EDUR 8131
Chat 6

Notes 5a One-sample t-test
Notes 5b Two-independent Samples t-test

Notes 5a: One-sample t-test

1. One-sample t-test worked example

Is there any evidence that my heart rate has changed since taking blood pressure medication? Before medication my heart rate was 55.36 beats per minute after arising each morning. Below are 14 observations of my heart rate after taking the blood pressure medication. Set alpha (α) to .05 for hypothesis testing.

50	62
50	57
48	49
49	47
44	54
49	48
45	44

Formula for one-sample t-test vs. z-test

$Z_{\bar{x}} = \frac{\bar{X}-\mu}{\boldsymbol{\sigma}/\sqrt{n}}$ → to use, MUST have population SD

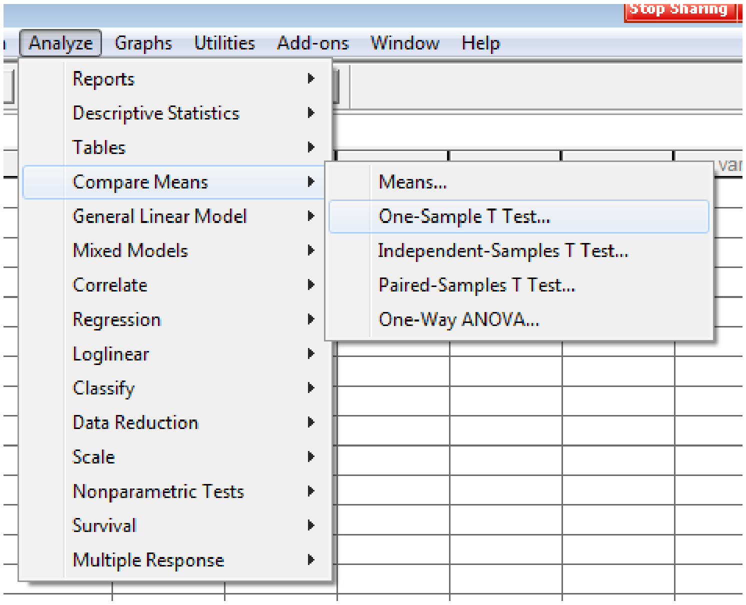
Vs.

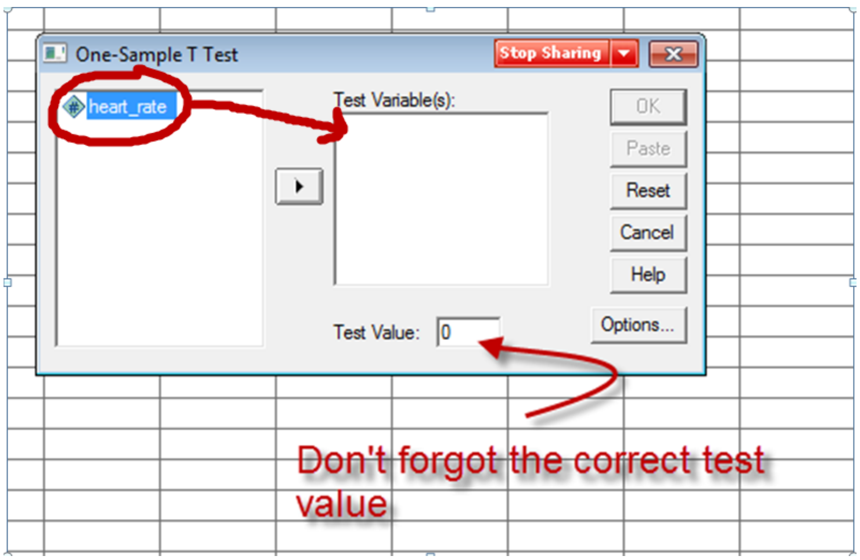
$t = \frac{\bar{X}-\mu}{\boldsymbol{s}/\sqrt{n}}$ → to use t, need only the sample SD

Note: Work in Excel to show calculations, then in SPSS

SPSS results for one-sample t-test

Commands (below)


Stop Sharing
Analyze
Graphs
Utilities
Add-ons
Window
Help
Reports
Descriptive Statistics
Tables
Compare Means
General Linear Model
Mixed Models
Correlate
Regression
Loglinear
Classify
Data Reduction
Scale
Nonparametric Tests
Survival
Multiple Response
Means...
One-Sample T Test...
Independent-Samples T Test...
Paired-Samples T Test...
One-Way ANOVA...


One-Sample T Test
Stop Sharing
heart_rate
Test Variable(s):
OK
Paste
Reset
Cancel
Help
Test Value:
0
Options...
Don't forgot the correct test value

SPSS Results

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
heart_rate	14	49.7143	4.99890	1.33601

One-Sample Test

	Test Value = 55.36					
					95% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
heart_rate	-4.226	13	.001	-5.64571	-8.5320	-2.7594

What do these results tell us?

Decision Rule with p and α: **If p ≤ α reject Ho, if p > α fail to reject Ho**

Decision Rule with p and α: **If .001 ≤ .05 reject Ho, ~~if .001 > .05 fail to reject Ho~~**
So reject Ho

Since p (= .001) is less than alpha = .05, one would reject Ho and conclude there is a difference in heart rates per minute between the comparison value of 55.36 beats per minute and the mean number of beats observed after taking the medication.

APA Styled Results

Note: Show location of APA Word document on course web site.

Table 1

Results of One-sample t-test and Descriptive Statistics for Heart Rate Per Minute

Outcome	M	SD	n	Comparison Value	95% CI for Mean Difference	t	df
Heart Rate	49.71	4.99	14	55.36	-8.53, -2.76	-4.23*	13

* p < .05.

Note:

* p < .05. ← this must be present to inform reader that hypothesis testing was performed and at what level of significance that test was performed (i.e., what was the alpha level, probability of Type 1 error, in this example it is .05)

Written Results –

Written results always contain two bits in information --

- Inference – did we reject Ho?
- Interpretation – what do the result mean in simple language?

There is a statistically significant mean difference in heart rate before and after taking blood pressure medication. Results show that the medication reduces the mean heart rate by about 5.5 beats per minute on average.

Use CI for Hypothesis testing

(a) Ho: $\bar{X} = \mu$ ----------------> Does μ lie within CI, if yes, fail to reject Ho

Vs.

(b) Ho: $\bar{X} - \mu = 0.00$ ------> Does 0.00 lie within CI, if yes, fail to reject Ho

Both can be used, but our focus will be on the second Ho: $\bar{X} - \mu = 0.00$, for presentation I will skip to section (b) below, but I include (a) for those interested.

(a) If Ho: $\bar{X} = \mu$

CI = $\bar{X} \pm (critical\ t)(standard\ error\ of\ mean)$

The formula above provides a confidence interval **about the sample mean**.

Example:

95% CI

Step 1: Calculate df = n-1

df = 14 -1 = 13

Step 2: Find Critical t-value given α (=.05) and df

Critical t = ± 2.16

Step 3: Calculate standard error of mean ${}^{s}/_{\sqrt{n}}$

S = 4.999
N = 14

SEM = ${}^{s}/_{\sqrt{n}}$ = ${}^{4.999}/_{\sqrt{14}}$ = 1.336

Step 4: Plug numbers into CI formula and find Upper and Lower Limits

CI = $\bar{X} \pm (critical\ t)(standard\ error\ of\ mean)$
(Recall that $\bar{X} = 49.71$)

CI = $49.71 \pm (2.16)(1.336)$

Upper Limit = $49.71 + (2.16)(1.336)$ = 52.59
Lower Limit = $49.71 - (2.16)(1.336)$ = 46.82

Recall that μ = 55.36
Interpretation

One may be X% confident that the interval LL to UL includes the population mean.

One may be 95% confident that the interval 46.82 to 52.59 includes the population mean from which this sample was drawn.

Hypothesis Testing

Ho: $\bar{X} = \mu$ ----------------> Does μ lie within CI, if yes, fail to reject Ho; if no, then reject Ho

Do we reject or fail to reject Ho?

Ho: μ = 55.36 (mean heart rate before taking medications)
95% CI = 46.82, 52.59

Yes, reject Ho (because 55.36 is not within the 95% CI), our sample has a heart rate that differs from the value of 55.36; the new heart rate is lower by about 5.6 beats per minute.

We believe that the population heart rate, after taking the BP medication, is somewhere between 46.82 and 52.59, and our single best estimate of heart rate is the sample mean at 49.71.

If reject, what does this tell us? If we fail to reject, what does this tell us?

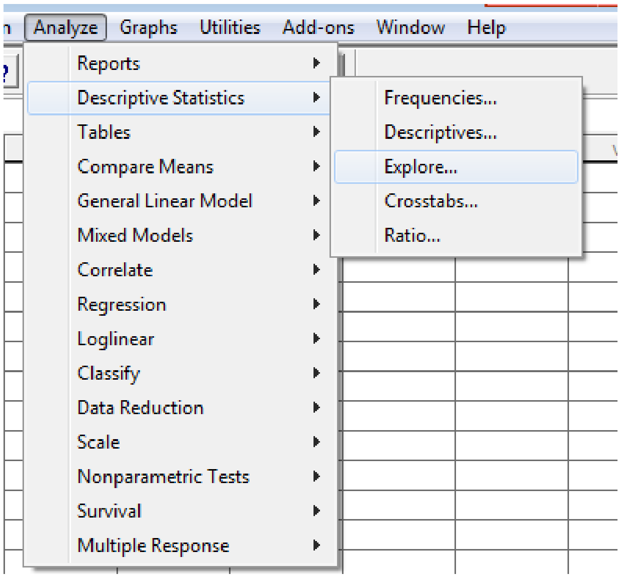
If reject Ho – our sample produces a mean heart rate that differs from the specified value of 55.36

If fail to reject Ho – our sample heart rates appear to be consistent with the specified value of 55.36

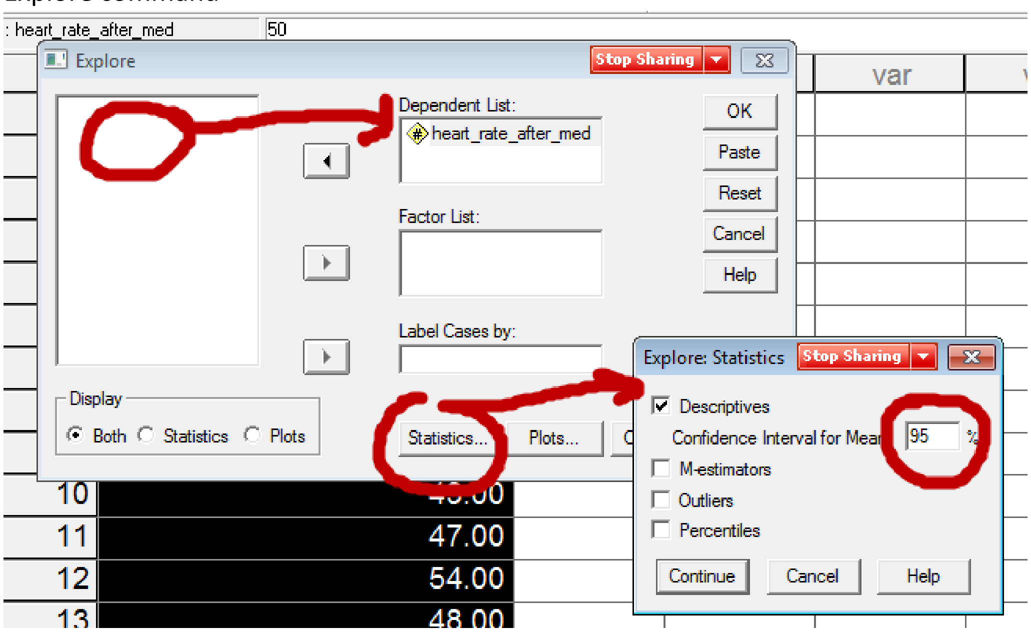
SPSS Results

Note: Illustrate how to obtain the above CI with SPSS – use Explore command:

Analyze -> Descriptive Statistics -> Explore (then click on Statistics and set CI to level desired)



Explore command



95%CI limits are 46.828 to 52.6006 (similar to that presented above <u>46.82, 52.59</u> – within rounding error, also, SPSS uses a more precise critical t-value than our table provides)

Descriptives

			Statistic	Std. Error
Heart_Rate	Mean		49.7143	1.33601
	95% Confidence Interval for Mean	Lower Bound	46.8280	
		Upper Bound	52.6006	
	5% Trimmed Mean		49.3492	
	Median		49.0000	
	Variance		24.989	
	Std. Deviation		4.99890	
	Minimum		44.00	
	Maximum		62.00	
	Range		18.00	
	Interquartile Range		4.50	
	Skewness		1.301	.597
	Kurtosis		1.771	1.154

(b) If Ho: $\boldsymbol{\bar{X} - \mu = 0.00}$

CI = $(\bar{X} - \mu) \pm (critical\ t)(standard\ error\ of\ mean)$

The formula above provides a confidence interval **about the mean difference**.

Example: 95% CI

Critical t = 2.16 (df = 13)

Repeat the same steps outlined above except use $(\bar{X} - \mu)$ rather than $\bar{X}$ in the CI formula:

From this → CI = $(\bar{X}) \pm (critical\ t)(standard\ error\ of\ mean)$

To this → CI = $(\bar{X} - \mu) \pm (critical\ t)(standard\ error\ of\ mean)$

Step 1: Calculate df = n-1

df = 14 -1 = 13

Step 2: Find Critical t-value given α (= .05) and df

Critical t = 2.16

Step 3: Calculate standard error of mean $^{s}/_{\sqrt{n}}$

SEM = $^{s}/_{\sqrt{n}}$ = $^{4.999}/_{\sqrt{14}}$ = 1.336

Step 4: Plug numbers into CI formula and find Upper and Lower Limits

CI = $(\bar{X} - \mu) \pm (critical\ t)(standard\ error\ of\ mean)$

Mean difference is 49.71 – 55.36 = -5.65

What are the CIs for $(\bar{X} - \mu)$?

CI = $(49.71 - 55.36) \pm (2.16)(1.336)$
CI = $(-5.646) \pm (2.16)(1.336)$

Upper Limit =$(-5.646) + (2.16)(1.336)$ = -2.764
Lower Limit =$(-5.646) - (2.16)(1.336)$ = -8.535

What is the interpretation for the 95% CI?
Recall Ho: $\bar{X} - \mu = 0.00$

We can be 95% confidence that the real difference in heart rates before and after taking BP medication lies somewhere between -8.5 to -2.7 beats per minute.

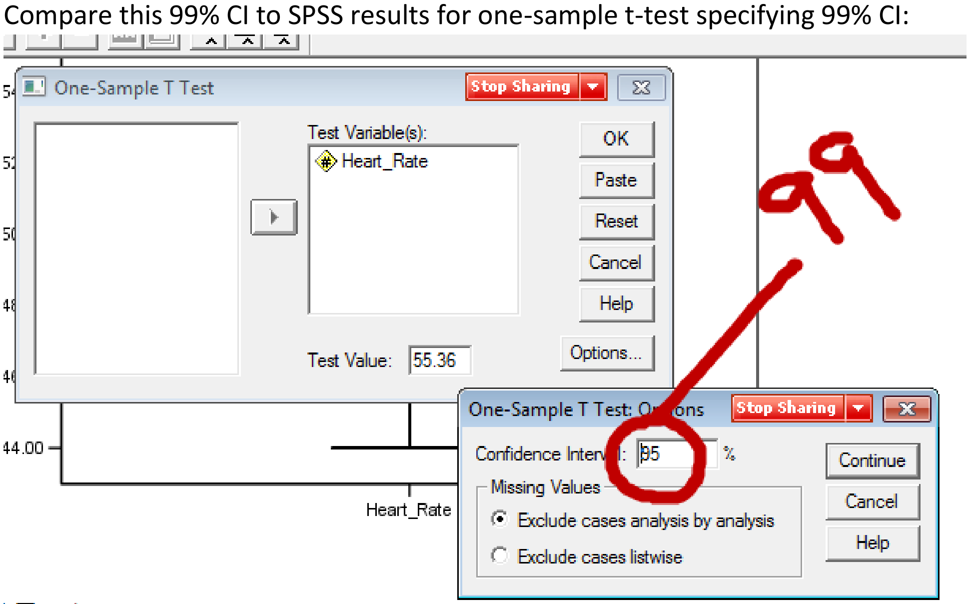
99% CI
Same as above but use different critical value
CI = $(\bar{X} - \mu) \pm (\textit{critical t})(\textit{standard error of mean})$
What is the critical value for α = .01 and df = 13?
Critical t = ±3.01

Recall the mean difference is -5.646 and the standard error of the mean (SEM) is 1.336.
What is the 99% CI for $(\bar{X} - \mu)$?

CI = $(49.71 - 55.36) \pm (3.01)(1.336)$
CI = $(-5.646) \pm (3.01)(1.336)$

Upper Limit =$(-5.646) + (3.01)(1.336)$ = -1.628
Lower Limit =$(-5.646) - (3.01)(1.336)$ = -9.67

Compare this 99% CI to SPSS results for one-sample t-test specifying 99% CI:



One-Sample Test

	Test Value = 55.36					
					99% Confidence Interval of the Difference	
	t	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
pulse	-4.226	13	.001	-5.64571	-9.6702	-1.6213

Interpretation:

One may be 99% confident that the true population <u>mean difference</u> between sample mean of 49.71 and prior-medication heart rate of 55.36 is between -9.67 and -1.62.

For hypothesis testing purposes, if 0 does <u>NOT</u> lie within this CI, then reject Ho; but if 0 lies within the CI then fail to reject Ho

Ho: $\bar{X} - \mu = 0.00$

So, if 0 is within the CI, that means 0 is one of the possible values for the true mean difference, but if 0 is not within the CI that tells us that 0 is not likely to be one of the values representing the true mean difference.

Notes 5b: Two Independent Samples t-test
2. Two-samples t-test worked example.

Is there a change in mean heart rate per minute before and after taking blood pressure medication for a single individual? Below are data for this individual.

Heart Rate After		Heart Rate Before	
50	62	57	59
50	57	58	57
48	49	56	53
49	47	55	63
44	54	55	54
49	48	53	51
45	44	53	51

First, why is this not a correlated samples t-test since it appears we have before and after data?

Data are not linked – scores are not aligned or correlated specifically with other scores. These scores are taken from one individual and do not represent a matched set from multiple participants or even a matched set for one participant.

Compare these data to one in which correlated scores are present:

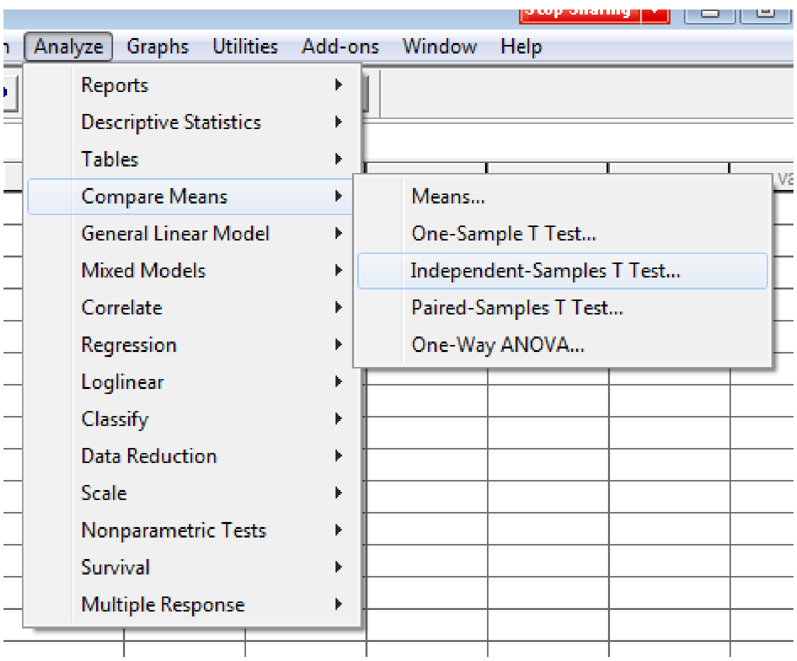
Does heart rate change after blood medication for these individuals?

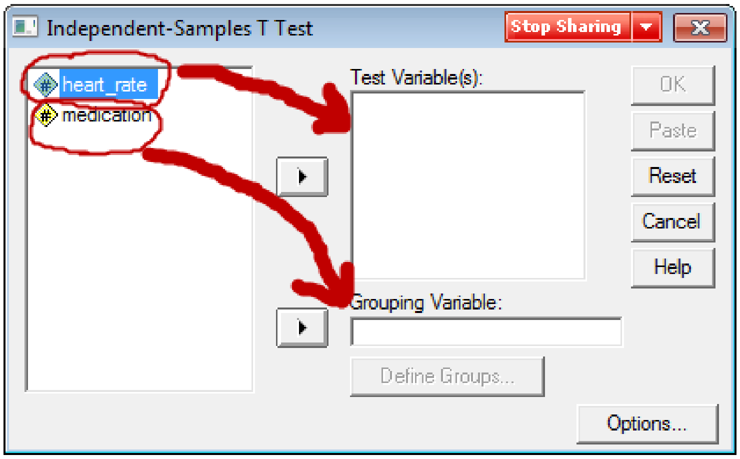
	After		Before
John	55	<->	51
Bill	59	<->	56
Sue	67	<->	53
Pam	48	<->	47
Jon	41	<->	42
Paul	71	<->	68
Fred	55	<->	51

SPSS Data and Results

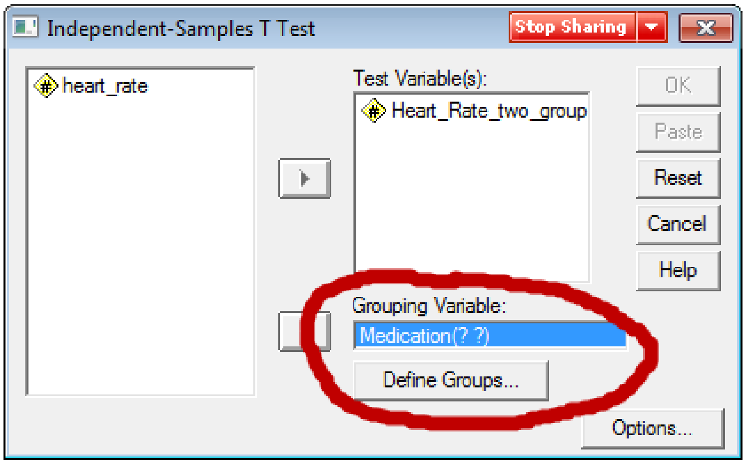
http://www.bwgriffin.com/gsu/courses/edur8131/data/heartrate.sav

Commands





Note, Medication 1 = after medications, 0 = before medications



Group Statistics

	medication	N	Mean	Std. Deviation	Std. Error Mean
heart_rate	1.00	14	49.7143	4.99890	1.33601
	.00	14	55.3571	3.29585	.88085

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
heart_rate	Equal variances assumed	.784	.384	-3.526	26	.002	-5.64286	1.60026	-8.93224	-2.35348
	Equal variances not assumed			-3.526	22.506	.002	-5.64286	1.60026	-8.95727	-2.32844

Equal vs. Unequal Variances

Use Levene's test to determine which row to use for t-test results.

- Levene's Test assesses this null, Ho: variance group 1 = variance group 2

- If fail to reject, we assume the two groups have similar variances; if reject, then assume group variances are not equal.
- If variances are not equal, that affects how p-values and CI are calculated for the t-test, so an adjustment is made.
- If sig. (p-value) for Levene's is less than .10 or .05 (you pick alpha here), then variances appear to be different so use "Equal variances not assume" row,
- but if the Levene's p-value (sig. value) is greater than .10 or .05 then use "Equal Variances Assumed" row.

Null Hypothesis

What is the written null hypothesis?

Recall that the IV is blood pressure medication use (before and after using medication) and the DV is heart rate.

There is no difference in mean heart rate before and after taking blood pressure medication.

What is the symbolic Ho?

Ho: $\mu_{before} = \mu_{after}$

or

Ho: $\mu_{before} - \mu_{after} = 0.00$ (most commonly tested by statistical software)

Reject or Fail to Reject Ho?

What information from SPSS output is used to determine whether Ho is rejected?
Also, would we reject or fail to reject Ho?

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
heart_rate	Equal variances assumed	.784	.384	-3.526	26	.002	-5.64286	1.60026	-8.93224	-2.35348
	Equal variances not assumed			-3.526	22.506	.002	-5.64286	1.60026	-8.95727	-2.32844

p-value = t-test Sig(2-tailed) = **.002**

Note - this is not the p-value for the Levene's test; Levene's sig is the p-value for the Levene's only test. Recall that Levene's tests whether variances of two groups are equal

confidence interval, if 0 is within the CI, fail to reject; if 0 is not within CI, reject Ho

APA Styled Results

Note: Show APA Word document on web page.

Table 5
Results of t-test and Descriptive Statistics for Heart Rate per Minute by Medication Usage

	Medication Usage						95% CI for Mean Difference		
	After Usage			Before Usage					
	M	SD	n	M	SD	n		t	df
Heart Rate	49.71	5.00	14	55.36	3.30	14	-8.93, -2.35	-3.53*	26

* p < .05.

Recall there must be two components to the written results, inference and interpretation.

What might be the written results for the results reported above?

(Recall that Ho states no differences in heart rate before and after taking blood pressure medication.)

First, what would be the **inference** statement?

> There is a statistically significant mean difference in heart rate per minute before and after taking blood pressure medication.

Next, what would be the **interpretation** offered for readers?

> There is a statistically significant mean difference in heart rate per minute before and after taking blood pressure medication. Results show that the blood pressure medication reduced heart rate by about 5.5 beats per minute.

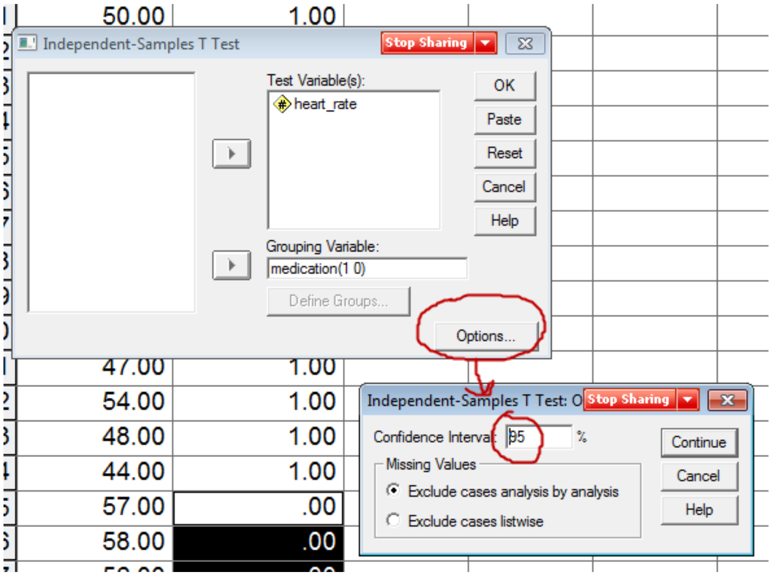
Use CI for Hypothesis testing

Ho: $\mu_1 - \mu_2 = 0.00$ --------> Does 0.00 lie within CI, if yes, fail to reject Ho

CI = $(\bar{X}_1 - \bar{X}_2) \pm (critical\ t)(standard\ error\ of\ mean\ difference)$

Example:

> See SPSS output, also, show how to obtain 99% CI in SPSS



99% CI Results

99% Confidence Interval of the Difference	
Lower	Upper
-10.08952	-1.19619
-10.14414	-1.14158

Is 0 within the 99% CI? Does this mean we can reject or fail to reject Ho?

The value of 0 is not within the 99% CI, therefore we can reject Ho and conclude that the population mean **difference** in heart rate must be different from 0, therefore the two means, heart rate before and after, appear to be different.

Interpretation of either 95% or 99% CI:

One may be X% confident that the interval LL to UL includes the population mean difference of DV between group 1 and group 2.

One may be **95% confident** that the interval -8.93 to -2.35 includes the population mean difference in heart rate per minute between the two sets of scores (before and after taking blood pressure medication).

Or

One may be **99% confident** that the interval -10.09 to -1.20 includes the population mean difference in heart rate per minute between the two sets of scores (before and after taking blood pressure medication).