAABAAAAB

H0: The sequence of the stock's performance for gain and loss is random.

HA: The sequence of the stock's performance for gain and loss is not random.




*Untitled1 [DataSet0] - IBM SPSS Statistics Data Editor
Data View
Variable View


Analyze
Nonparametric Tests
Legacy Dialogs
Runs...
Runs Test
Test Variable List:
data
Cut Point
Custom: 1
OK
Type a value in the box that is between the events' assigned values. in our example, we used 0=A and 2 =B for the events' values, so type a custom value of 1

NPar Tests

[DataSet0]

Runs Test

	data
Test Value[a]	1.0000
Total Cases	20
Number of Runs	9
Z	-.689-
Asymp. Sig. (2-tailed)	.491

a. User-specified.

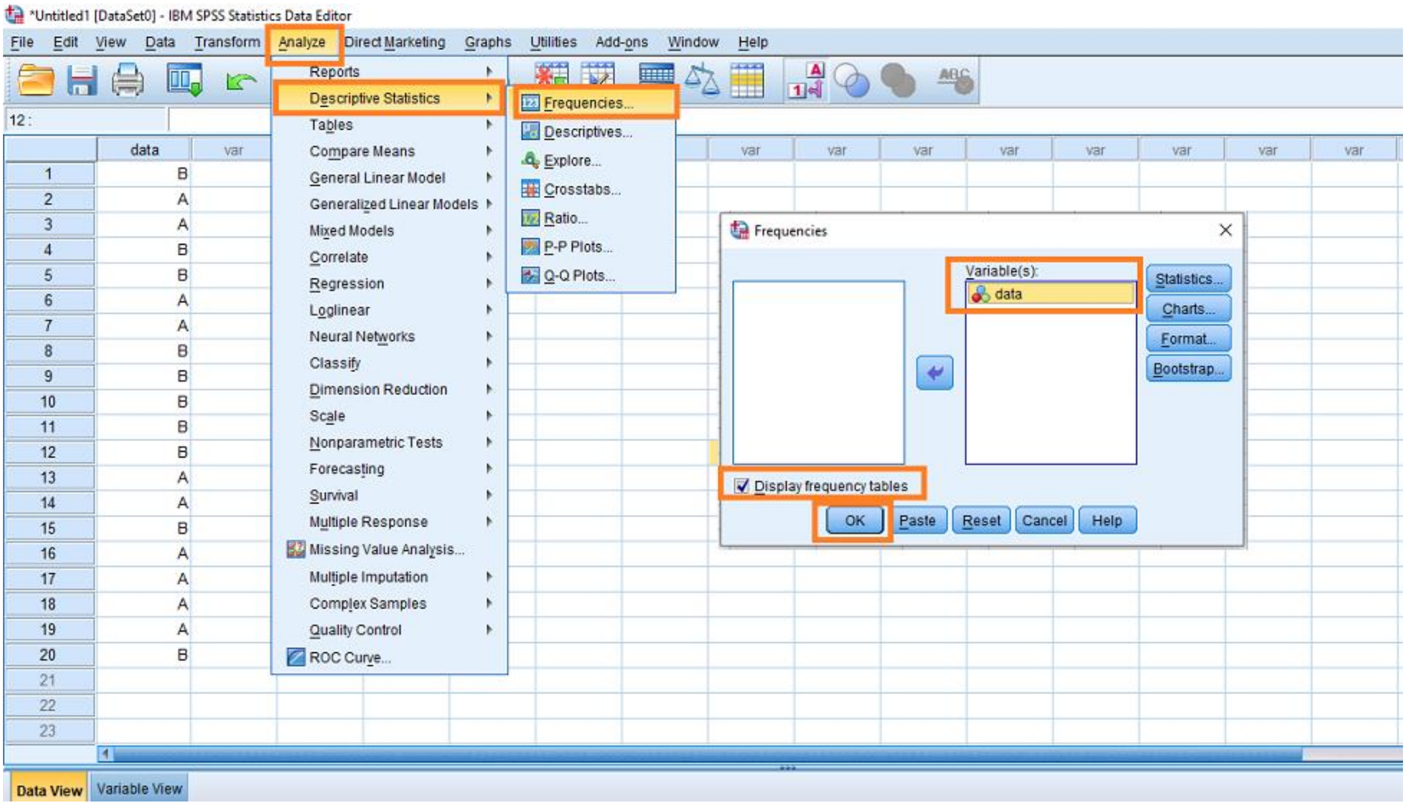
Total number of observations (N = 20)

Number of runs (R = 9)

the z-score (z^* = - 0.689)

two-tailed significance (p = 0.491). (p-value =0.491)

The runs test output table , returns the total number of observations (N = 20) and the number of runs (R = 9). SPSS also calculates the z-score (z* = 0.689) and the two-tailed significance (p = 0.491).



The second output table displays the frequencies for each event. (n1=10 ,n2=10 ,N=20)

data

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	A	n1= 10	50.0	50.0	50.0
	B	n2= 10	50.0	50.0	100.0
	Total	N= 20	100.0	100.0	

total number of observations (N = 20)

The sequence of the stock's gains and losses was random ($R = 9$, $n1 = 10$, $n2=10$, $p>0.05$)

2- A machine on an automated assembly line produces a unique type of bolt. If the machine fails more than three times in an hour, the total production on the line is slowed down. The machine has often exceeded the number of acceptable failures for the last week. The machine is expensive and more cost-effective to repair, but the maintenance crew cannot find the problem. The plant manager asks you to determine if the failure rates are random or if a pattern exists. Table 1 shows the number of failures per hour for a 24-h period.

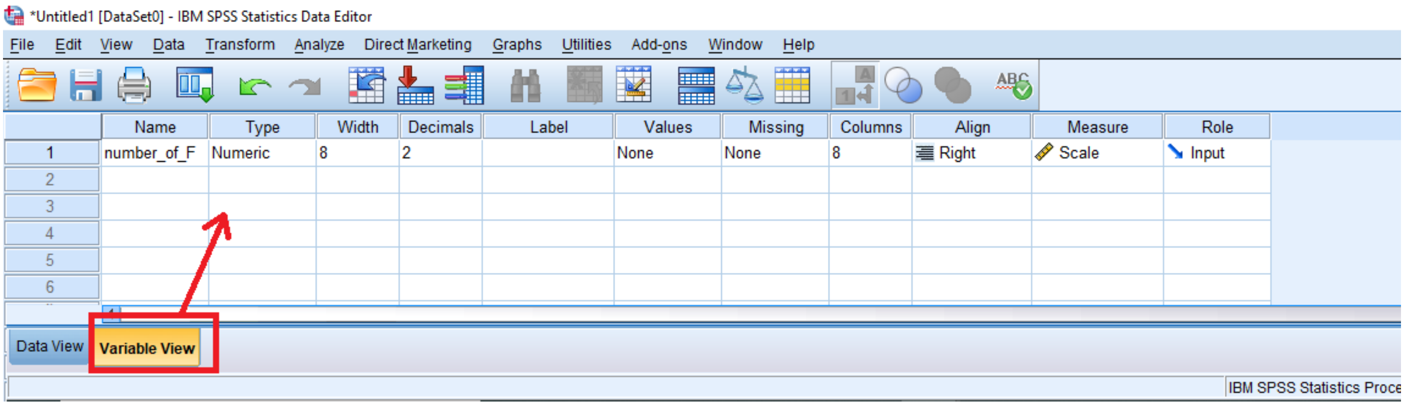
TABLE 1

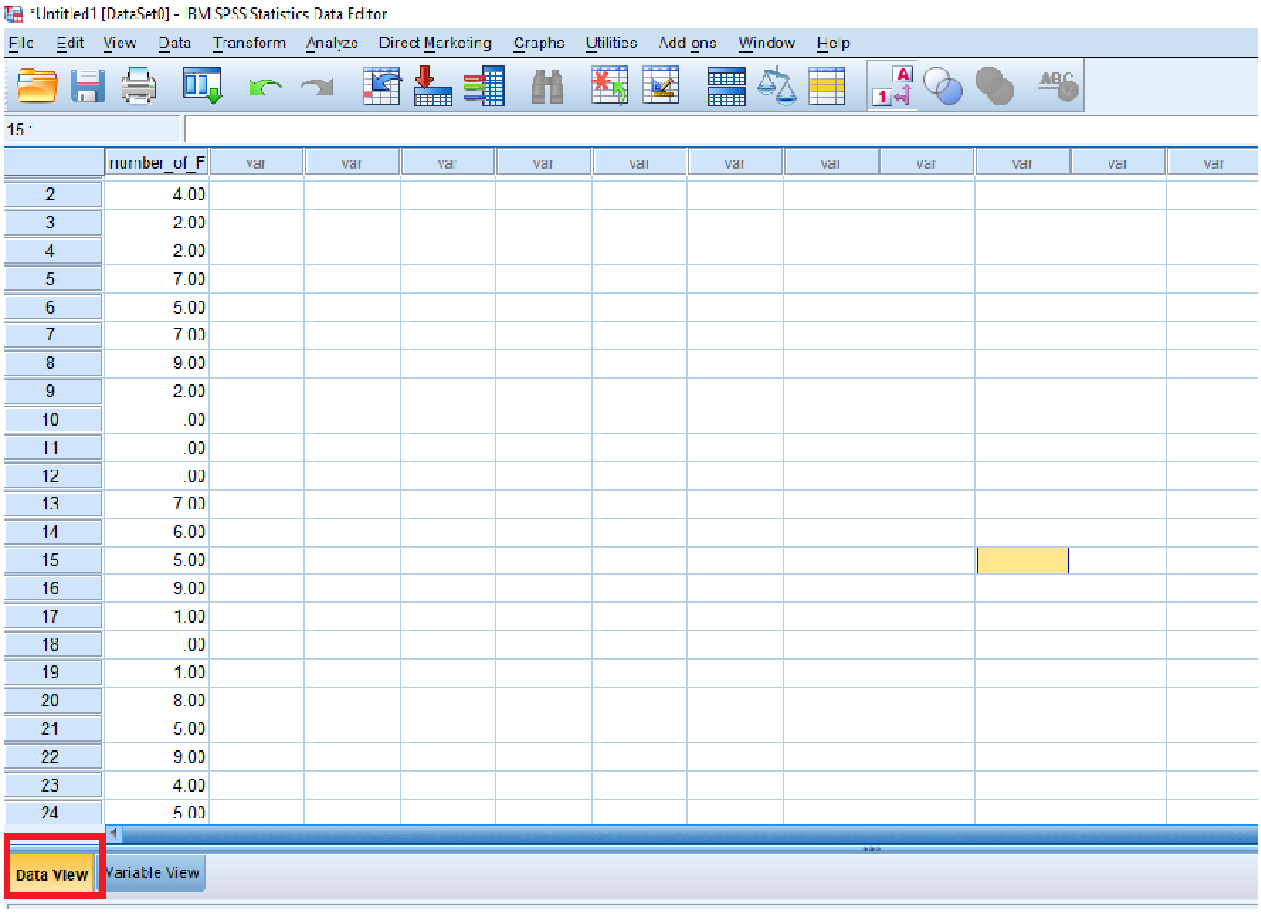
Hour	Number of failures
1	6
2	4
3	2
4	2
5	7
6	5
7	7
8	9
9	2
10	0
11	0
12	0
13	7
14	6
15	5
16	9
17	1
18	0
19	1
20	8
21	5
22	9
23	4
24	5

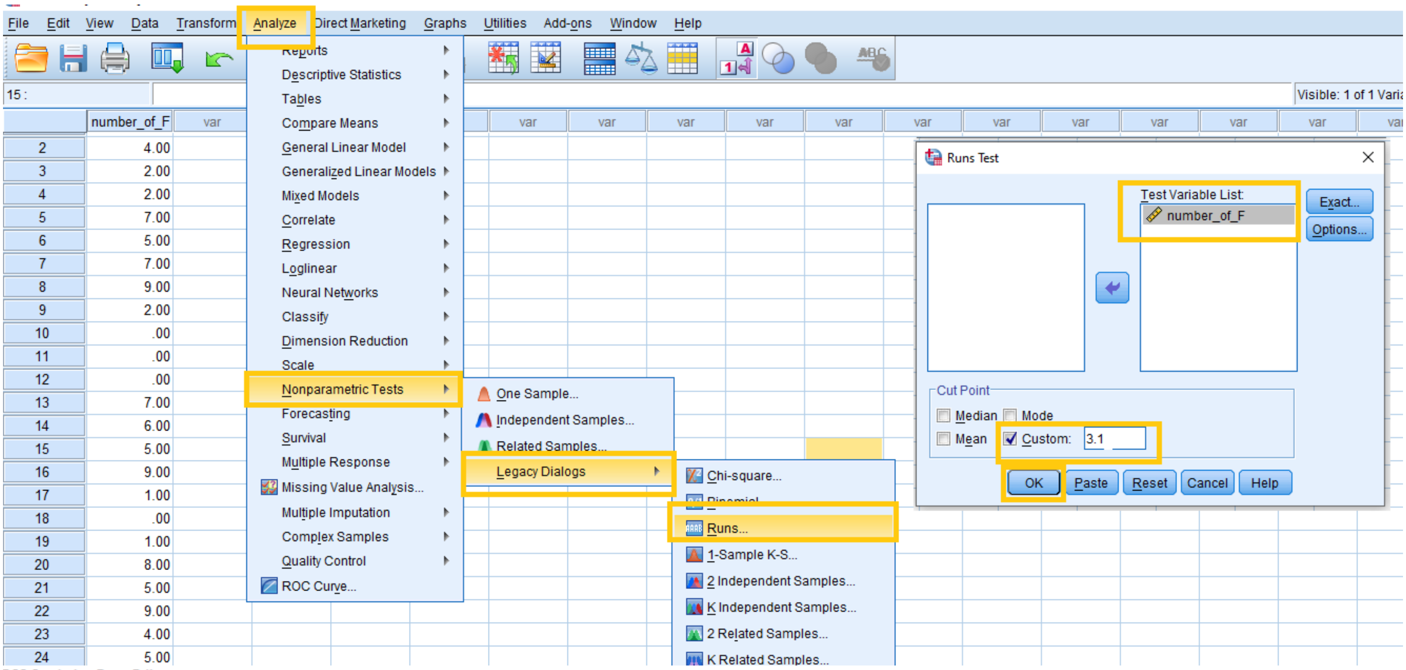
Use a runs test with **a custom value of 3.1** to analyze the acceptable/unacceptable failure rate for randomness. Set $\alpha = 0.05$. Report the results.

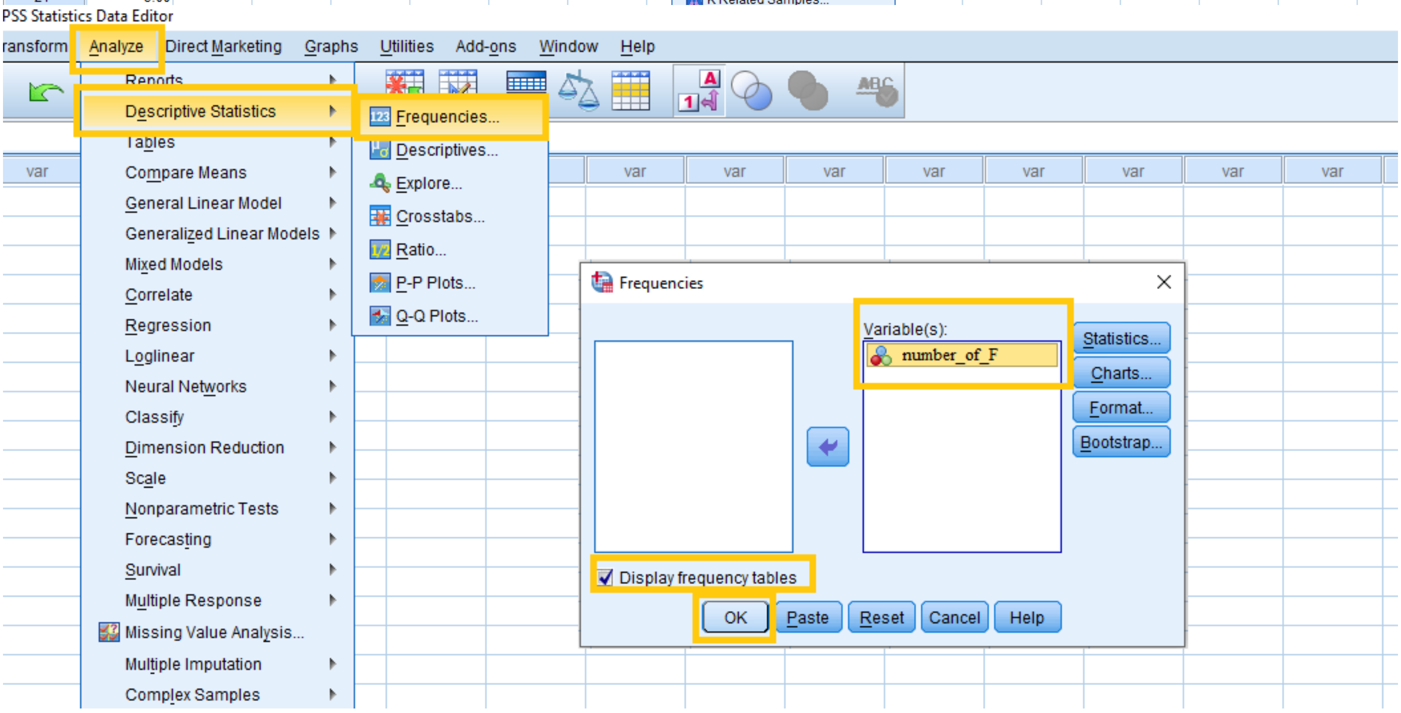
H0: The sequence of the failure rates are random

H1: The sequence of the failure rates are not random


*Untitled1 [DataSet0] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
Name Type Width Decimals Label Values Missing Columns Align Measure Role
1 number_of_F Numeric 8 2 None None 8 Right Scale Input
Data View
Variable View
IBM SPSS Statistics Proce


*Untitled1 [DataSet0] - IBM SPSS Statistics Data Editor
File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
15 :
number_of_F
var
2 4.00
3 2.00
4 2.00
5 7.00
6 5.00
7 7.00
8 9.00
9 2.00
10 .00
11 .00
12 .00
13 7.00
14 6.00
15 5.00
16 9.00
17 1.00
18 .00
19 1.00
20 8.00
21 5.00
22 9.00
23 4.00
24 5.00
Data View
Variable View


File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
Scale
Nonparametric Tests
Forecasting
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Quality Control
ROC Curve...
One Sample...
Independent Samples...
Related Samples...
Legacy Dialogs
Chi-square...
Runs...
1-Sample K-S...
2 Independent Samples...
K Independent Samples...
2 Related Samples...
K Related Samples...
number_of_F
Runs Test
Test Variable List:
number_of_F
Exact...
Options...
Cut Point
Median
Mode
Mean
Custom: 3.1
OK Paste Reset Cancel Help


PSS Statistics Data Editor
ransform Analyze Direct Marketing Graphs Utilities Add-ons Window Help
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Generalized Linear Models
Mixed Models
Correlate
Regression
Loglinear
Neural Networks
Classify
Dimension Reduction
Scale
Nonparametric Tests
Forecasting
Survival
Multiple Response
Missing Value Analysis...
Multiple Imputation
Complex Samples
Frequencies...
Descriptives...
Explore...
Crosstabs...
Ratio...
P-P Plots...
Q-Q Plots...
Frequencies
Variable(s):
number_of_F
Statistics...
Charts...
Format...
Bootstrap...
Display frequency tables
OK Paste Reset Cancel Help

NPar Tests

```
[DataSet0]
```

Runs Test

	data
Test Value[a]	3.1000
Total Cases	24
Number of Runs	7
Z	-2.121-
Asymp. Sig. (2-tailed)	.034

a. User-specified.

N=24
R=7

p-value =0.034

```
FREQUENCIES VARIABLES=data
  /ORDER=ANALYSIS.
```

Frequencies

```
[DataSet0]
```

Statistics

data

N	Valid	24
	Missing	0

data

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	.00	4	16.7	16.7	16.7
	1.00	2	8.3	8.3	25.0
	2.00	3	12.5	12.5	37.5
	4.00	2	8.3	8.3	45.8
	5.00	4	16.7	16.7	62.5
	6.00	2	8.3	8.3	70.8
	7.00	3	12.5	12.5	83.3
	8.00	1	4.2	4.2	87.5
	9.00	3	12.5	12.5	100.0
	Total	24	100.0	100.0	

The second SPSS output table displays the frequencies for each value.

You must count the number of values above the custom value and the number values below it to determine the frequency for each event.

custom = 3.1 , n1=9 , n2= 15

The sequence of the machine's acceptable/unacceptable failure rate was not random (R = 7, n1 = 9, n2 = 15, p < 0.05).

Some Common Nonparametric Tests