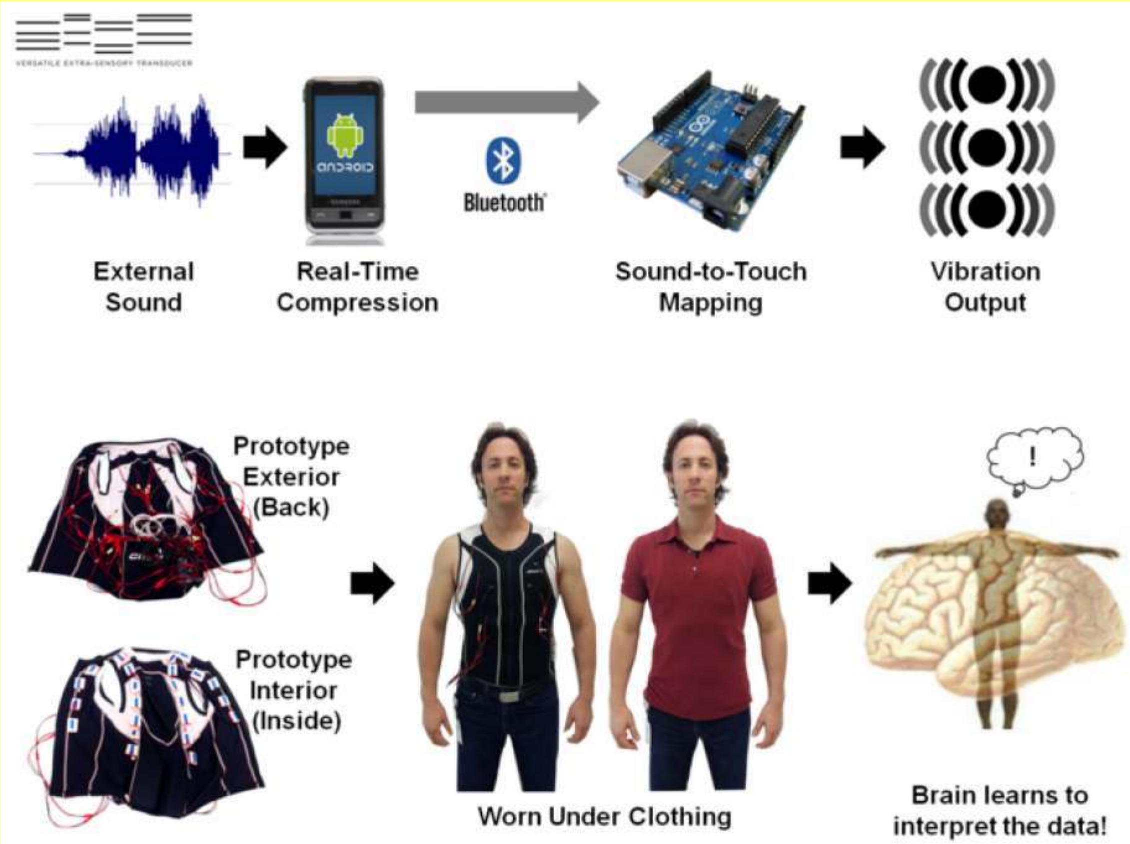
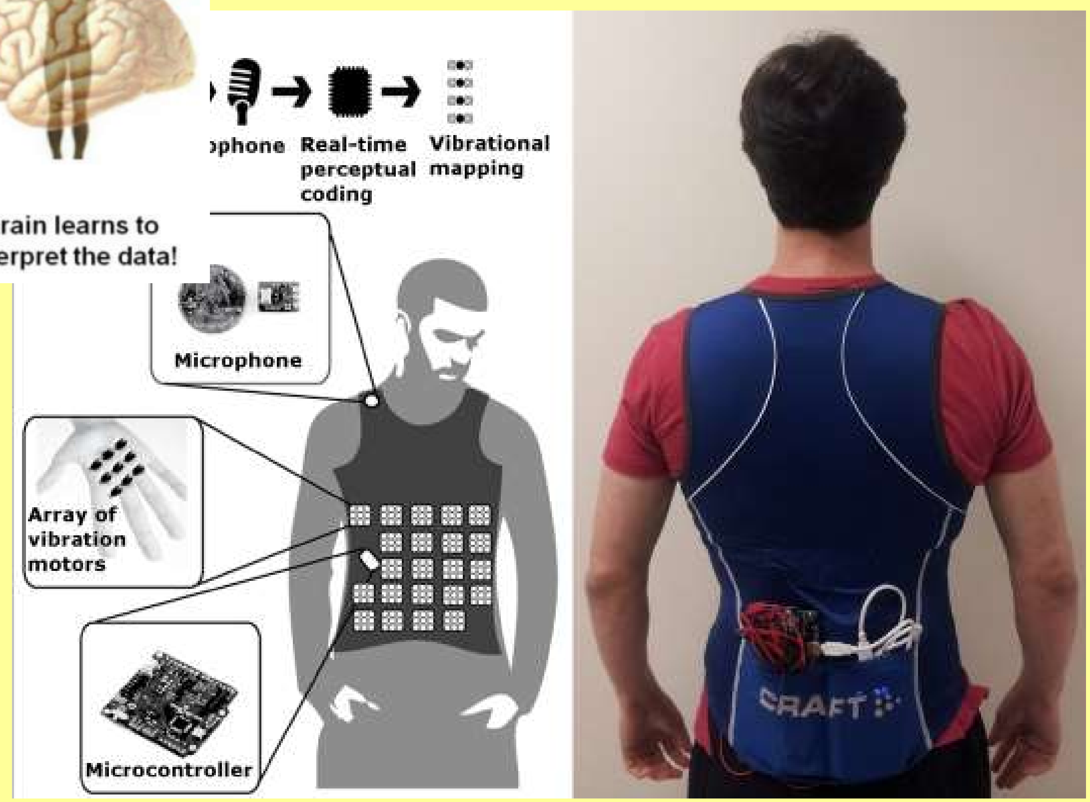
SWE3053
Human Computer Interaction

Lecture 21

Interpreting Data
Computer Aided Data Analysis

Sensory Substitution – Extrasensation ...





Agenda

-
- Inferential Statistic
    - t-test
    - ANOVA

Refresh your memory ……

t-value

difference between means
(SYSTEMATIC)

if "large enough" (e.g., |t|>1.96) then you say difference is statistically significant

$$t = \frac{\bar{x} - \bar{y}}{s_{x\&y}}$$

large values indicate statistical significance

variability of both distributions
(ERROR)

Table entry for p and C is the point t^* with probability p lying above it and probability C lying between $-t^*$ and t^*.

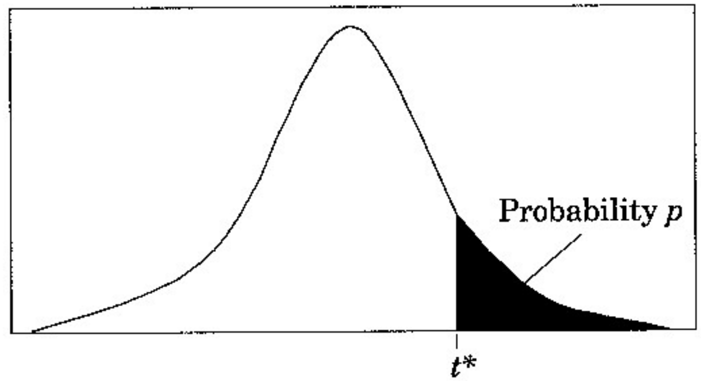


Table B t distribution critical values

	Tail probability p											
df	.25	.20	.15	.10	.05	.025	.02	.01	.005	.0025	.001	.0005
1	1.000	1.376	1.963	3.078	6.314	12.71	15.89	31.82	63.66	127.3	318.3	636.6
2	.816	1.061	1.386	1.886	2.920	4.303	4.849	6.965	9.925	14.09	22.33	31.60
3	.765	.978	1.250	1.638	2.353	3.182	3.482	4.541	5.841	7.453	10.21	12.92
4	.741	.941	1.190	1.533	2.132	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	.727	.920	1.156	1.476	2.015	2.571	2.757	3.365	4.032	4.773	5.893	6.869
6	.718	.906	1.134	1.440	1.943	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	.711	.896	1.119	1.415	1.895	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	.706	.889	1.108	1.397	1.860	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	.703	.883	1.100	1.383	1.833	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	.700	.879	1.093	1.372	1.812	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	.697	.876	1.088	1.363	1.796	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	.695	.873	1.083	1.356	1.782	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	.694	.870	1.079	1.350	1.771	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	.692	.868	1.076	1.345	1.761	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	.691	.866	1.074	1.341	1.753	2.131	2.249	2.602	2.947	3.286	3.733	4.073
16	.690	.865	1.071	1.337	1.746	2.120	2.235	2.583	2.921	3.252	3.686	4.015
17	.689	.863	1.069	1.333	1.740	2.110	2.224	2.567	2.898	3.222	3.646	3.965
18	.688	.862	1.067	1.330	1.734	2.101	2.214	2.552	2.878	3.197	3.611	3.922
19	.688	.861	1.066	1.328	1.729	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	.687	.860	1.064	1.325	1.725	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	.686	.859	1.063	1.323	1.721	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	.686	.858	1.061	1.321	1.717	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	.685	.858	1.060	1.319	1.714	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	.685	.857	1.059	1.318	1.711	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	.684	.856	1.058	1.316	1.708	2.060	2.167	2.485	2.787	3.078	3.450	3.725
26	.684	.856	1.058	1.315	1.706	2.056	2.162	2.479	2.779	3.067	3.435	3.707
27	.684	.855	1.057	1.314	1.703	2.052	2.158	2.473	2.771	3.057	3.421	3.690
28	.683	.855	1.056	1.313	1.701	2.048	2.154	2.467	2.763	3.047	3.408	3.674
29	.683	.854	1.055	1.311	1.699	2.045	2.150	2.462	2.756	3.038	3.396	3.659
30	.683	.854	1.055	1.310	1.697	2.042	2.147	2.457	2.750	3.030	3.385	3.646
40	.681	.851	1.050	1.303	1.684	2.021	2.123	2.423	2.704	2.971	3.307	3.551
50	.679	.849	1.047	1.299	1.676	2.009	2.109	2.403	2.678	2.937	3.261	3.496
60	.679	.848	1.045	1.296	1.671	2.000	2.099	2.390	2.660	2.915	3.232	3.460
80	.678	.846	1.043	1.292	1.664	1.990	2.088	2.374	2.639	2.887	3.195	3.416
100	.677	.845	1.042	1.290	1.660	1.984	2.081	2.364	2.626	2.871	3.174	3.390
1000	.675	.842	1.037	1.282	1.646	1.962	2.056	2.330	2.581	2.813	3.098	3.300
∞	.674	.841	1.036	1.282	1.645	1.960	2.054	2.326	2.576	2.807	3.091	3.291
	50%	60%	70%	80%	90%	95%	96%	98%	99%	99.5%	99.8%	99.9%
	Confidence level C											

• The *t* Distribution

We use *t* when

1. the population variance is unknown (the usual case), and
2. sample size is small (N<100, the usual case).

The *t* distribution is a short, fat relative of the normal.
The shape of *t* depends on its *df (df = N-1).* As *N* becomes infinitely large, *t* becomes normal.

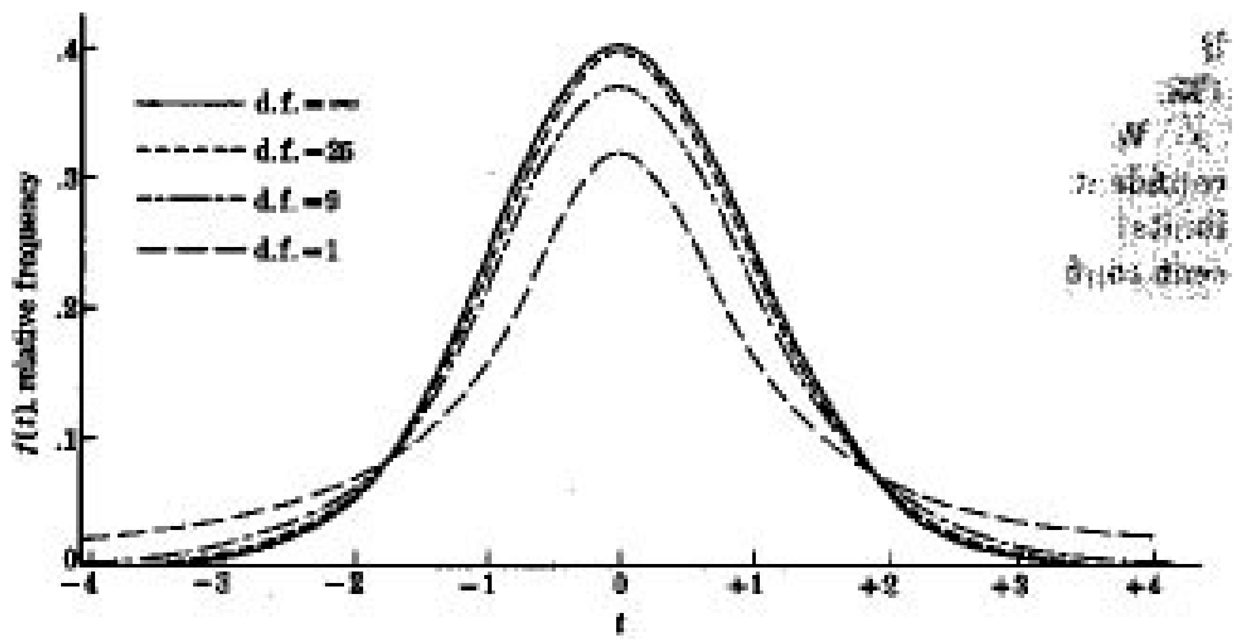
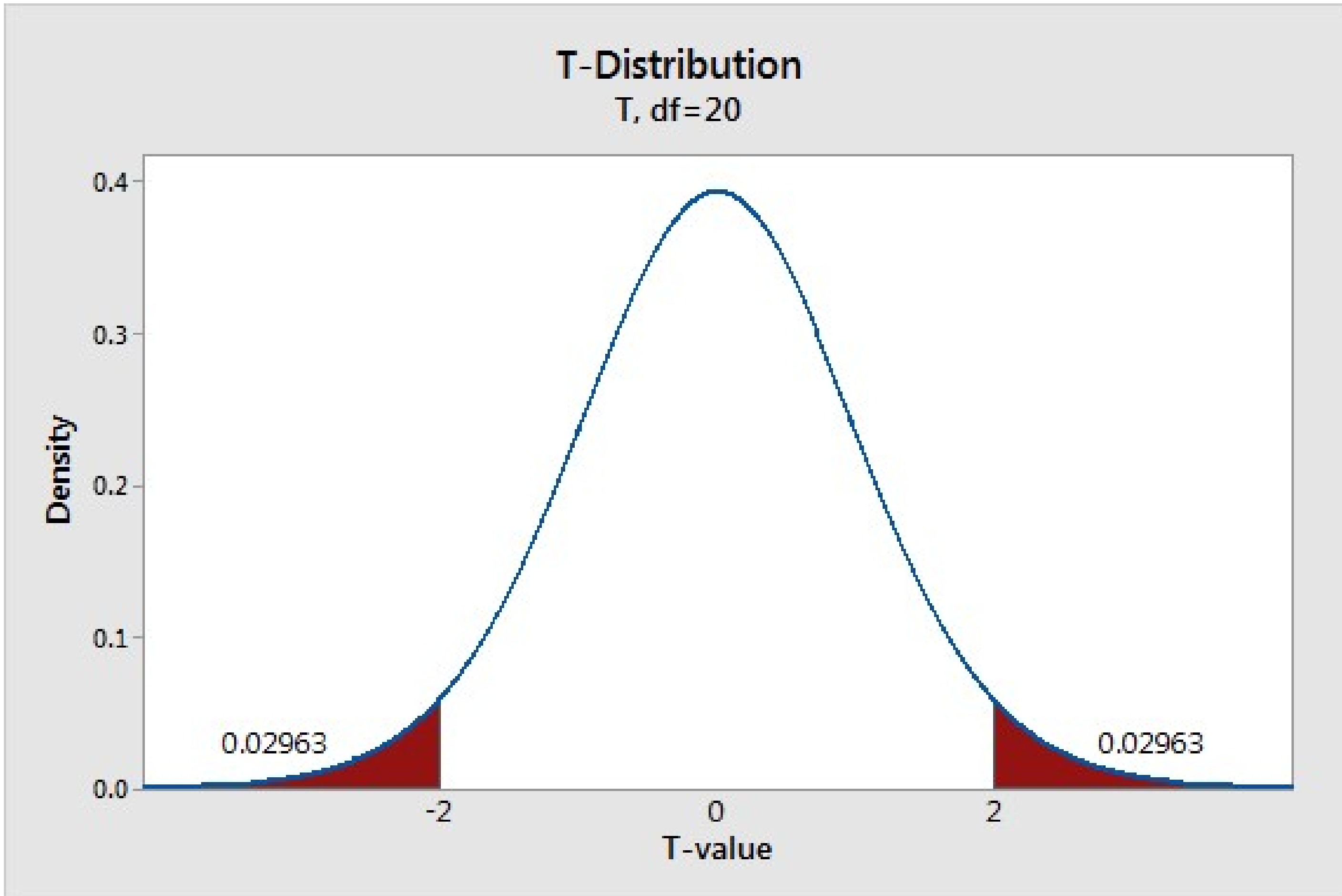


fig. 10.1 Distribution of *t* for various degrees of freedom. (*From D. Lewis, quantitative methods in psychology, McGraw-Hill Book Company, New York, 1960.*)

The t-distribution

What is the meaning when you have a t-value of 2?

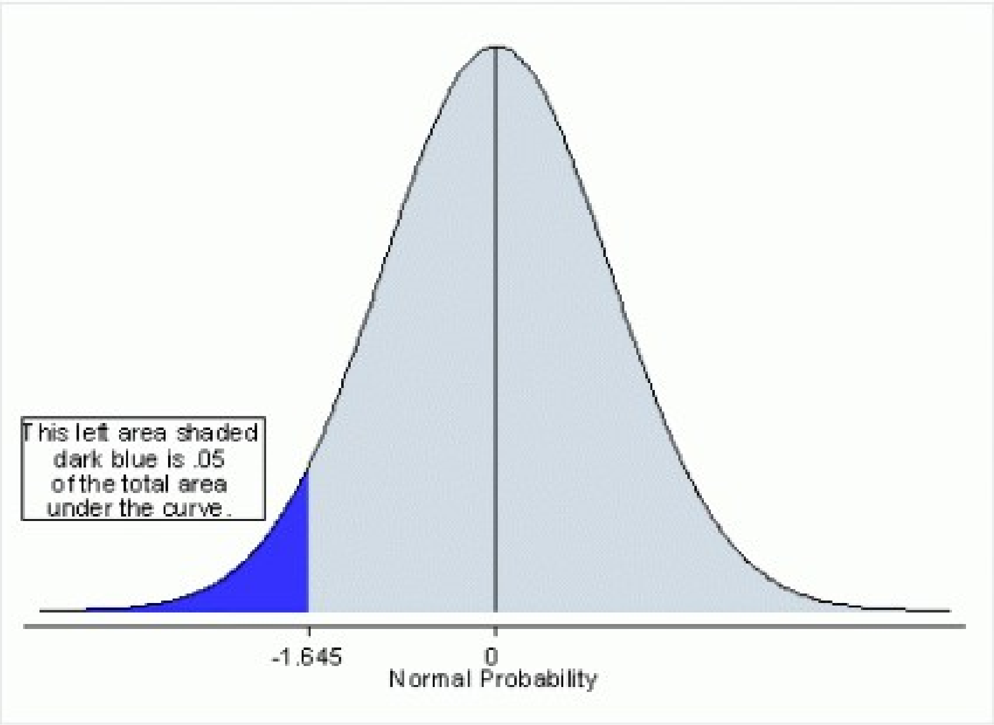


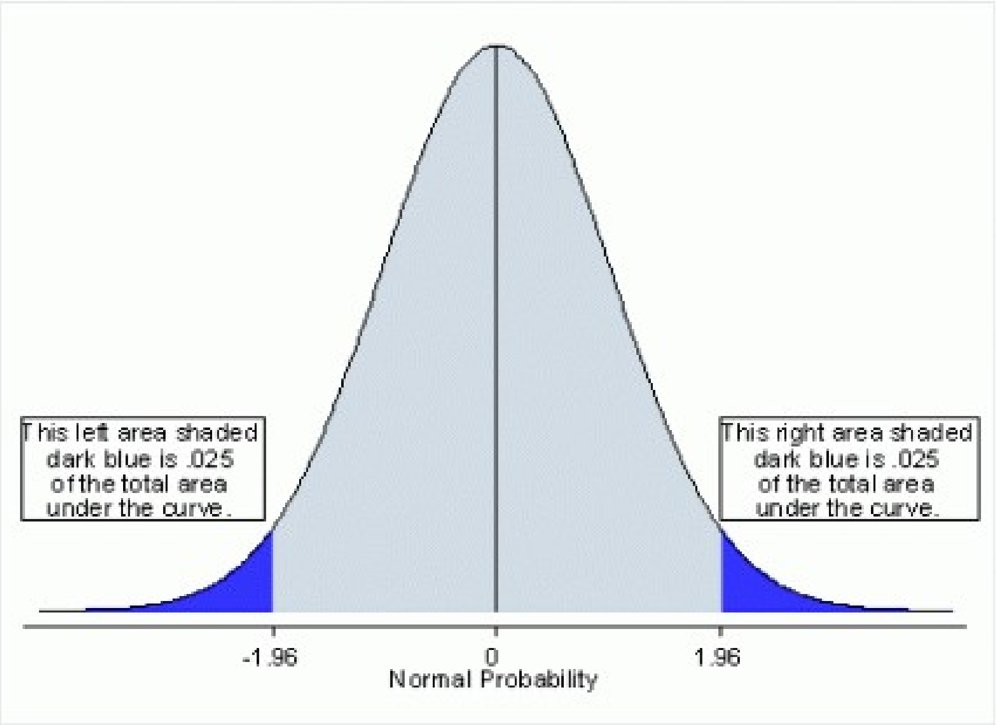
The probability for observing a difference from the null hypothesis that is at least as extreme as the difference present in our sample data while assuming that the null hypothesis is actually true – 5.962%.

This is called the p-value!

1-tailed vs. 2-tailed

- The t-value to achieve a significant level of 0.05 is:
  - 1-tailed – 1.645
  - 2-tailed – 1.96





2-tailed

- When you are comparing if the 2 mean values are the same.

1-tailed

- When you are comparing if one of the mean value significantly bigger/smaller than the other.

- What kind of *t* is it?

1) Single sample *t-test* – we have only 1 group; want to test against a hypothetical mean.
2) Independent samples *t-test* – we have 2 means, 2 groups; no relation between groups, e.g., people randomly assigned to a single group.
3) Dependent samples *t-test* – we have two means. Either same people in both groups, or people are related, e.g., husband-wife, left hand-right hand, hospital patient and visitor.

1. Single Sample t-test

- Used for comparing a sample mean to a population mean to determine if they are statistically significantly different
- Sample mean
  - The mean value of your sample
  - i.e. the mean of your data!
- Population mean
  - The real mean value

1. You know the population mean
2. You ran an experiment and obtained a sample mean from your samples
3. You want to know if the mean of your sample is significantly different from the known population mean

1. Single Sample t-test - Example

- You invented a drug to increase people's IQ!
- You know the population mean IQ score is 100.
- You recruited 20 people, give them the drug, and ask them to take the IQ test.
- And here's your sample data:

107	117
122	103
113	99
96	80
101	103
92	130
115	74
81	132
128	98
128	130

Mean = 107.45
STDEV = 17.83
df = N-1 = 19

1. Single Sample t-test - Example

- The t-value formula for single sample t-test:

$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}}$$

107	117
122	103
113	99
96	80
101	103
92	130
115	74
81	132
128	98
128	130

Mean = 107.45
STDEV = 17.83
df = 19

$t = (107.45-100) / (17.83/(20)^{1/2})$
$= 7.45 / 3.99$
$= 1.87$

1. Single Sample t-test - Example

- Look up the t-table ……
- 1-tailed table

http://www.statisticshowto.com/tables/t-distribution-table/

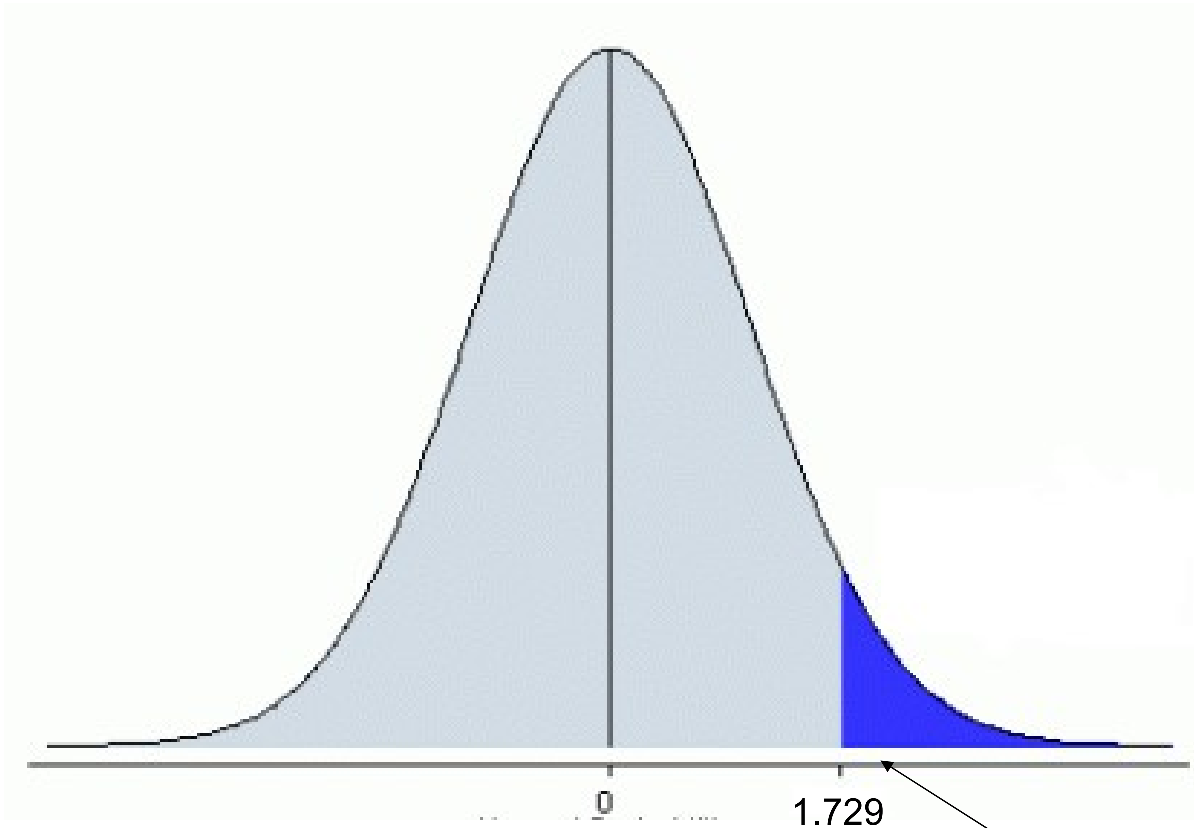
107	117
122	103
113	99
96	80
101	103
92	130
115	74
81	132
128	98
128	130

Mean = 108.45
STDEV = 19.63
t = 1.87

DF	A = 0.1	0.05	0.025	0.01	0.005	0.001	0.0005
∞	t_a = 1.282	1.645	1.960	2.326	2.576	3.091	3.291
1	3.078	6.314	12.706	31.821	63.656	318.289	636.578
2	1.886	2.920	4.303	6.965	9.925	22.328	31.600
3	1.638	2.353	3.182	4.541	5.841	10.214	12.924
4	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	1.476	2.015	2.571	3.365	4.032	5.894	6.869
6	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	**1.328**	**1.729**	**2.093**	**2.539**	**2.861**	**3.579**	**3.883**
20	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	1.321	1.717	2.074	2.508	2.819	3.505	3.792

t value for achieving sig. level of 5% is 1.729

df = 19; 1-tailed



t-value calculated from your sample is 1.87

t(19) = 1.87, p < .05

=> The effect is significant.

=> The Null Hypothesis is rejected.

5 steps for hypothesis proving

1. State the Null Hypothesis H_0 and Alternative Hypothesis $H_{1.}$

H_0: sample mean <= 100

H_1: sample mean > 100

2. Select the appropriate statistical method.

One sample t-test, 1-tailed

3. Select a level of significance.

.05; df = 19; critical t-value needs to be larger than 1.729

4. Calculate the statistic.

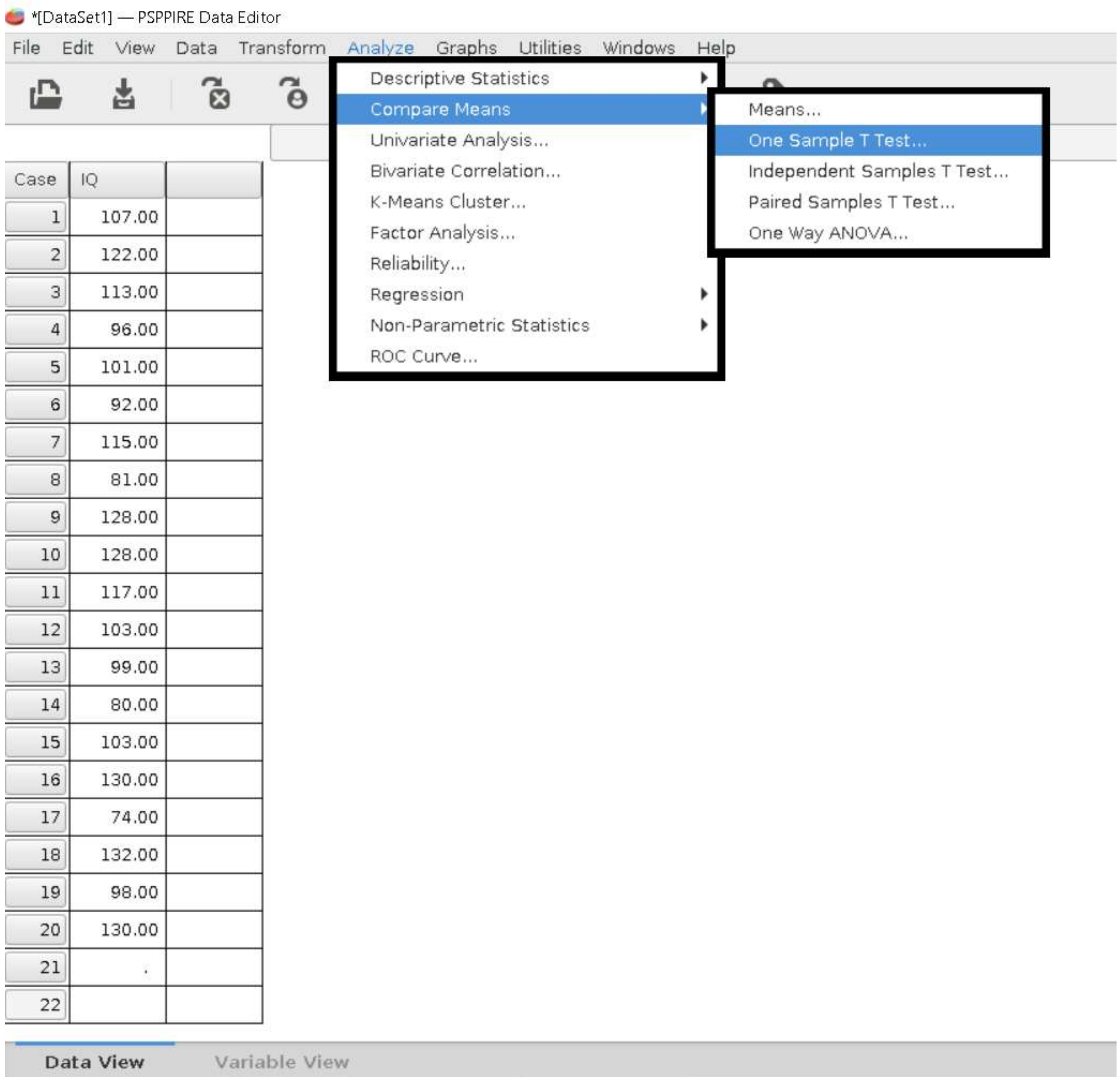
$t(19) = 1.87$; $p < .05$

5. Make the decision.

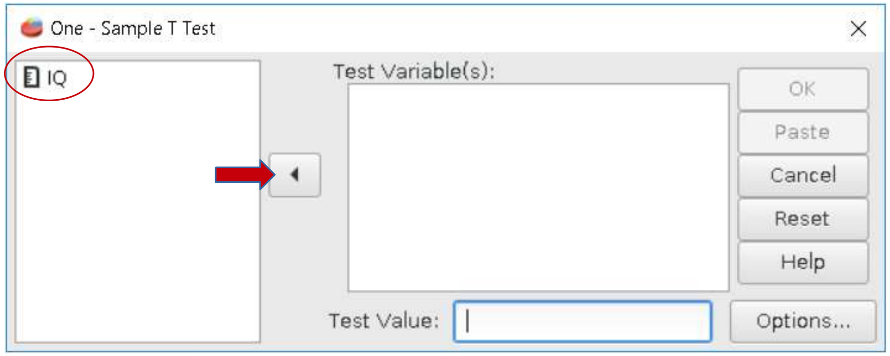
H_0 is reject; H_1 is supported.

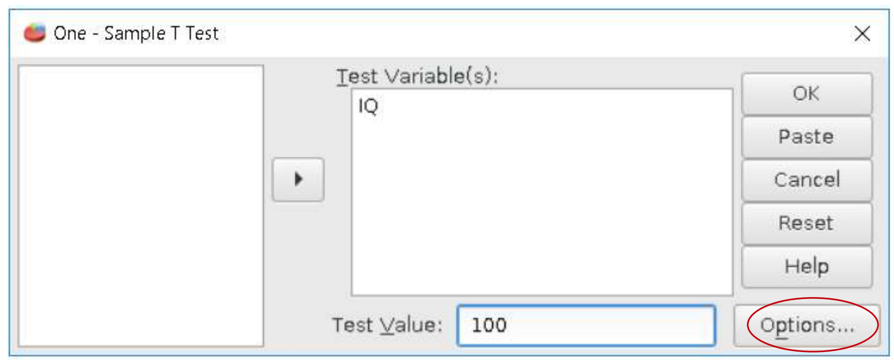
The effect of the drug is statistically significant

How to do it in PSPP



How to do it in PSPP

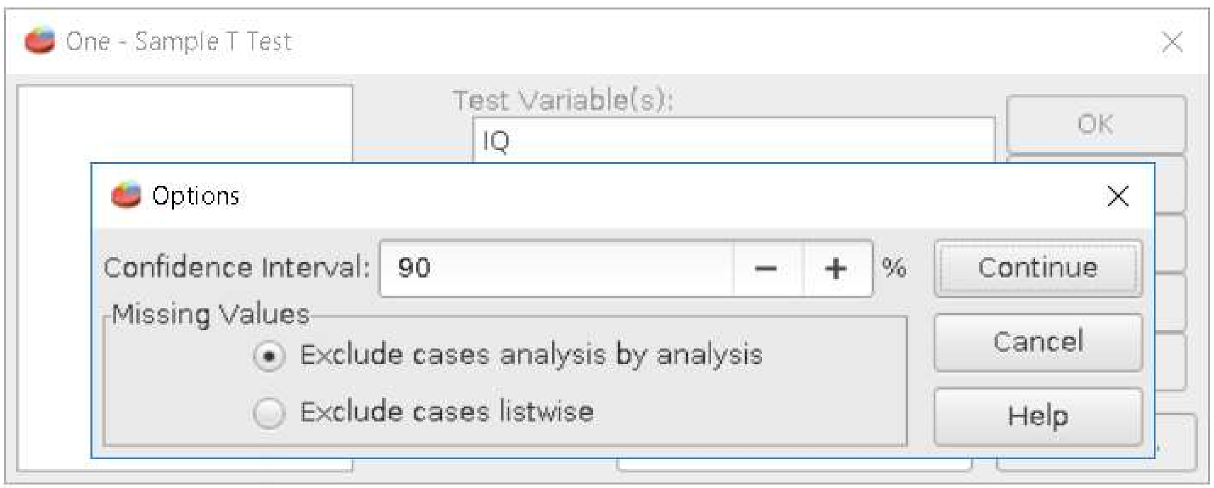




How to do it in PSPP

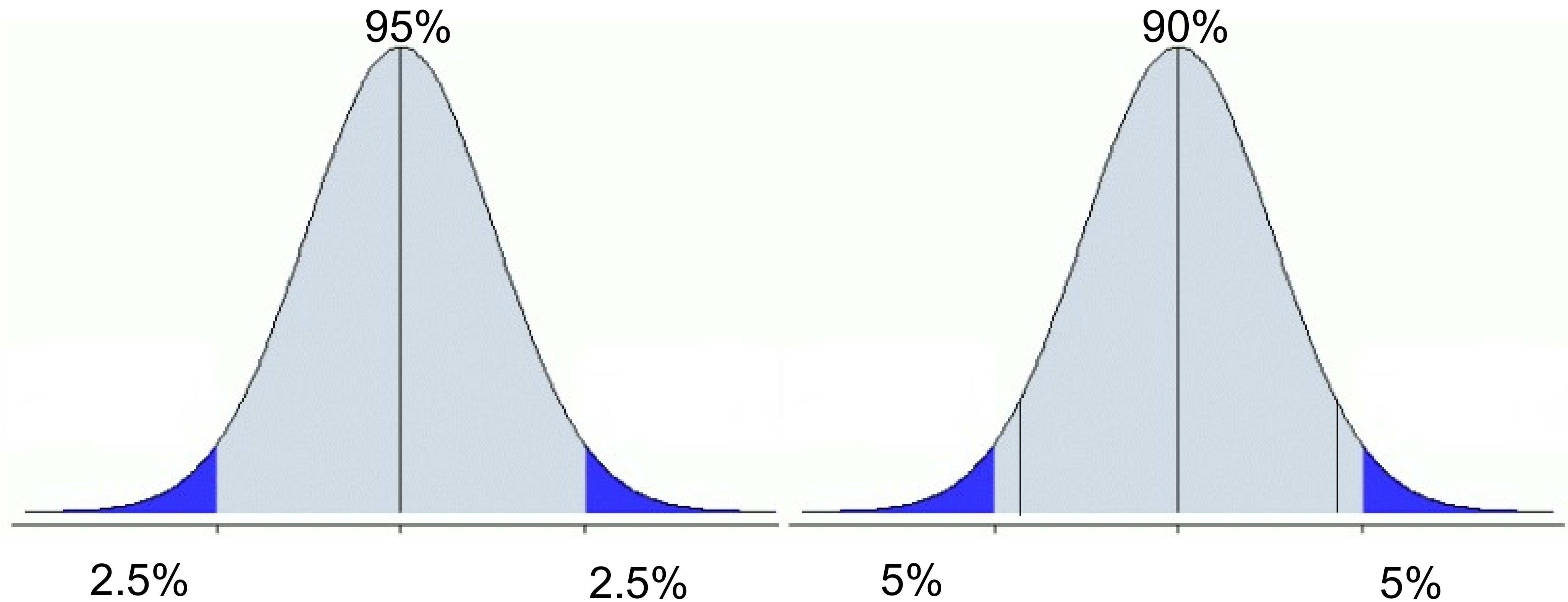
Note: PSPP (and SPSS) does not have the option to do 1-tailed t-test; so you have to “hack” it…

Your level of significant is 95%.
To do a 1-tailed test, change the significant level to 90%



Explanation ...

- If you ignore the left hand side of the curve, 90% significant of 2-tailed is the same as 95% of 1-tailed



Result

- Note the significant value reported from PSPP is for 2-tailed test
- To get the correct value for 1-tailed test, divide the value by 2
  - i.e. actual significant value should be **.0385**

```
T-TEST /TESTVAL=100
       /VARIABLES= IQ     /MISSING=ANALYSIS
       /CRITERIA=CI(0.9).
```

One-Sample Statistics

	N	*Mean*	*Std. Deviation*	*S.E. Mean*
IQ	20	107.45	17.83	3.99

Descriptive Statistic

One-Sample Test

	Test Value = 100.000000					
					90% Confidence Interval of the Difference	
	t	*df*	*Sig. (2-tailed)*	*Mean Difference*	*Lower*	*Upper*
IQ	1.87	19	.077	7.45	.56	14.34

t-value

Significant value: p-value

What is the meaning of the significant value p?

- A p value of .0385 means:
  - If you repeat the experiment 100 times, the Null Hypothesis H_0 will be correct for 3.85 times.
  - i.e. the Alternative Hypothesis H_1 will be correct 96.15 times.

H_0: sample mean <= 100
H_1: sample mean > 100

  - If you recruit 2000 subjects, split them into 100 groups, with 20 subjects per group.
  - Then you give them drugs.
  - Then you ask them to do the IQ test.
  - Out of the 100 groups:
    - 96.15 groups will have mean score of >100
    - 3.85 groups will have mean score of <=100

How do you compare means of 2 conditions?

- How do you analysis data in our cellphone driving experiment?

Independent samples *t-test* – we have 2 means, 2 groups; no relation between groups, e.g., people randomly assigned to a single group.

2. Independent Sample t-test

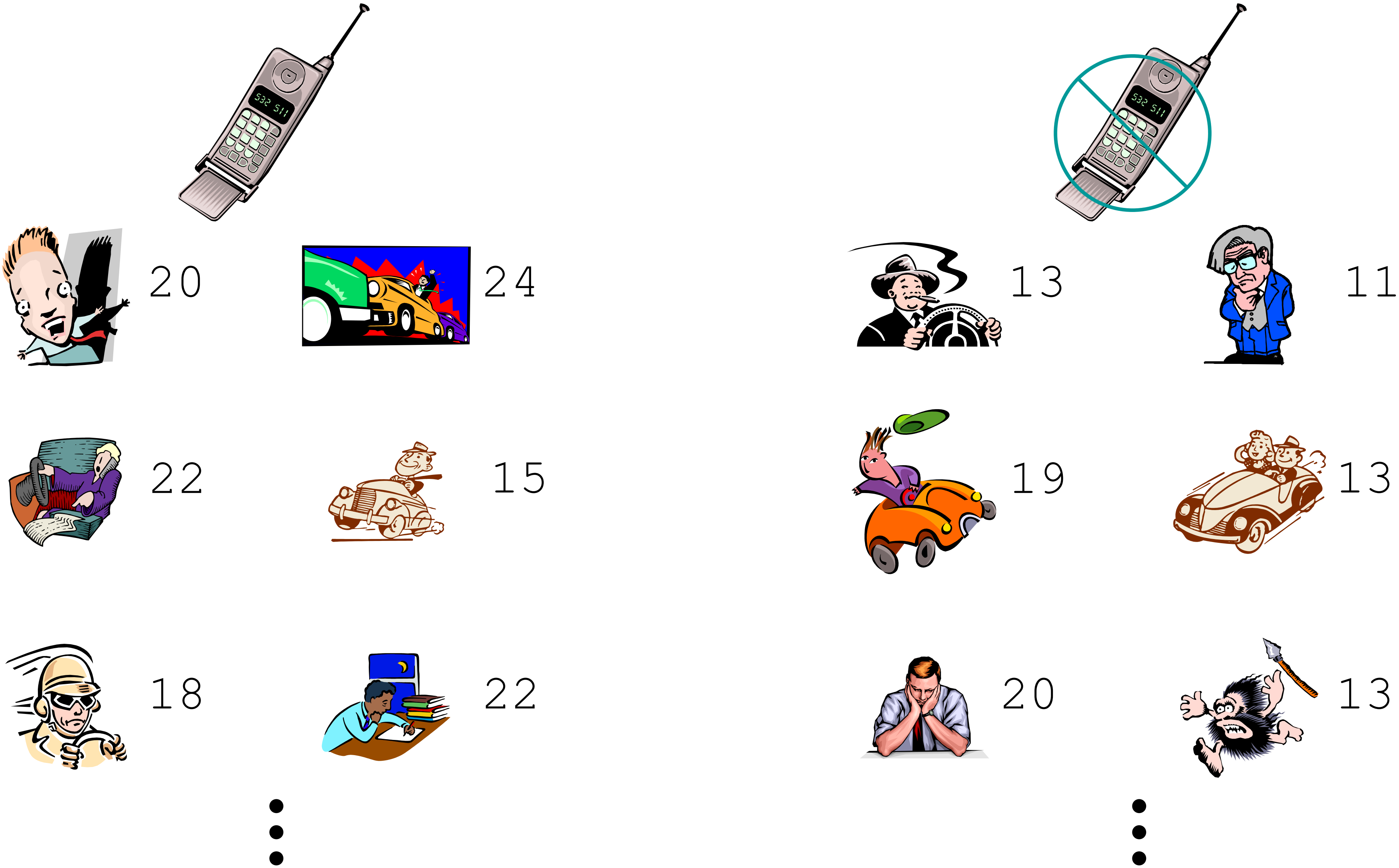
- Used for comparing the mean of one group to the mean of another independent group to determine if they are statistically significantly different
- Used for between-subject design comparison

- Requirement:
  - DV should be independence: Scores in one sample do not influence scores in other samples
  - Must be 2 groups (i.e. 2 conditions)
  - Measurement should be scaled
    - i.e. not categorical (e.g. male vs. female)
  - Homogenous assumption
    - Levene Test should not reach significance

2. Independent Sample t-test

$$t = \frac{\overbrace{\bar{X}_1 - \bar{X}_2}^{A}}{\sqrt{\underbrace{\left[\frac{(N_1 - 1)s_1^2 + (N_2 - 1)s_2^2}{N_1 + N_2 - 2}\right]}_{B}\underbrace{\left[\frac{1}{N_1} + \frac{1}{N_2}\right]}_{C}}}$$

- X1 = mean of group 1; X2 = mean of group 2;
- N1 = number of sample of group 1
- N2 = number of sample of group 2
- S1 = Standard deviation of group 1
- S2 = Standard deviation of group 2



Consider our cellphone driving example ...

17	26
25	21
33	16
17	15
18	17
18	21
22	21
25	20
18	15
28	17
23	18
27	19
26	16
22	7
14	12
20	16
24	21
23	16
25	18
20	15

And these are the data we collected (20 subjects in each condition)

5 steps for hypothesis proving

1. State the Null Hypothesis H_0 and Alternative Hypothesis $H_{1.}$

H_0: sample mean a <= sample mean b

H_1: sample mean a > sample mean b

2. Select the appropriate statistical method.

Independent sample t-test, 1-tailed

3. Select a level of significance.

.05; df = 38; critical t-value needs to be larger than 1.684

4. Calculate the statistic.

5. Make the decision.

17
25
33
17
18
18
22
25
18
28
23
27
26
22
14
20
24
23
25
20

Mean = 22.5

STDEV = 4.59

26
21
16
15
17
21
21
20
15
17
18
19
16
7
12
16
21
16
18
15

Mean = 17.35

STDEV = 3.96

2. Independent Sample t-test

$$t = \frac{\overbrace{\bar{X}_1 - \bar{X}_2}^{A}}{\sqrt{\underbrace{\left[\frac{(N_1-1)s_1^2+(N_2-1)s_2^2}{N_1+N_2-2}\right]}_{B}\underbrace{\left[\frac{1}{N_1}+\frac{1}{N_2}\right]}_{C}}}$$

- X1 = 22.25; X2 = 17.35;
- N1 = 20
- N2 = 20
- S1 = 4.59
- S2 = 3.96

- A = 4.9
- B = 18.38
- C = 0.1
- ***t = 3.61***

5 steps for hypothesis proving

1. State the Null Hypothesis H_0 and Alternative Hypothesis H_1.

H_0: sample mean a <= sample mean b
H_1: sample mean a > sample mean b

2. Select the appropriate statistical method.

Independent group t-test, 1-tailed

3. Select a level of significance.

.05; df = 38; critical t-value needs to be larger than 1.684

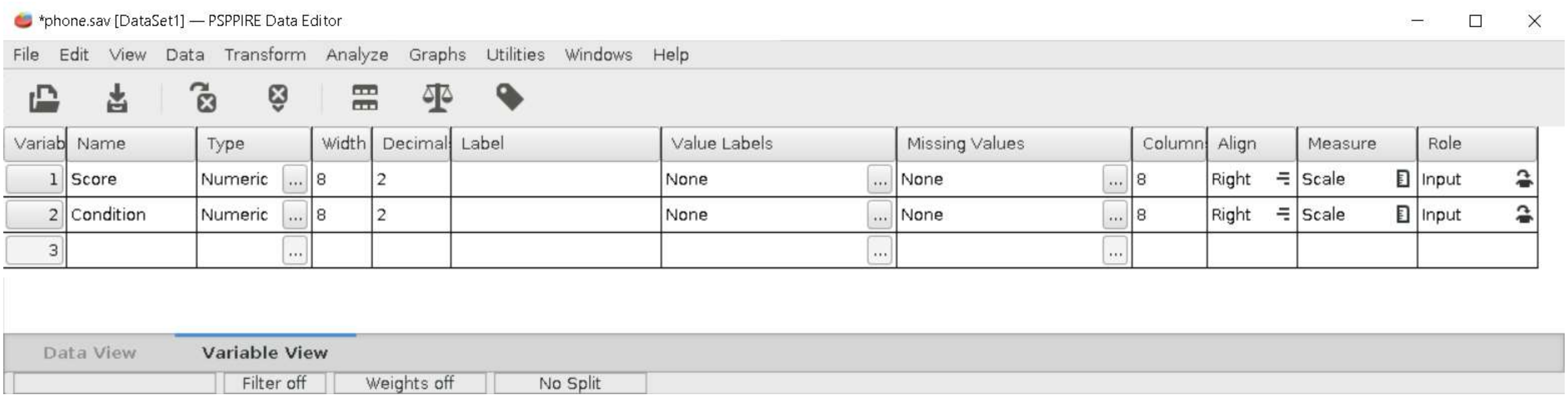
4. Calculate the statistic.

$t(38) = 3.61$; $p < .05$

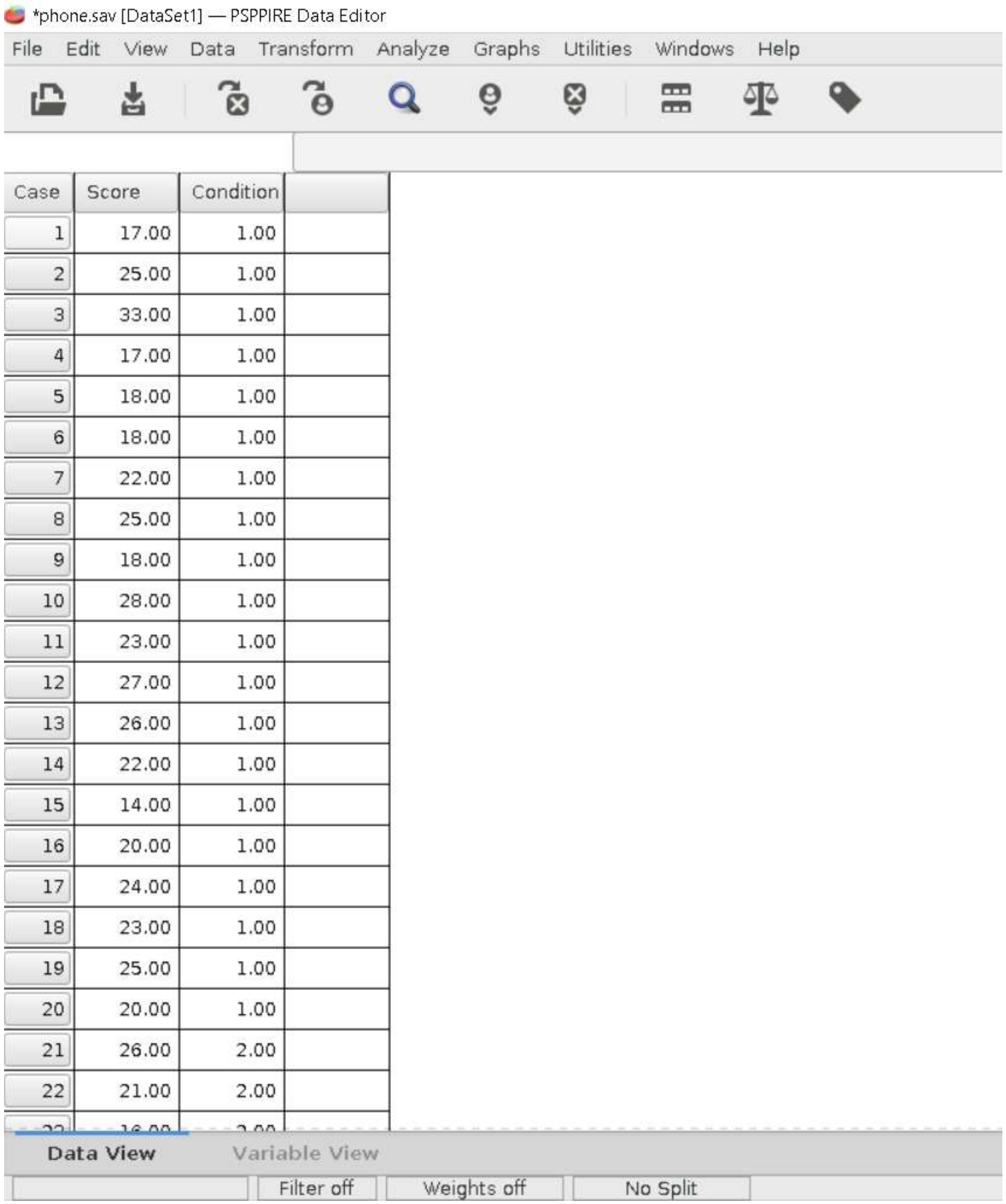
5. Make the decision.

H_0 is reject; H_1 is supported.
The phone condition has a significantly higher score than the no phone condition.

How to do it in PSPP

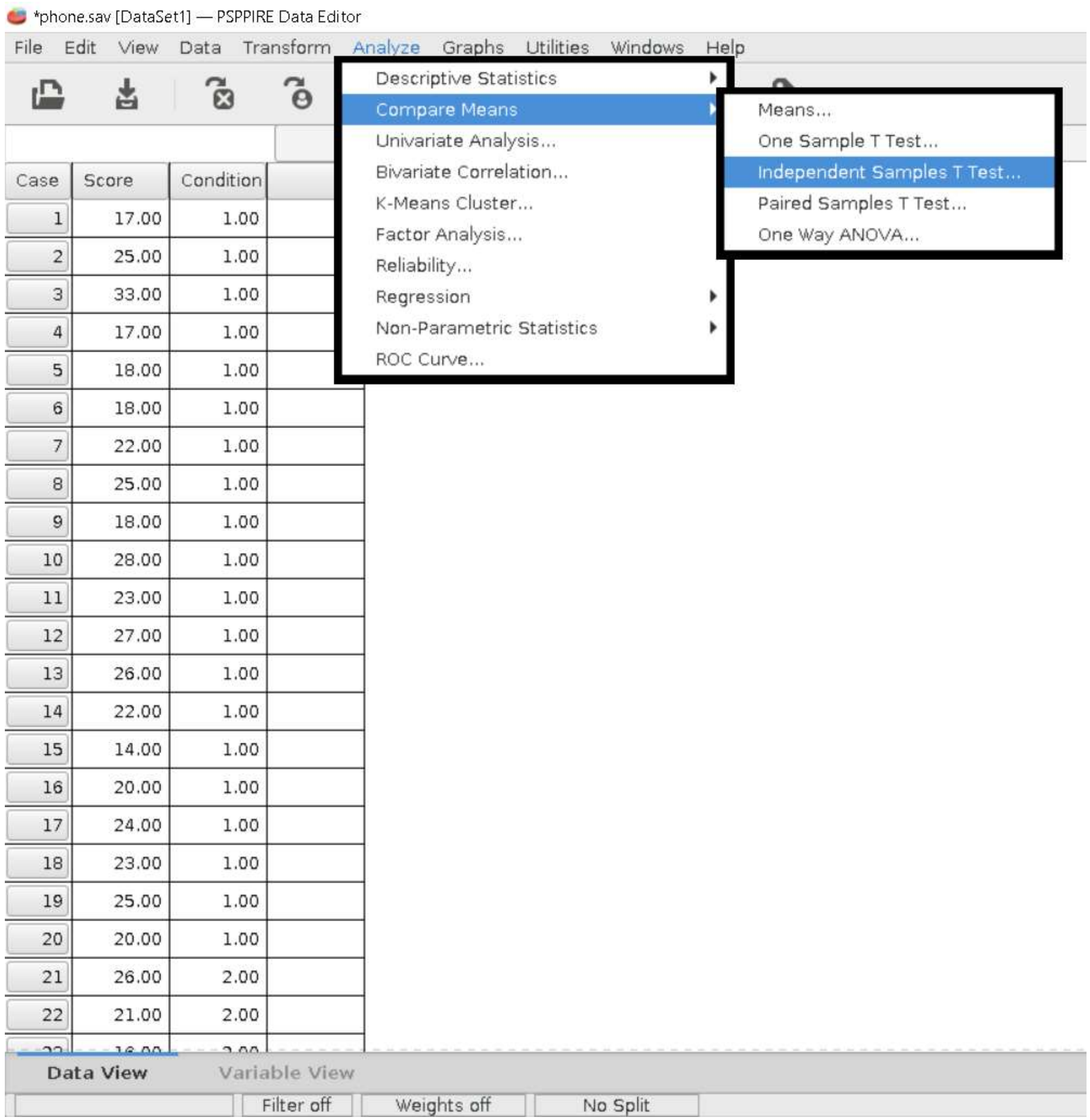


How to do it in PSPP



Case	Score	Condition
1	17.00	1.00
2	25.00	1.00
3	33.00	1.00
4	17.00	1.00
5	18.00	1.00
6	18.00	1.00
7	22.00	1.00
8	25.00	1.00
9	18.00	1.00
10	28.00	1.00
11	23.00	1.00
12	27.00	1.00
13	26.00	1.00
14	22.00	1.00
15	14.00	1.00
16	20.00	1.00
17	24.00	1.00
18	23.00	1.00
19	25.00	1.00
20	20.00	1.00
21	26.00	2.00
22	21.00	2.00

How to do it in PSPP



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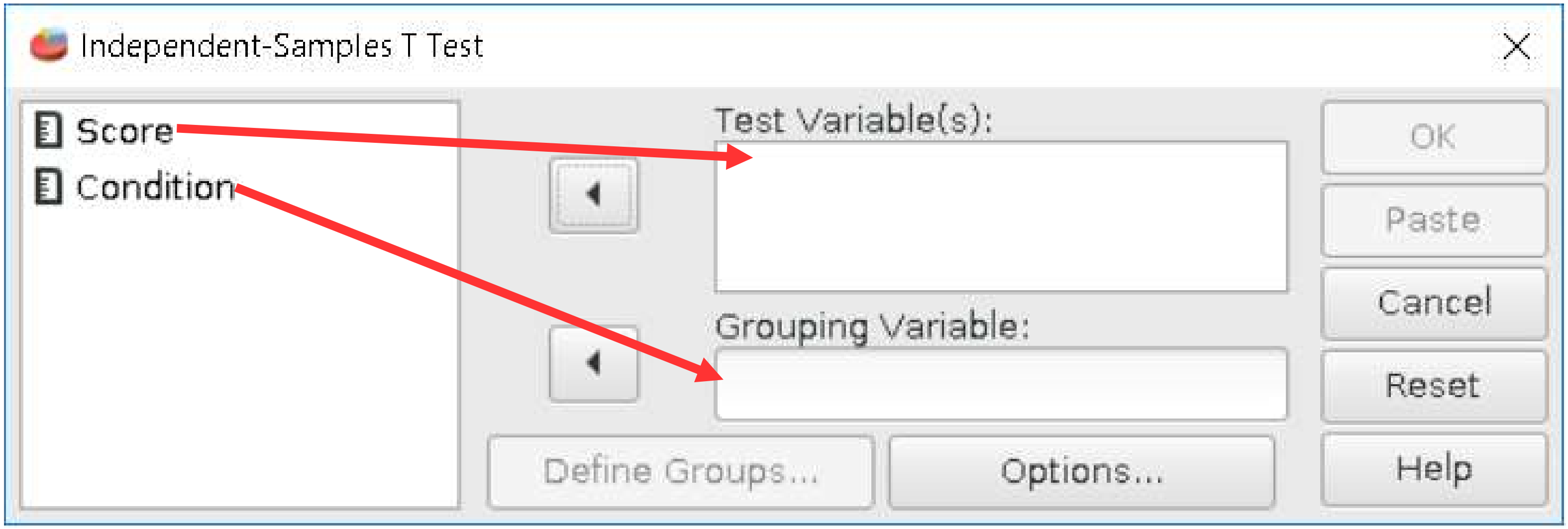
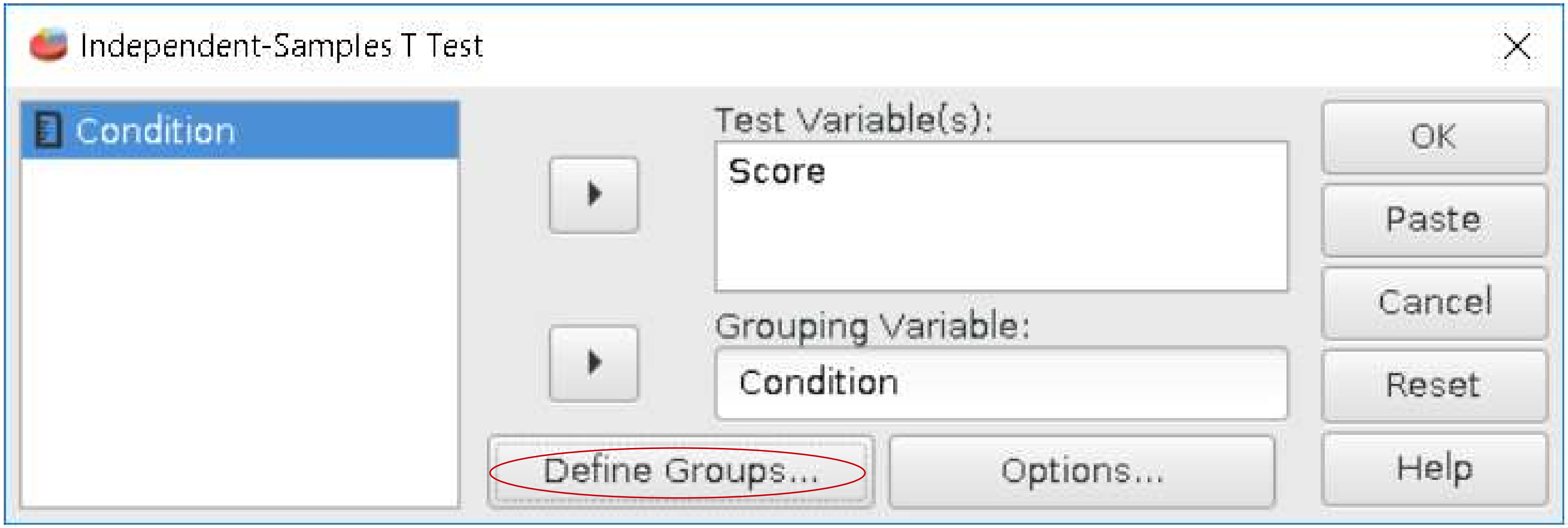
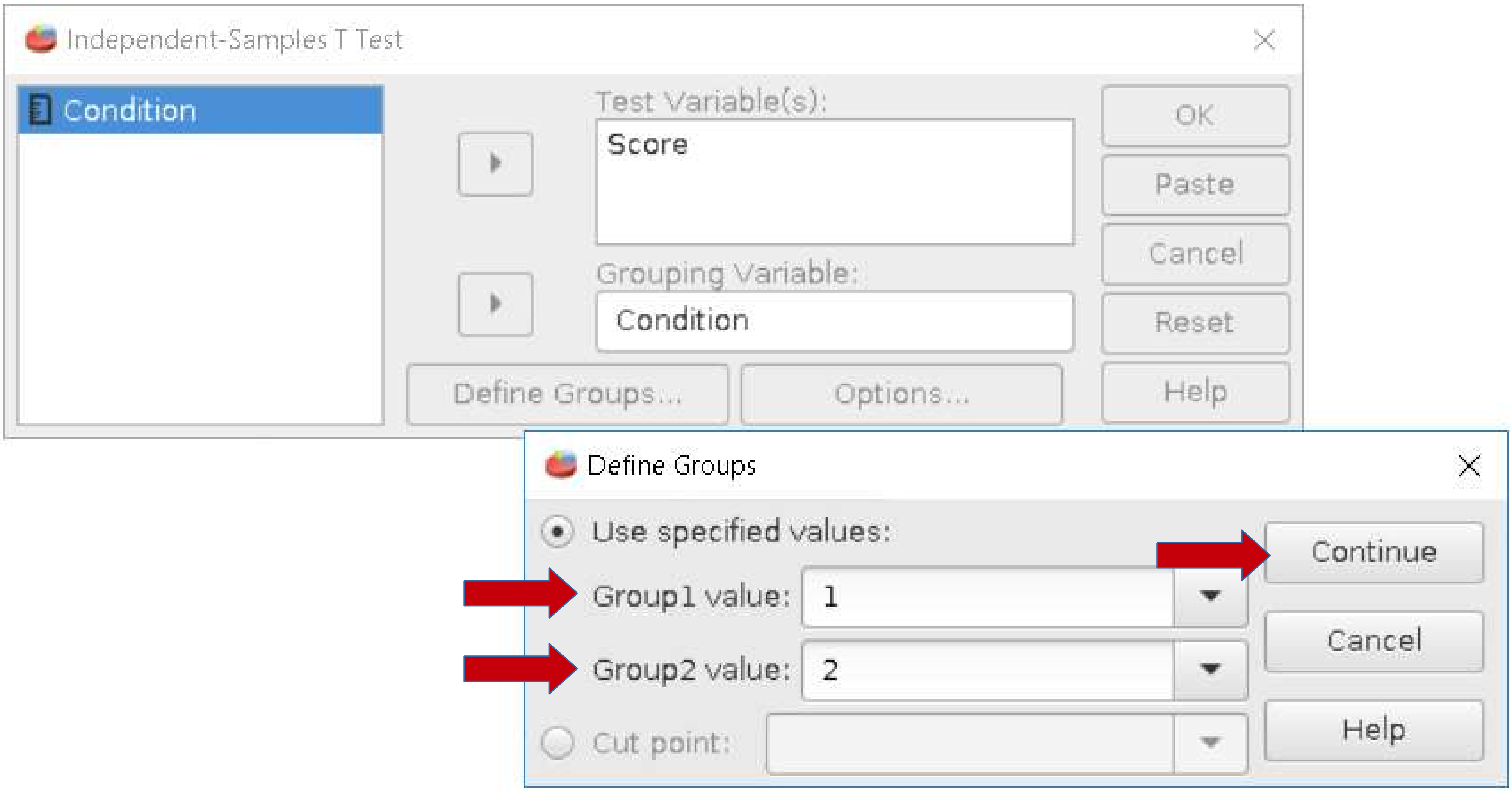


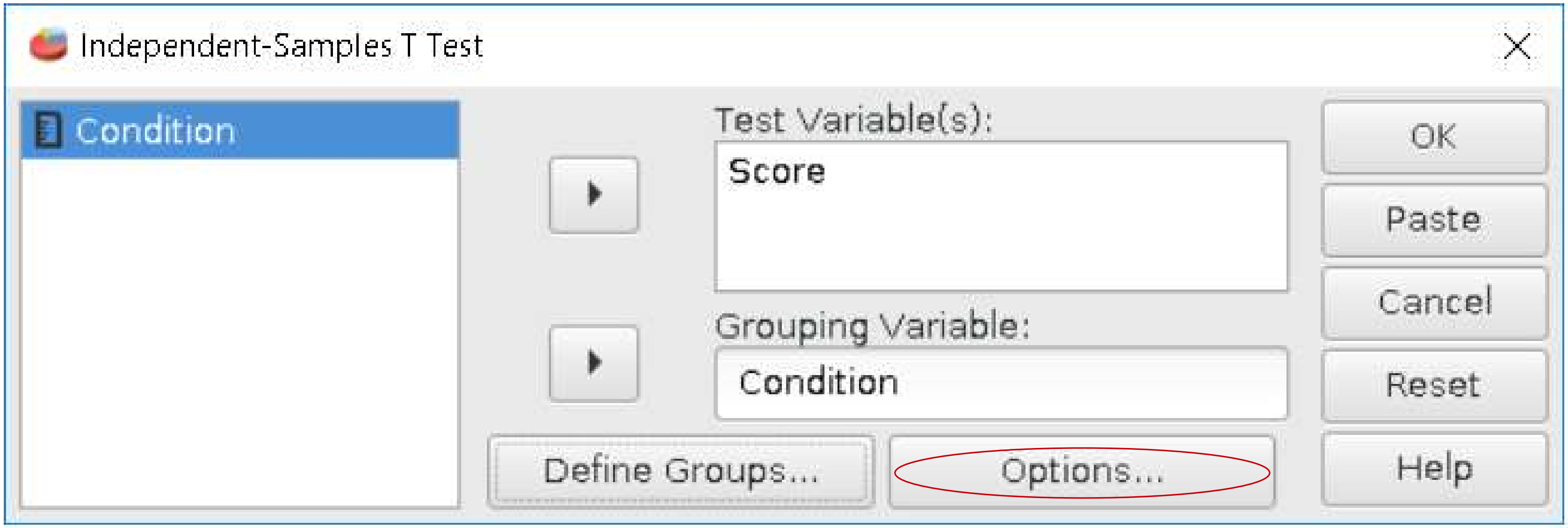
How to do it in PSPP



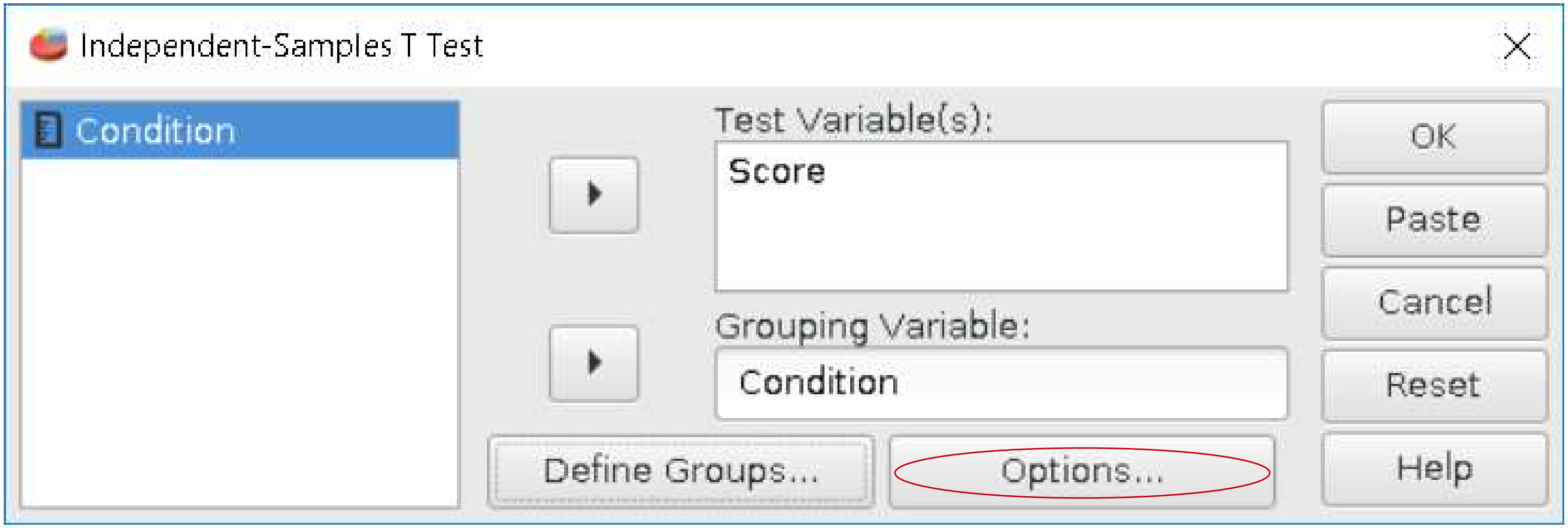
How to do it in PSPP



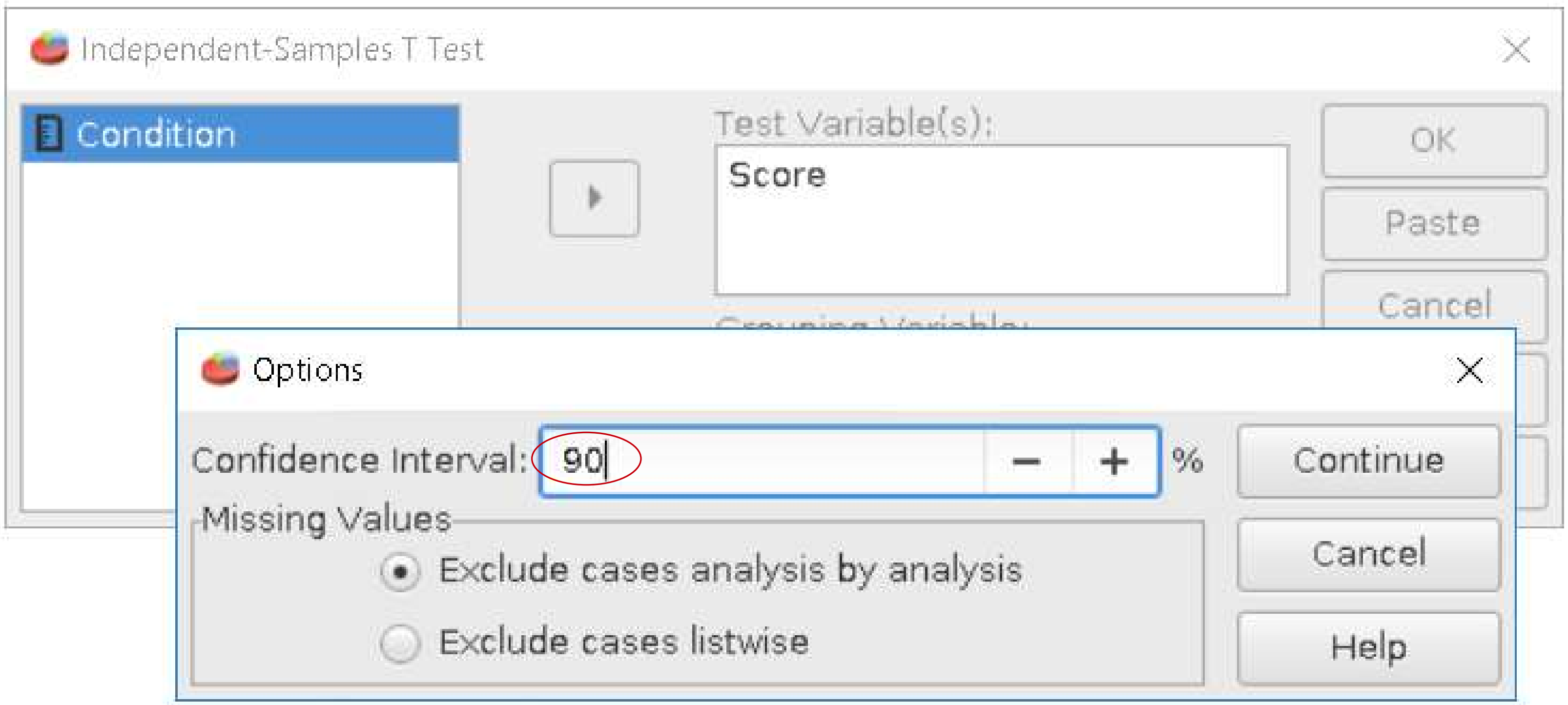
How to do it in PSPP



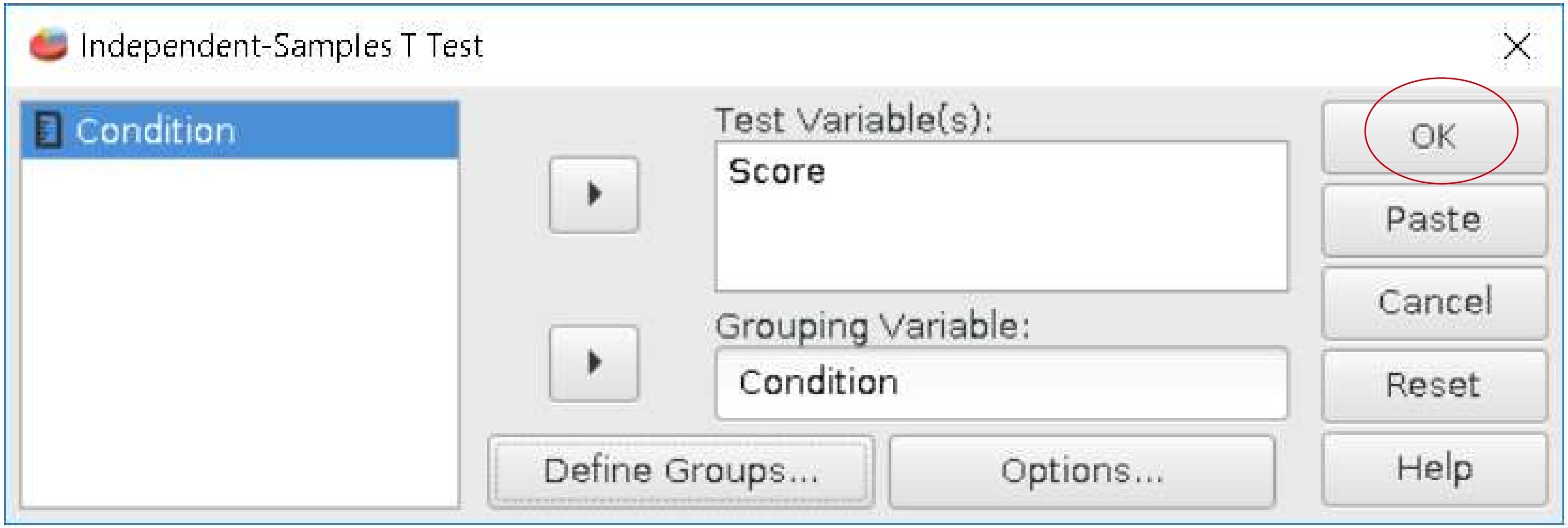
How to do it in PSPP



Set 90% confidence interval …
(For 1-Tailed 95% confidence)



How to do it in PSPP



Result

Descriptive Statistic

```
T-TEST

T-TEST /VARIABLES= Score
    /GROUPS=Condition(1,2)     /MISSING=ANALYSIS
    /CRITERIA=CI(0.9).
```

Group Statistics

	Condition	N	Mean	Std. Deviation	S.E. Mean
Score	1.00	20	22.25	4.59	1.03
	2.00	20	17.35	3.96	.89

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									90% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.84	.366	3.61	38.00	.001	4.90	1.36	2.61	7.19
	Equal variances not assumed			3.61	37.22	.001	4.90	1.36	2.61	7.19

2nd row

Levene's Test Result

- If Sig. is below .05, then Levene's Test shows significance
- i.e. The variance between groups is not homogenous (not equal)
- In that case, we should read the second row in the t-test result
- In our case, Levene's Test does not show significance
- Read the first row (equal variances)

Result

T-TEST

```
T-TEST /VARIABLES= Score
    /GROUPS=Condition(1,2)    /MISSING=ANALYSIS
    /CRITERIA=CI(0.9).
```

Group Statistics

	Condition	N	Mean	Std. Deviation	S.E. Mean
Score	1.00	20	22.25	4.59	1.03
	2.00	20	17.35	3.96	.89

Descriptive Statistic

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									90% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Score	Equal variances assumed	.84	.366	3.61	38.00	.001	4.90	1.36	2.61	7.19
	Equal variances not assumed			3.61	37.22	.001	4.90	1.36	2.61	7.19

t-value

Significance value (p value) for 2-tailed
p value for 1-tailed should be divided by 2
i.e. .0005

3. Paired Sample t-test

- Used for comparing the mean of one group to the mean of two dependent conditions
- Test if the average difference of two measurements is different from zero
- Used for within-subject design comparison
- Often used for “before-after effect” analysis

- Requirement:
  - Must be 2 conditions
  - Measurement should be scaled
    - i.e. not categorical (e.g. male vs. female)

- No requirement for variances homogeneity
  - Levene’s Test is not required
  -

NHST Settings

- Null Hypothesis H_0:
  - The mean difference between condition 1 and condition 2 is zero
  - $\text{Mean}_1 - \text{Mean}_2 = 0$
- Alternative Hypothesis H1:
  - The mean difference between condition 1 and condition 2 is not zero
  - $\text{Mean}_1 - \text{Mean}_2 \mathrel{!=} 0$
- *df* = N – 1
- 2-tailed (since you're comparing is the means are the same or different)

Scenario

- You created 2 interfaces for the same task
- Performance of the task was measured
- N = 20 (i.e. 20 subjects)
- Using within subject design
  - The same subject uses Interface #1 and Interface #2 to complete the task
  - Performances were compared within subject
  - Performance was measured using a 10-point scale
  - Sequence of the Interfaces was counterbalanced

The Data

Subject	Interface1	Interface2
1	9	1
2	7	5
3	8	4
4	5	10
5	7	5
6	4	4
7	10	10
8	3	5
9	10	5
10	10	5
11	7	6
12	6	4
13	5	3
14	4	6
15	10	3
16	6	3
17	5	5
18	7	5
19	5	2
20	7	10
Mean	6.75	5.05
STDEV	2.1974866026	2.4809802816

5 steps for hypothesis proving

1. State the Null Hypothesis H_0 and Alternative Hypothesis $H_{1.}$

H_0: sample mean 1 = sample mean 2

H_1: sample mean 1 != sample mean 2

2. Select the appropriate statistical method.

Paired sample t-test, 2-tailed

3. Select a level of significance.

.05; df = 19; critical t-value needs to be larger than 2.093

4. Calculate the statistic.

5. Make the decision.

Formula for paired-sample t-test

$$t = \frac{\frac{\Sigma d}{N}}{\sqrt{\frac{\Sigma d^2 - \frac{(\Sigma d)^2}{N}}{N(N-1)}}}$$

Formula for paired-sample t-test

$$t = \frac{\frac{\sum d}{N}}{\sqrt{\frac{\sum d^2 - \frac{(\sum d)^2}{N}}{N(N-1)}}}$$

$t = (34/20)$ /

sqrt($(260-(34^{2/}/20))$ / $(20\text{x}19)$)

= 2.33

Subject	Interface1	Interface2	d	d square
1	9	1	8	64
2	7	5	2	4
3	8	4	4	16
4	5	10	-5	25
5	7	5	2	4
6	4	4	0	0
7	10	10	0	0
8	3	5	-2	4
9	10	5	5	25
10	10	5	5	25
11	7	6	1	1
12	6	4	2	4
13	5	3	2	4
14	4	6	-2	4
15	10	3	7	49
16	6	3	3	9
17	5	5	0	0
18	7	5	2	4
19	5	2	3	9
20	7	10	-3	9
Sum	135	101	34	260

5 steps for hypothesis proving

1. State the Null Hypothesis H_0 and Alternative Hypothesis H_1.

H_0: sample mean 1 = sample mean 2

H_1: sample mean 1 != sample mean 2

2. Select the appropriate statistical method.

Paired sample t-test, 2-tailed

3. Select a level of significance.

.05; df = 19; critical t-value needs to be larger than 2.093

4. Calculate the statistic.

$t(19) = 2.33$; $p < .05$

5. Make the decision.

H_0 is reject; H_1 is supported.

Mean for Interface 1 is significantly different from Mean for Interface 2

How to do it in PSPP

*[DataSet2] — PSPPIRE Data Editor

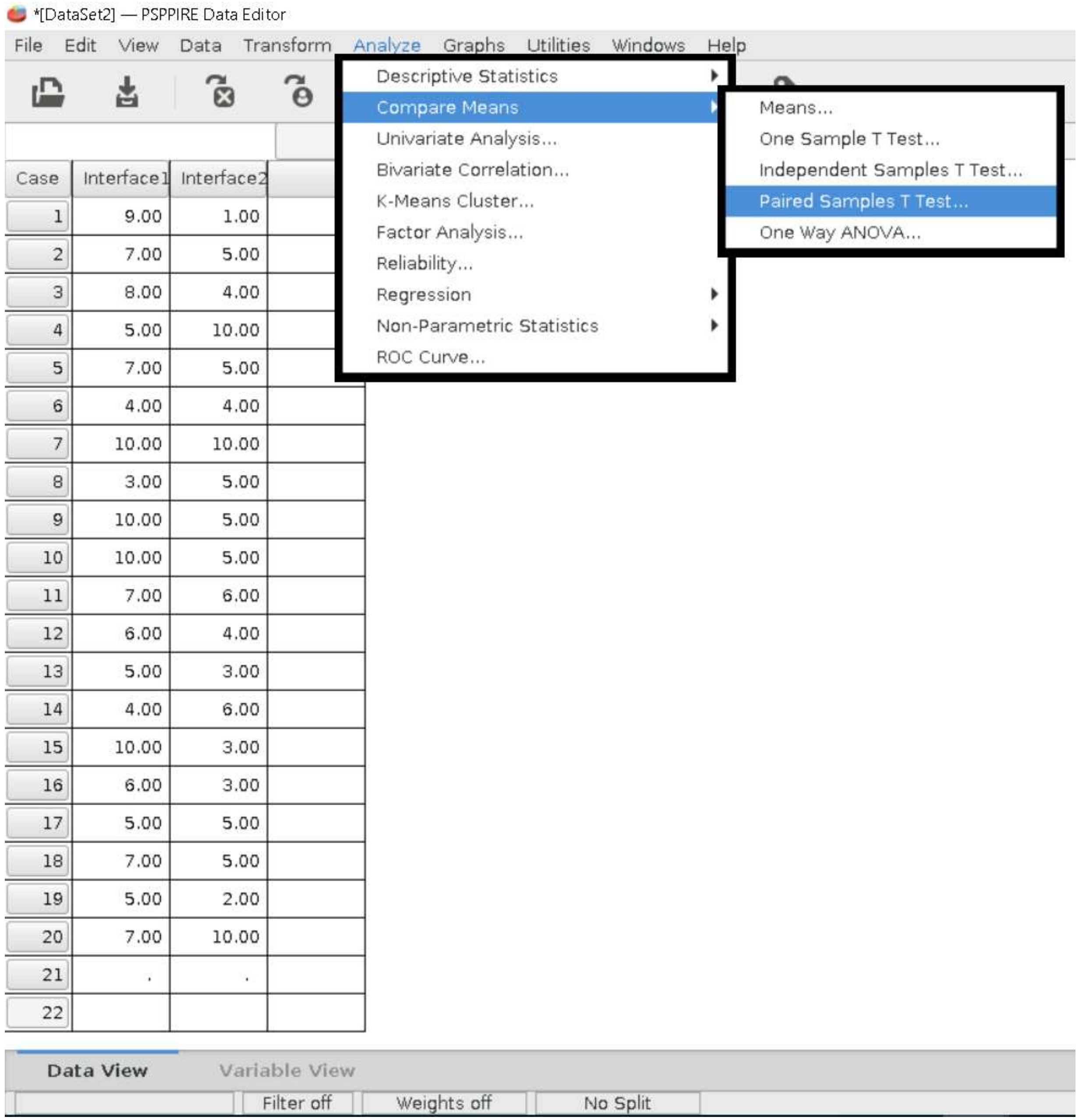
File Edit View Data Transform Analyze Graphs Utilities Windows Help

Case	Interface1	Interface2	
1	9.00	1.00	
2	7.00	5.00	
3	8.00	4.00	
4	5.00	10.00	
5	7.00	5.00	
6	4.00	4.00	
7	10.00	10.00	
8	3.00	5.00	
9	10.00	5.00	
10	10.00	5.00	
11	7.00	6.00	
12	6.00	4.00	
13	5.00	3.00	
14	4.00	6.00	
15	10.00	3.00	
16	6.00	3.00	
17	5.00	5.00	
18	7.00	5.00	
19	5.00	2.00	
20	7.00	10.00	
21	.	.	
22			

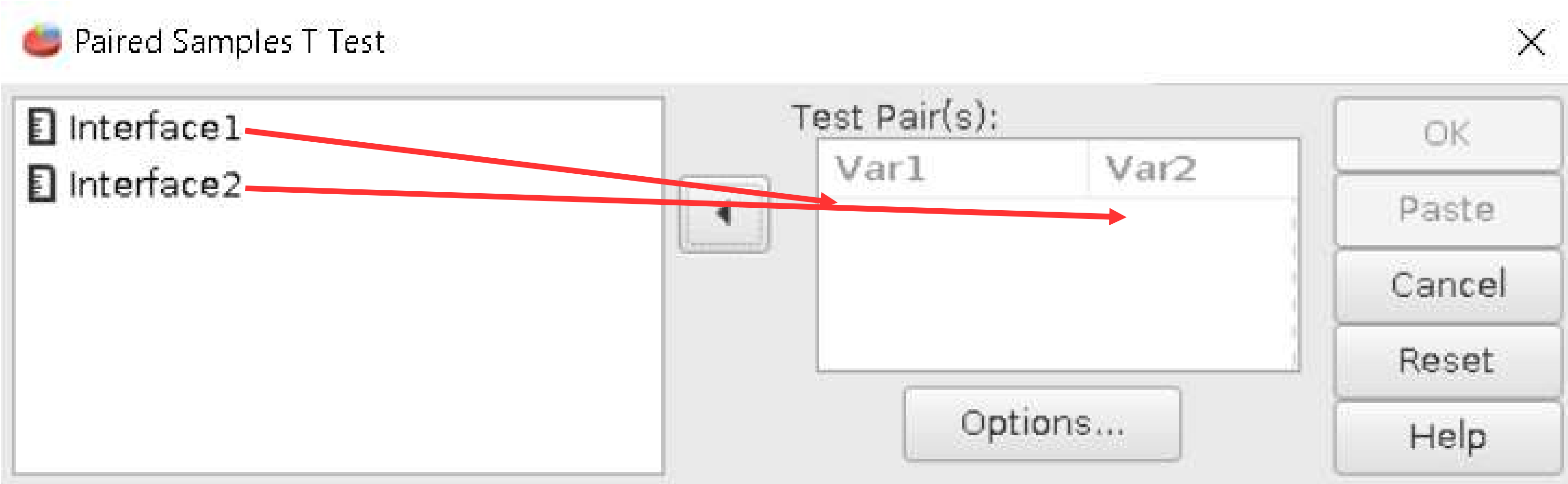
Data View Variable View

Filter off Weights off No Split

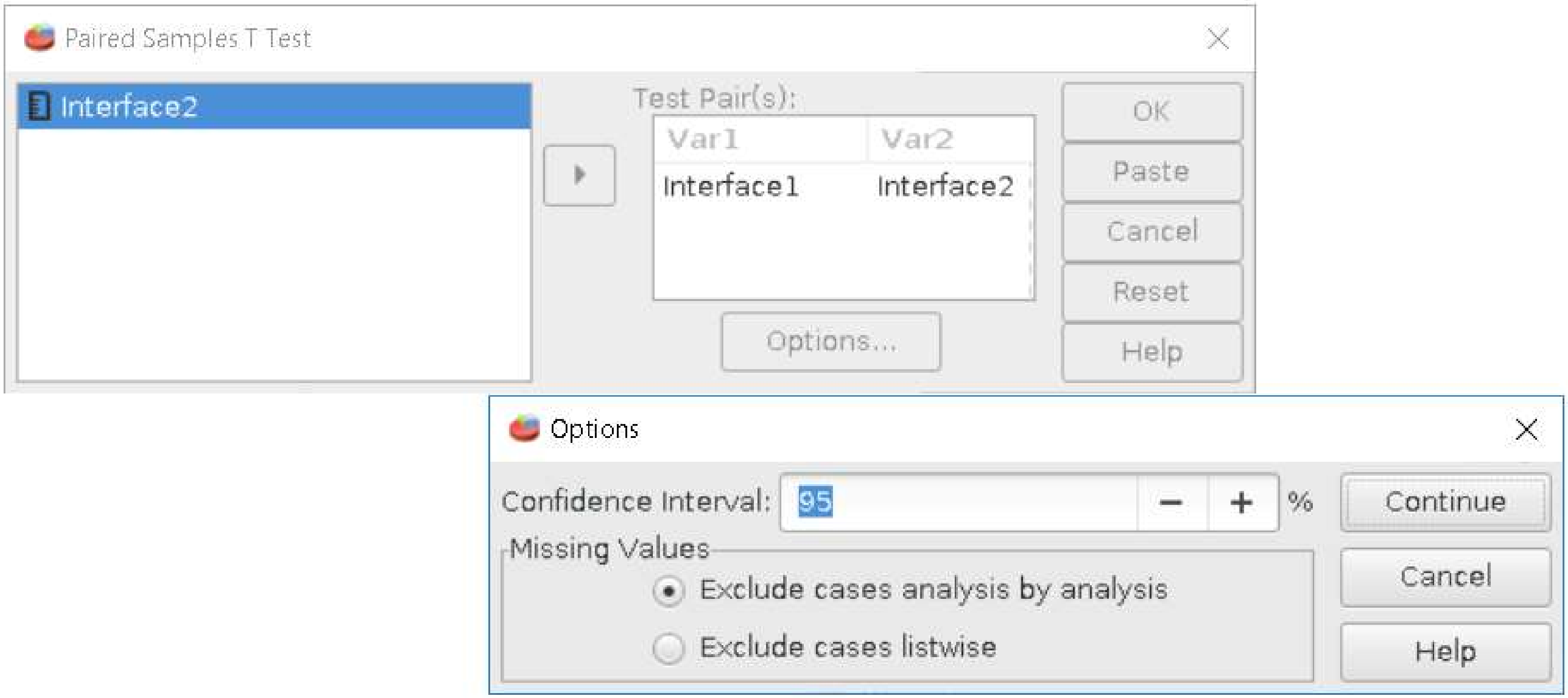
How to do it in PSPP



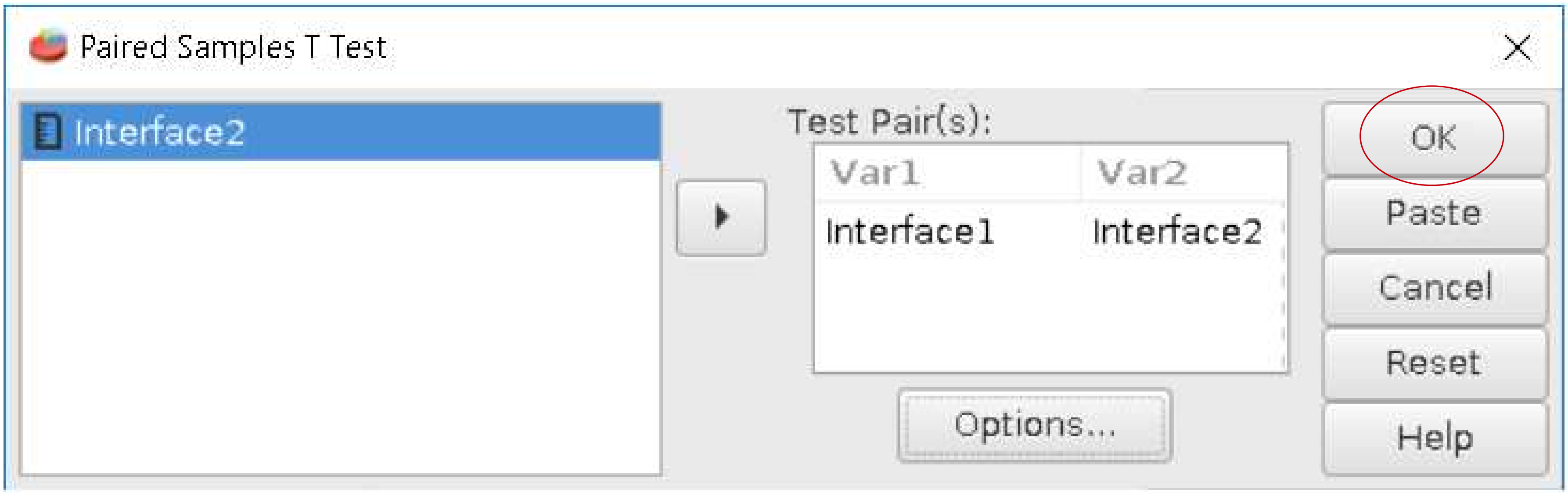
How to do it in PSPP



Set 95% Confidence Interval for 2-tailed test



How to do it in PSPP



Result

```
T-TEST

T-TEST
    PAIRS =  Interface1 WITH  Interface2 (PAIRED)
    /MISSING=ANALYSIS
    /CRITERIA=CI(0.95).
```

Paired Sample Statistics

		Mean	N	Std. Deviation	S.E. Mean
Pair 1	Interface1	6.75	20	2.20	.49
	Interface2	5.05	20	2.48	.55

Descriptive Statistic

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Interface1 & Interface2	20	.03	.896

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Interface1 - Interface2	1.70	3.26	.73	.17	3.23	2.33	19	.031

Summary: t-test

T-tests

For comparing 2 mean values

1. Single sample t-test

   Comparing a sample mean to a population mean

2. Independent sample t-test

   Comparing two sample mean values

   - The two sample means has to be independent
   - Levene’s Test must not pass

3. Paired sample t-test

   Comparing teo sample mean values

   - The two sample means does not need to be independent
   - Levene’s Test not required

What if you have more than 2 conditions?

For example, you may have one Independent Variable (IV) with three levels:

- Interface #1
- Interface #2
- Interface #3

When your IV has more than 2 levels, you can’t use the t-test!!!

You need to use ANOVA!

ANOVA

ANOVA – Analysis of Variances

Similar to t-test, but for more than 2 conditions

Different variants of ANOVA
- One way ANOVA
- MANOVA
- ANCOVA
- MANCOVA

Requirement of ANOVA

Independent Variable (IV)
- must be independent
- Sample size of each condition should be roughly equal

Dependent Variable (DV)
- Measurement must be quantitative
- Normality: DV must be normally distributed
- Homogeneity of Variance:
  Equal variance (tested by Levene's Test)

NHST using ANOVA

1. State the Null Hypothesis H_0 and Alternative Hypothesis $H_{1.}$

   Null Hypothesis N_0: Mean1 = Mean2 = Mean3

   Alternative Hypothesis N_1: Mean1 != Mean2 != Mean3

2. Select the appropriate statistical method.

One way ANOVA

3. Select a level of significance.

.05

4. Calculate the statistic.

5. Make the decision.

6. Calculate the post-hoc test

A note about the hypotheses

In the case of 3 conditions:

Null Hypothesis N_0: **Mean1 = Mean2 = Mean3**
Alternative Hypothesis N_1: **Mean1 != Mean2 != Mean3**

Mean1 = Mean2 = Mean3

Mean1=Mean2 AND Mean2=Mean3 AND Mean1=Mean3
=> (Mean1=Mean2 AND Mean1=Mean3 AND Mean2=Mean3)

Mean1 != Mean2 != Mean3

Mean1 != Mean2 OR Mean2 != Mean3 OR Mean1 != Mean3
=> (Mean1!=Mean2 AND Mean1=Mean3 AND Mean2=Mean3) OR
(Mean1=Mean2 AND Mean1!=Mean3 AND Mean2=Mean3) OR
(Mean1=Mean2 AND Mean1=Mean3 AND Mean2!=Mean3) OR
(Mean1!=Mean2 AND Mean1!=Mean3 AND Mean2=Mean3) OR
(Mean1=Mean2 AND Mean1!=Mean3 AND Mean2!=Mean3) OR
(Mean1!=Mean2 AND Mean1!=Mean3 AND Mean2!=Mean3)

A note about the hypotheses

When an ANOVA analysis is significant,
(1) the Null Hypothesis is rejected;
(2) the Alternative Hypothesis is supported.

That means at least one of the following cases are significant:

(Mean1!=Mean2 AND Mean1=Mean3 AND Mean2=Mean3) OR
(Mean1=Mean2 AND Mean1!=Mean3 AND Mean2=Mean3) OR
(Mean1=Mean2 AND Mean1=Mean3 AND Mean2!=Mean3) OR
(Mean1!=Mean2 AND Mean1!=Mean3 AND Mean2=Mean3) OR
(Mean1=Mean2 AND Mean1!=Mean3 AND Mean2!=Mean3) OR
(Mean1!=Mean2 AND Mean1!=Mean3 AND Mean2!=Mean3)

But we don’t know which cases are significant!!!

A further **post-hoc test** is required in order to find this out!

NHST using ANOVA

1. State the Null Hypothesis H_0 and Alternative Hypothesis $H_{1.}$
   Null Hypothesis N_0: Mean1 = Mean2 = Mean3
   Alternative Hypothesis N_1: Mean1 != Mean2 != Mean3

2. Select the appropriate statistical method.
One way ANOVA

3. Select a level of significance.
.05

4. Calculate the statistic.
I am skipping the maths and stats for this course……
Let's go directly into SPSS and let the computer do the calculations!

5. Make the decision.

6. Calculate the post-hoc test

17
25
33
17
18
18
22
25
18
28
23
27
26
22
14
20
24
23
25
20

Mean = 22.5
STDEV = 4.59

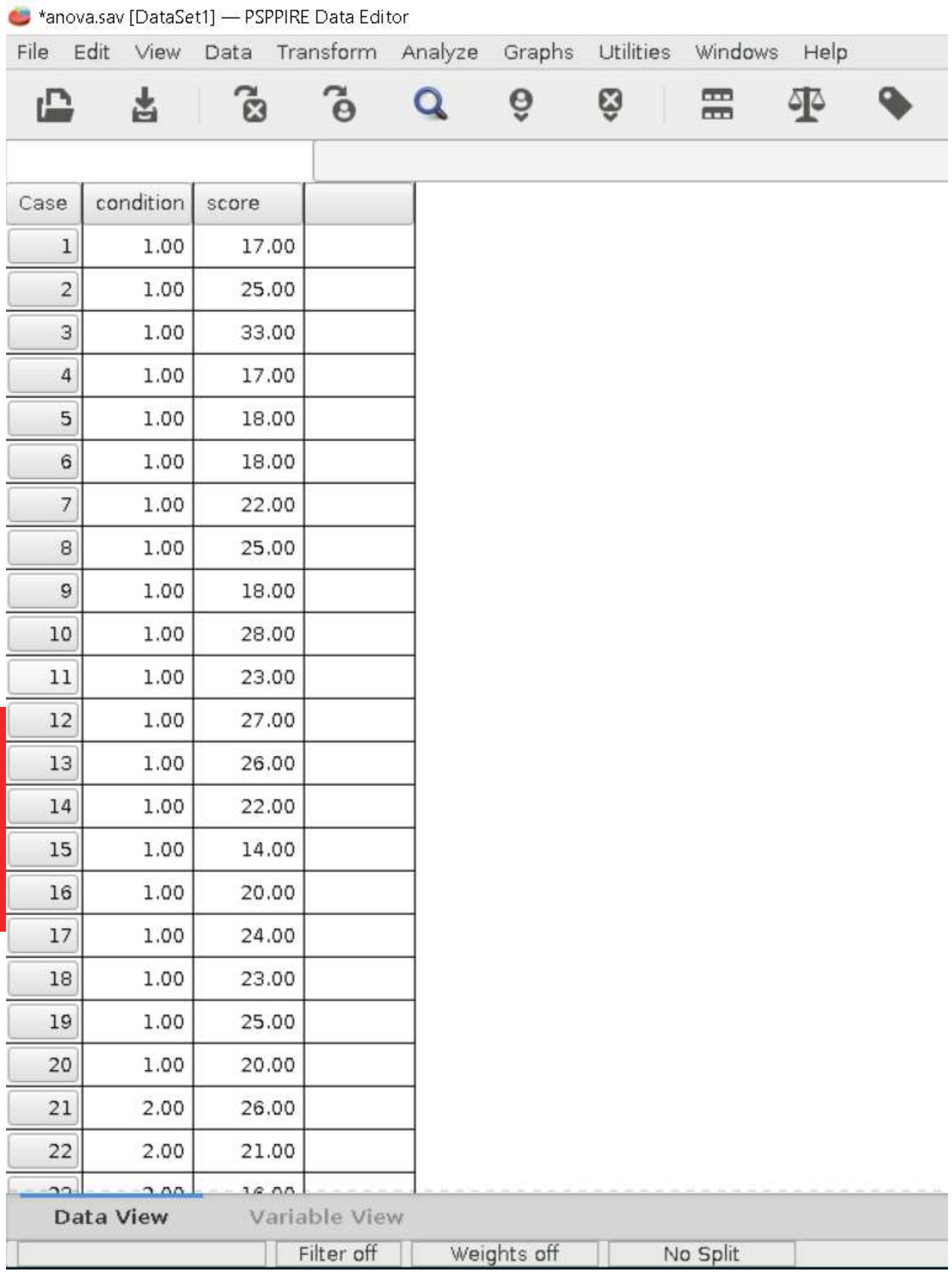
26
21
16
15
17
21
21
20
15
17
18
19
16
7
12
16
21
16
18
15

Mean = 17.35
STDEV = 3.96

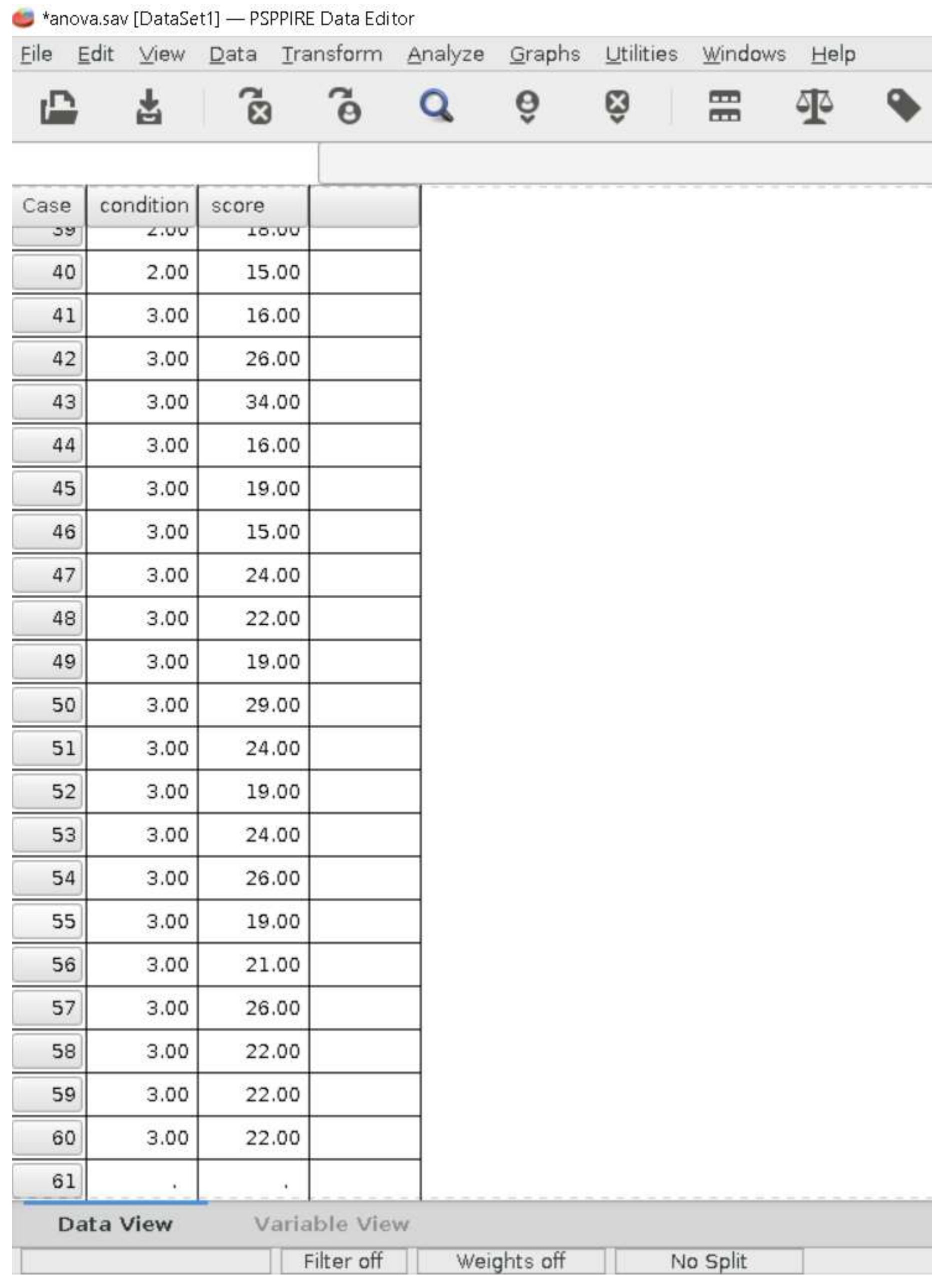
16
26
34
16
19
15
24
22
19
29
24
19
24
26
19
21
26
22
22
22

Mean = 22.5
STDEV = 4.64

How to do it in PSPP

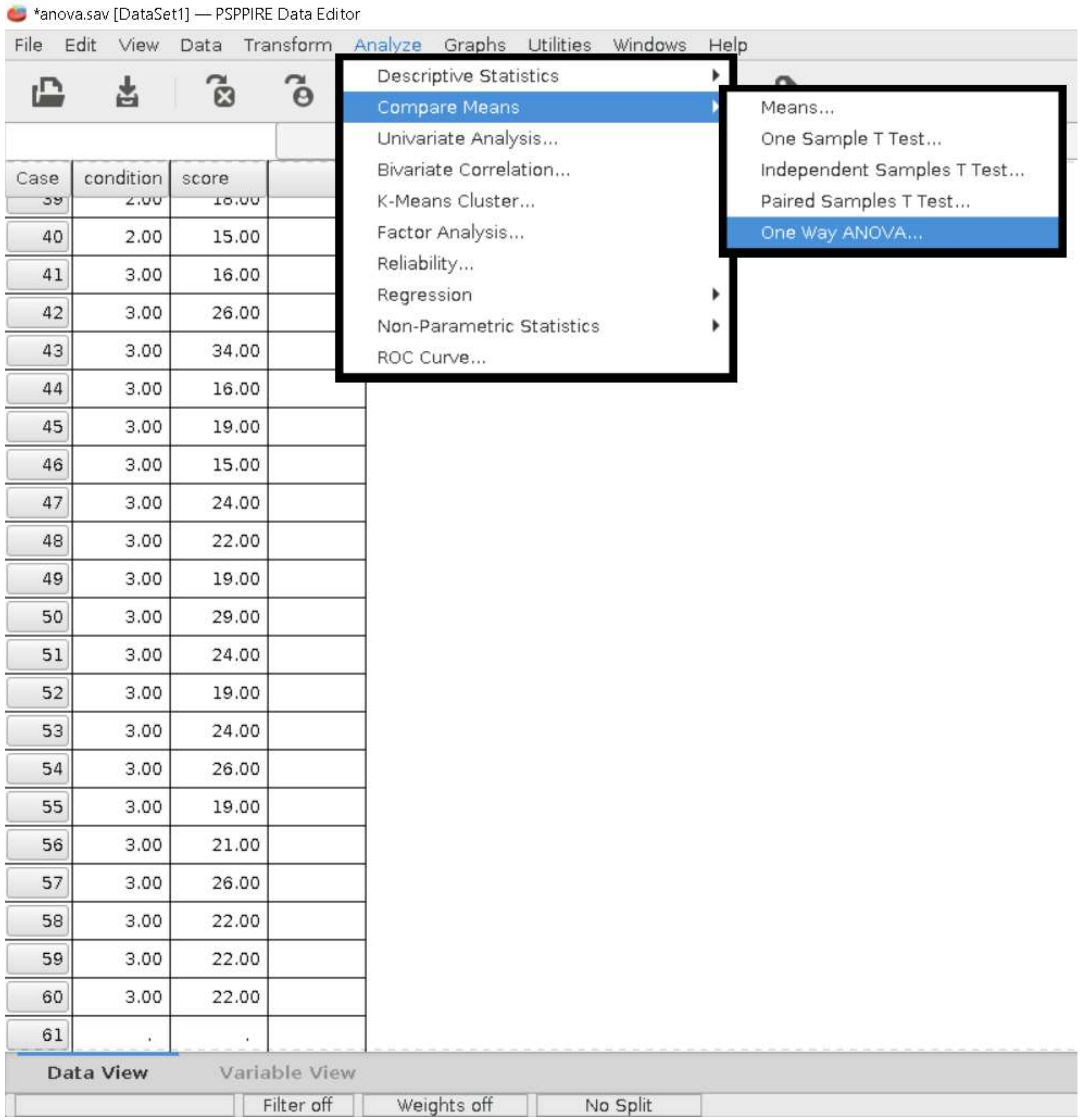


Case	condition	score
1	1.00	17.00
2	1.00	25.00
3	1.00	33.00
4	1.00	17.00
5	1.00	18.00
6	1.00	18.00
7	1.00	22.00
8	1.00	25.00
9	1.00	18.00
10	1.00	28.00
11	1.00	23.00
12	1.00	27.00
13	1.00	26.00
14	1.00	22.00
15	1.00	14.00
16	1.00	20.00
17	1.00	24.00
18	1.00	23.00
19	1.00	25.00
20	1.00	20.00
21	2.00	26.00
22	2.00	21.00



Case	condition	score
40	2.00	15.00
41	3.00	16.00
42	3.00	26.00
43	3.00	34.00
44	3.00	16.00
45	3.00	19.00
46	3.00	15.00
47	3.00	24.00
48	3.00	22.00
49	3.00	19.00
50	3.00	29.00
51	3.00	24.00
52	3.00	19.00
53	3.00	24.00
54	3.00	26.00
55	3.00	19.00
56	3.00	21.00
57	3.00	26.00
58	3.00	22.00
59	3.00	22.00
60	3.00	22.00
61	.	.

How to do it in PSPP



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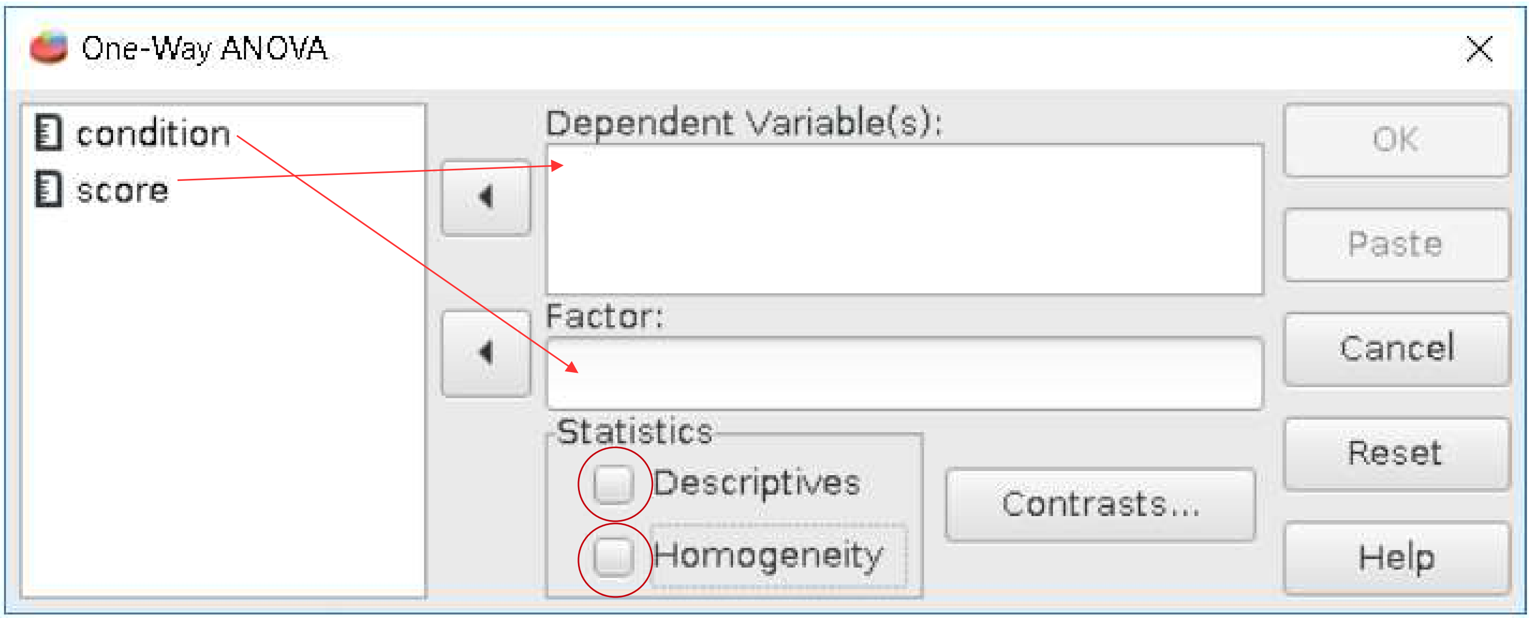


Results

Descriptive Statistics

Levene's Test

ONEWAY

```
ONEWAY /VARIABLES= score BY condition
      /STATISTICS=DESCRIPTIVES HOMOGENEITY .
```

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
score	1.00	20	22.25	4.59	1.03	20.10	24.40	14.00	33.00
	2.00	20	17.35	3.96	.89	15.49	19.21	7.00	26.00
	3.00	20	22.25	4.64	1.04	20.08	24.42	15.00	34.00
	Total	60	20.62	4.92	.64	19.35	21.89	7.00	34.00

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
score	.44	2	57	.649

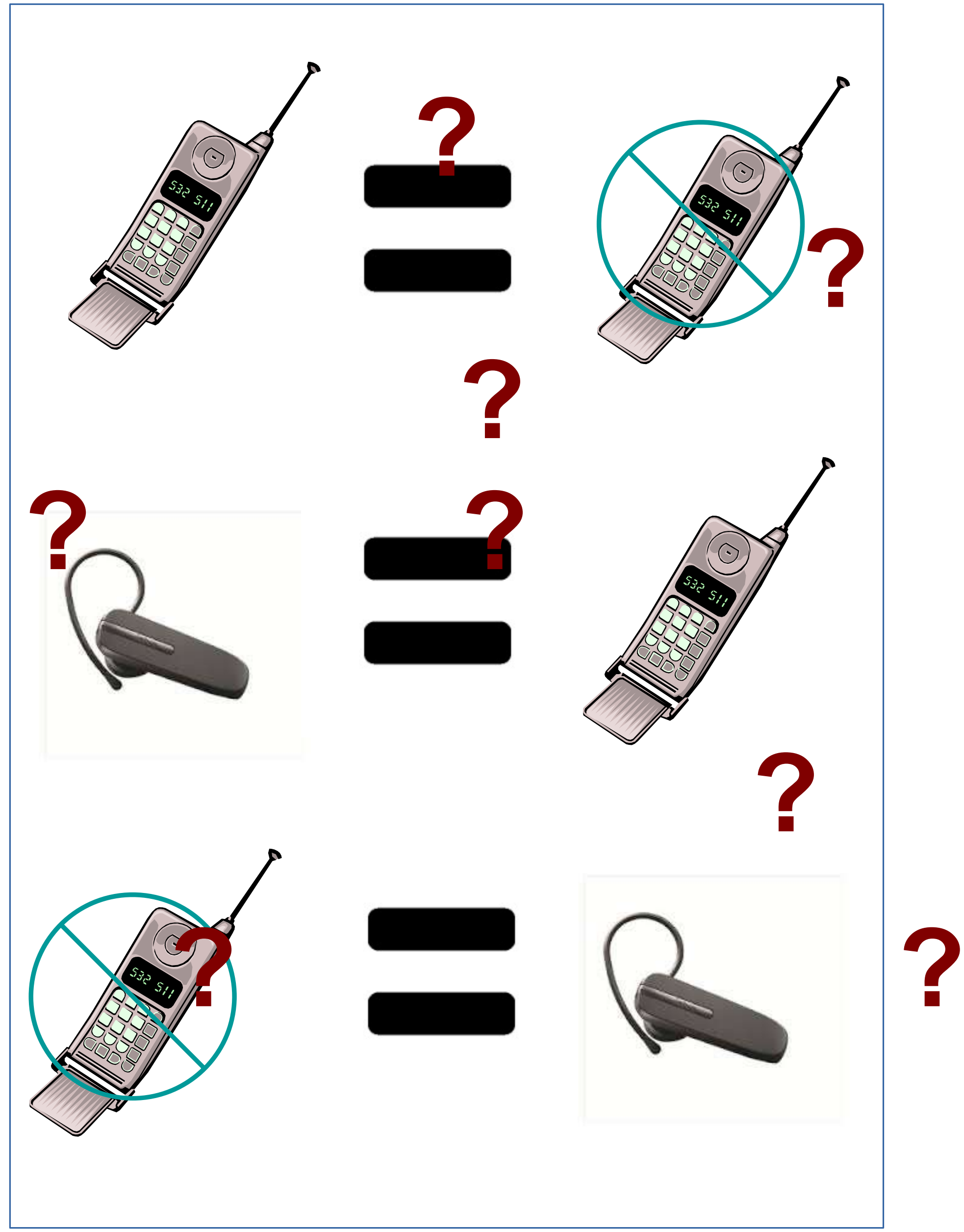
ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
score	Between Groups	320.13	2	160.07	8.23	.001
	Within Groups	1108.05	57	19.44		
	Total	1428.18	59			

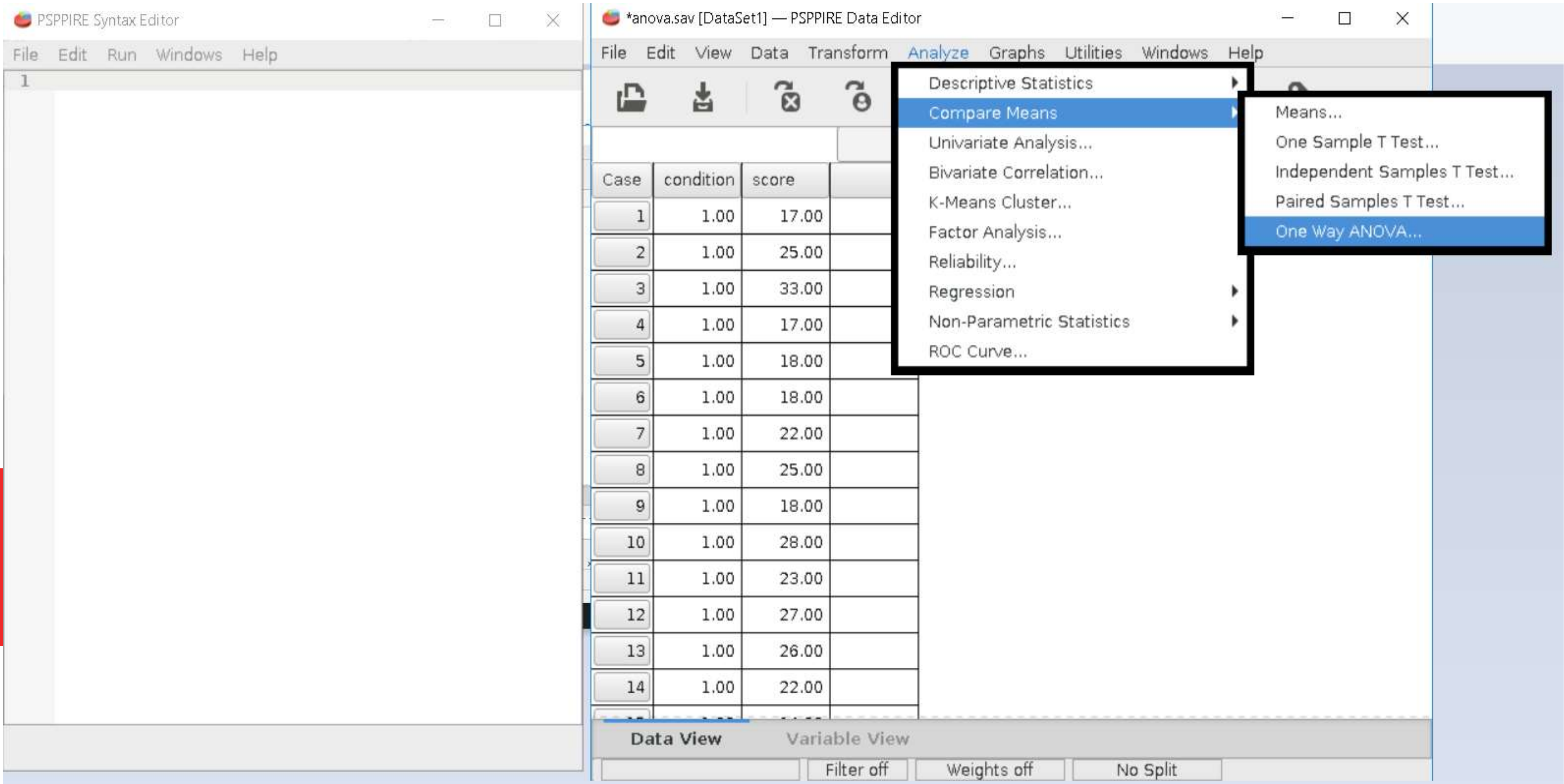
NHST using ANOVA

1. State the Null Hypothesis H_0 and Alternative Hypothesis H_1.
    Null Hypothesis N_0: Mean1 = Mean2 = Mean3
    Alternative Hypothesis N_1: Mean1 != Mean2 != Mean3
2. Select the appropriate statistical method.
One way ANOVA
3. Select a level of significance.
.05
4. Calculate the statistic.
I am skipping the maths and stats for this course……
Let's go directly into SPSS and let the computer do the calculations!
5. Make the decision.
H_0 is rejected.
- We know [Mean1 != Mean2 != Mean3]
6. Calculate the post-hoc test

Need Post-hoc test
to tell the difference!!!



How to do posthoc test in PSPP



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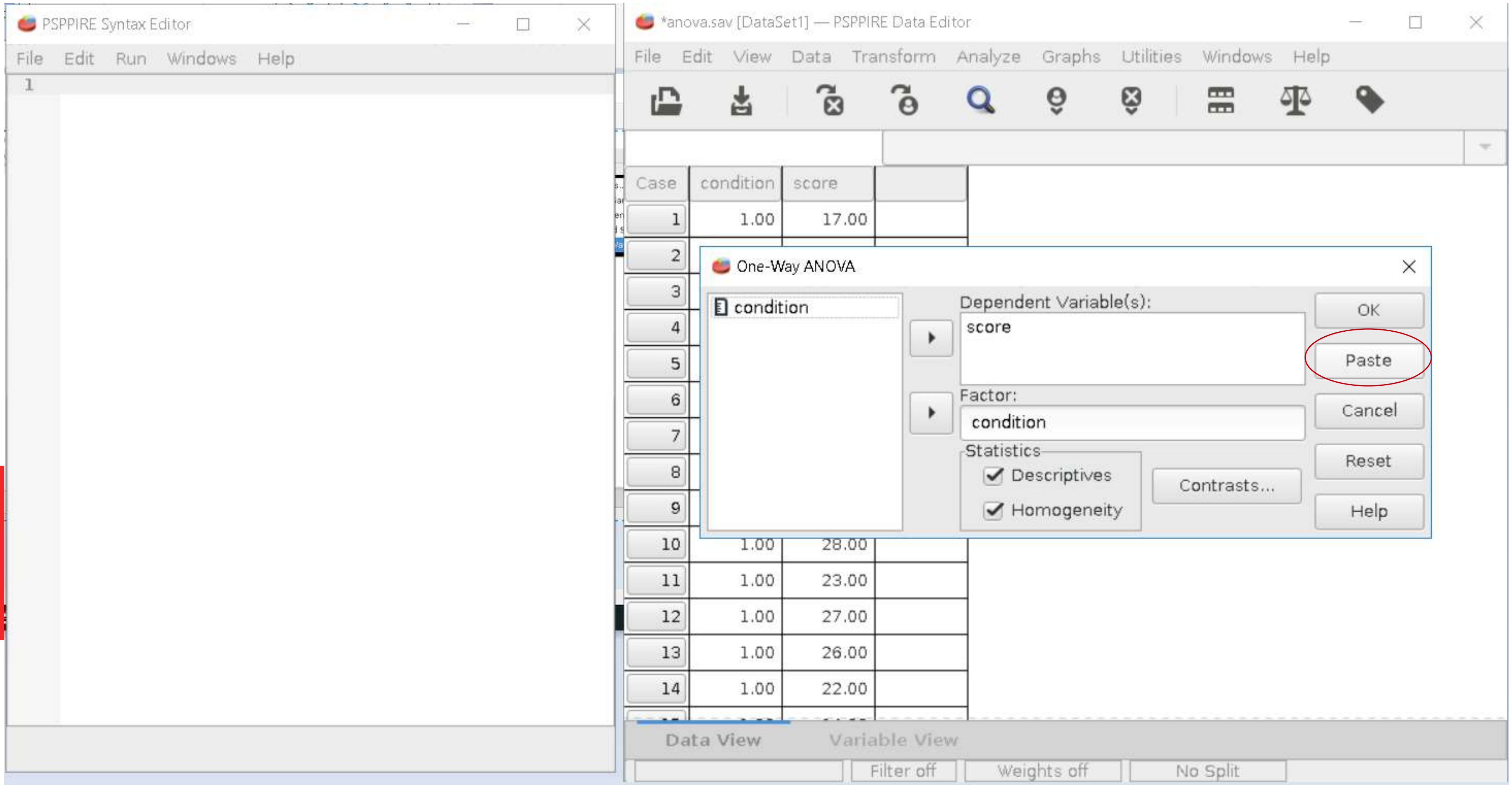
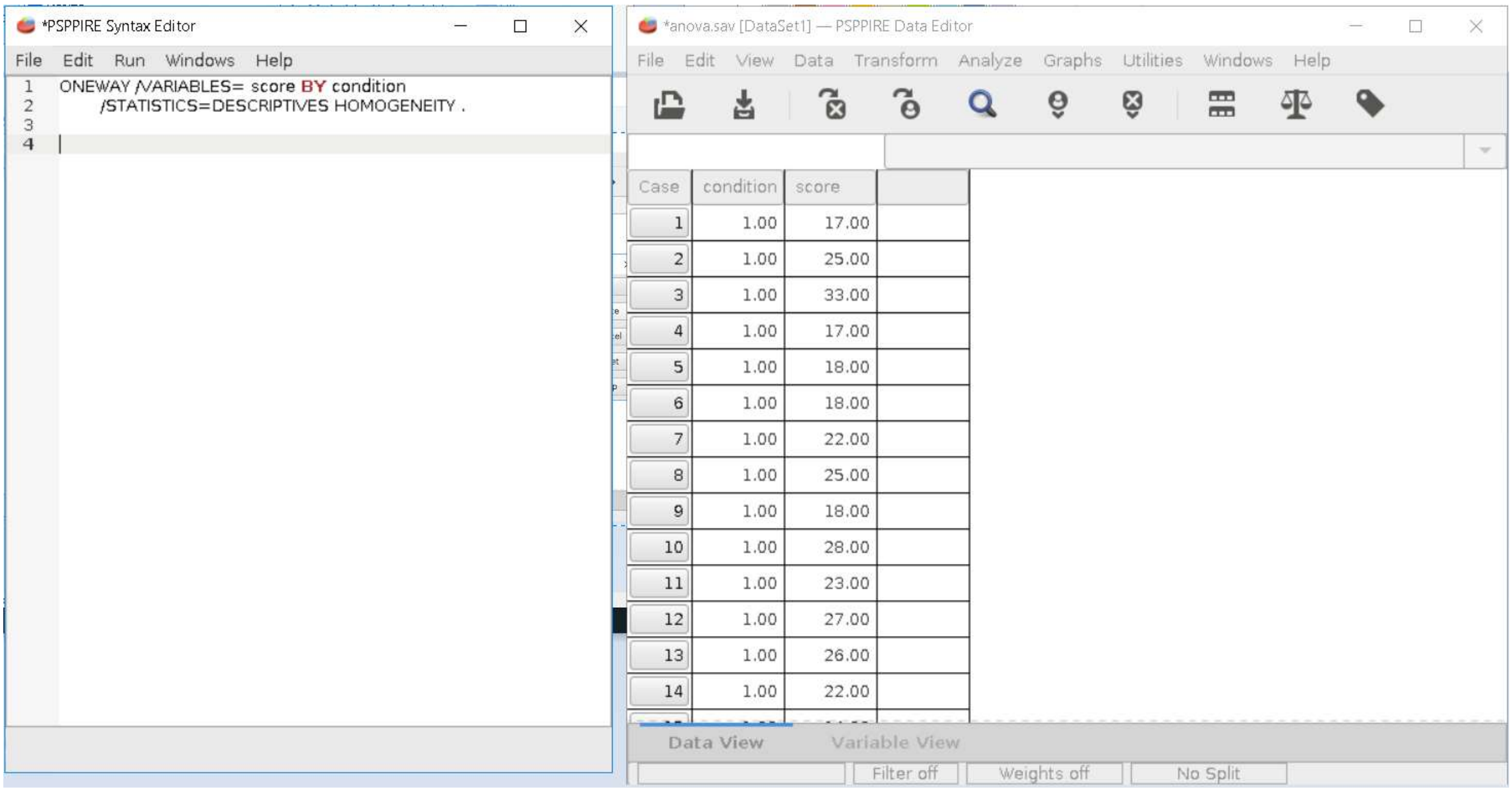
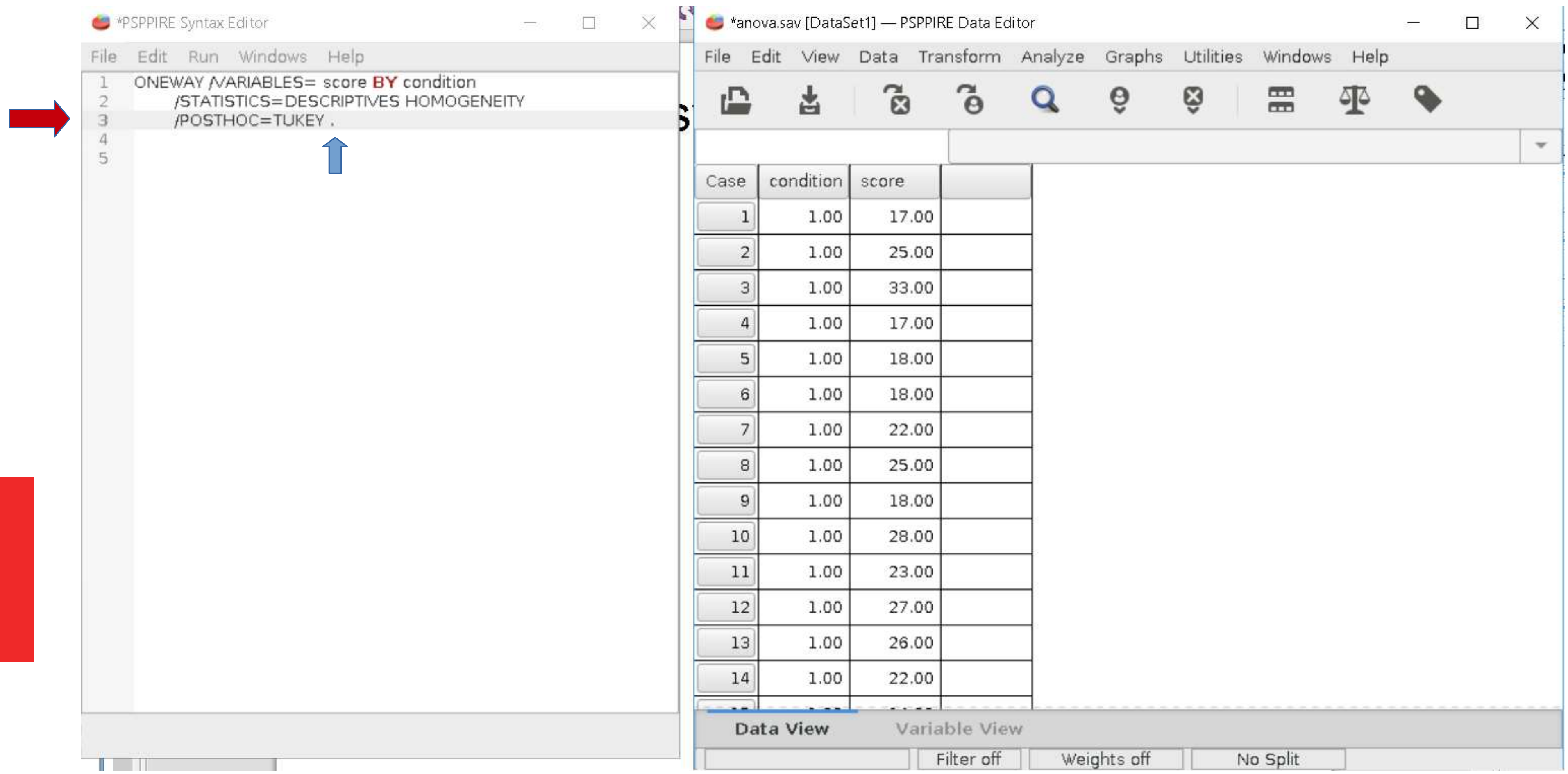


How to do posthoc test in PSPP



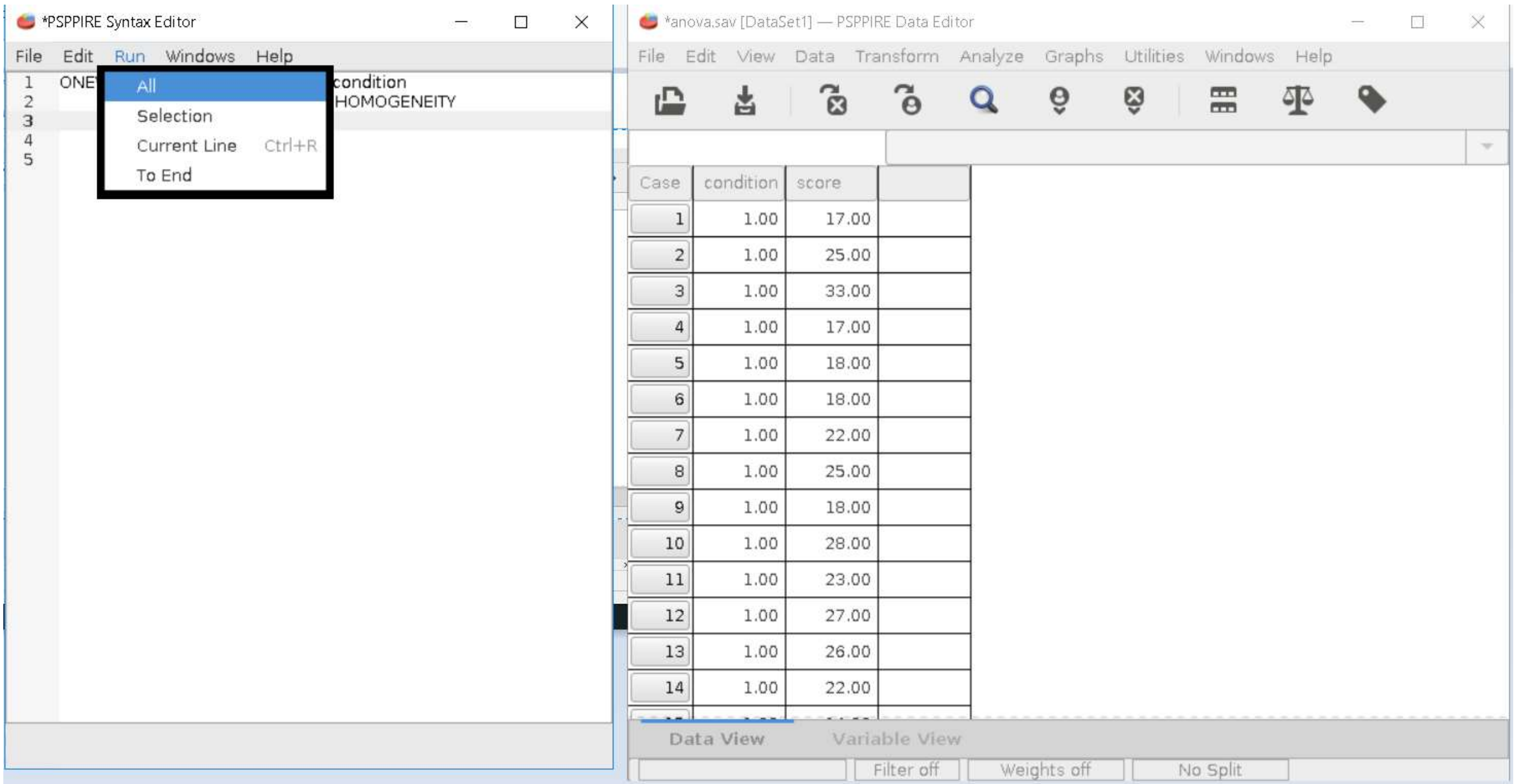
Now, edit the syntax to add posthoc test

Note: the full stop indicate the end of the script



Now, edit the syntax to add posthoc test

Note: the full stop indicate the end of the script



Result

ONEWAY

```
ONEWAY /VARIABLES= score BY condition
    /STATISTICS=DESCRIPTIVES HOMOGENEITY
    /POSTHOC=TUKEY .
```

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
score	1.00	20	22.25	4.59	1.03	20.10	24.40	14.00	33.00
	2.00	20	17.35	3.96	.89	15.49	19.21	7.00	26.00
	3.00	20	22.25	4.64	1.04	20.08	24.42	15.00	34.00
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Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
score	.44	2	57	.649

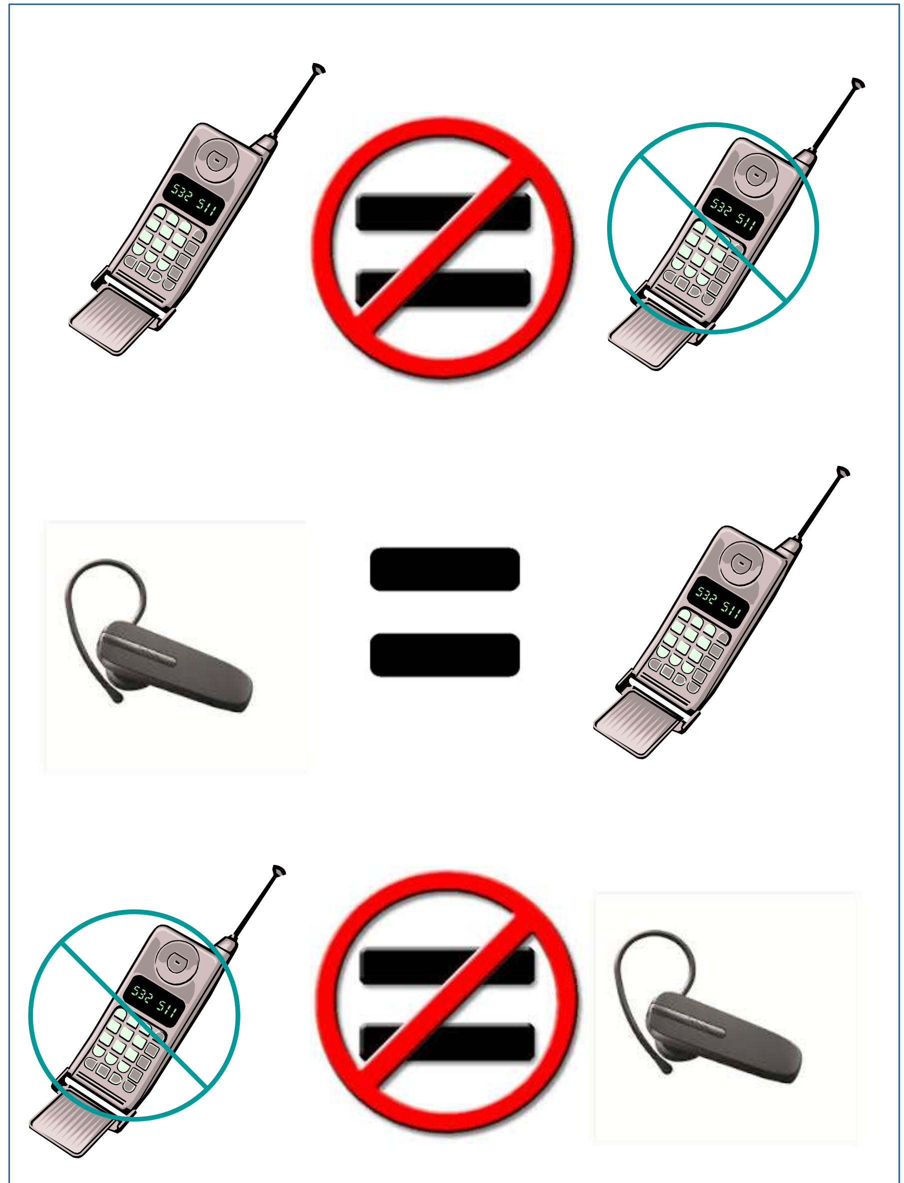
ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
score	Between Groups	320.13	2	160.07	8.23	.001
	Within Groups	1108.05	57	19.44		
	Total	1428.18	59			

Multiple Comparisons (score)

	(I) condition	(J) condition	Mean Difference (I - J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	1.00	2.00	4.90	1.39	.002	1.54	8.26
		3.00	.00	1.39	1.000	-3.36	3.36
	2.00	1.00	-4.90	1.39	.002	-8.26	-1.54
		3.00	-4.90	1.39	.002	-8.26	-1.54
	3.00	1.00	.00	1.39	1.000	-3.36	3.36
		2.00	4.90	1.39	.002	1.54	8.26

Effect between Condition 1 and Condition 2 reaches significance ($p<.05$)
Effect between Condition 1 and Condition 3 does not reach significance ($p>.05$)
Effect between Condition 2 and Condition 3 reaches significance ($p<.05$)



Effect between Condition 1 and Condition 2 reaches significance ($p<.05$)
Effect between Condition 1 and Condition 3 does not reach significance ($p>.05$)
Effect between Condition 2 and Condition 3 reaches significance ($p<.05$)