

How to use the t -Test

1 The Student's t -test

The Student's t -test is a robust, well-documented test that compares the means of two sets of data. The end result of the test is a single value of ' t ', which is a measure of the extent to which the two sets of data overlap. Remember, where the data extensively overlap, the independent variable had little effect on the participants. This is the case if t is small. If t is large, the two sets of data only partially overlap which means that the independent variable had a (mathematically) noticeable effect on the participants. Put another way:

- If t is small, the null hypothesis (of no difference between the participants' performance in the two conditions) is accepted.
- If t is large, the null hypothesis is rejected.

Specific values of t are converted into a probability, so that the rather vague phrases about extensive and partial overlap used above become actual numbers, albeit still only probabilities. The computation of t is usually left to computer software packages; one such multimedia package is the t -test calculator available in The OpenScience Lab.

Requirements for doing a t -test

One value that must be known before you can apply a statistical test is the number of degrees of freedom. Degrees of freedom is an important, if elusive, mathematical term. Usually its numerical value is one less than the number of participants in each condition and this is the method of calculation you will use here.

Degrees of freedom are a measure of how many items in a set of data need to be specified before all the items in that set are known. For example if, in a two-participant trial, the mean score is 25, and you know that Participant 2 scored 18, then Participant 1 must have scored 32 because no other value would give a mean for the two participants of 25. This trial therefore has 1 degree of freedom ($2 - 1 = 1$). In the case of an experiment that has two groups and the participants in each group are different, the degrees of freedom are calculated for each group as reported above, and then added together. As an example, consider an experiment which has seven participants in Group A and eight participants in Group B. In this case the degrees of freedom would be $(7-1) + (8-1) = 13$.

When running the t -test calculator software the results that need to be reported are the degrees of freedom, the value of t , and the p value calculated by the test. Here is a fictitious example. Let's imagine an experiment had 24 participants in each group. The degrees of freedom are therefore $(24-1) + (24-1) = 46$. The researcher calculates a t value from the data and the value returned by the calculator is 2.36. They also deduce a p value of 0.003. The researcher should then report these results in either of the following formats:

$$t(46) = 2.36, p = 0.003$$

or

$$t(46) = 2.36, p < 0.05$$

The number in brackets is the degrees of freedom in the investigation, the value after the first equal sign is the value of t and the number after the second equal sign is the value of p . In the next section we discuss specifically how to use the Student's t -test calculator provided in The OpenScience Laboratory in order to obtain such values for your investigations. Note that you may need to run several different t -tests in an investigation; one for each measure that you have chosen to record.

1.1 Using the t -test calculator

The t -test calculator that you will need to use can be accessed from the following link:

- [Click here to access the t-test calculator software](#)

It can also be accessed from The OpenScience Laboratory www.opensciencelab.ac.uk. Below are some screenshots taken from the t -test calculator.

The opening screen tells you that it is possible to use the t -test calculator:

- If you want to test for differences in population means
- Provided that your measurements are at the interval level
- Provided that your measurements can be assumed to come from normally distributed populations.

You should first check if your data meets these requirements before proceeding to entering your experimental data by clicking on the 'Data' tab. Figure 4 shows you how to do this.

When to use Data Mean and variance t test Significance

	Sample A (x_A)	x_A^2	Sample B (x_B)	x_B^2
1	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
2	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
3	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
4	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
5	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
6	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
7	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
8	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
9	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
10	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Enter your data in the columns for sample A and sample B. The squared value of each data point will be calculated for you.

$\Sigma x_A =$ $\Sigma x_A^2 =$ $\Sigma x_B =$ $\Sigma x_B^2 =$

$n_A =$ $n_B =$

Enter individual scores from each group into the two columns

Figure 4 Entering data in to the *t*-test calculator

Once you have entered your data you need to click on the ‘t test’ tab and note your degrees of freedom. Recall that these are calculated as one less than the number of participants in each condition. So if you had eight participants in one condition and seven in another your degrees of freedom would be 13 (as shown on the screen shot example in Figure 5).

When to use	Data	Mean and variance	t test	Significance
Note the sample size	$n_A =$	8	$n_B =$	7
Note the sample variance	$s_A^2 =$	0.802143	$s_B^2 =$	0.41619
Note the mean	$m_A =$	3.575	$m_B =$	3.14286
Calculate the number of degrees of freedom for the common population variance: $=(n_A-1)+(n_B-1)$		13		
Calculate the estimated common population variance from the equation $s_c^2 = \frac{(n_A-1)s_A^2 + (n_B-1)s_B^2}{(n_A-1) + (n_B-1)}$	$s_c^2 =$	0.624011		
Calculate the estimated standard error of the difference in sample means from the equation: $SE_D = \sqrt{(s_c^2/n_A + s_c^2/n_B)}$	$SE_D =$	0.408835		
Calculate the t from the equation: $t = (m_A - m_B) / SE_D$	$t =$	1.057011		
Note the number of degrees of freedom: $=(n_A-1)+(n_B-1)$	d.f. =	13		

Degrees of freedom can be read from here

Figure 5 Recording your degrees of freedom

Next you need to decide what your critical value of p will be, and this information is found on the ‘Significance’ tab. As you can see in Figure 6, a value of 0.05 has been suggested, but you can amend this if you wish. Once you have decided on this value you then need to calculate your critical value of t using Table 2, and enter this value into the t -test calculator as shown in Figure 6.

Experimental hypotheses can take two forms: they can be directional (also called ‘one-tailed’), predicting an effect in a particular direction, or they can be bi-directional (or ‘two-tailed’), simply predicting that there will be a difference between the experimental and the control condition, but not specifying what the effect will be.

When to use	Data	Mean and variance	t test	Significance
Note the absolute value of t	t =	1.057011		
Note the degrees of freedom	d.f. =	13		
Probability of obtaining t by chance	$P_0 =$	0.31		
Enter the desired critical significance level		0.05	Type a value	
Critical value of t at that significance level	$t_{crit} =$	0	Type a value	
Null hypothesis rejected?	:	-----		
Calculate confidence interval	$t_{crit} \times SE_D =$	0	±	
Difference in sample means	$m_A - m_B =$	0.432143		
Lower limit of c.i. of difference in means		0.432143		
Upper limit of c.i. of difference in means		0.432143		

Enter your chosen critical significance level. 0.05 is the value suggested here.

Then work out your critical value of t from Table 2 in the text and enter it here.

Figure 6 Entering your critical values of p and t

Table 2 Critical Values of t

Probability p	Directional	0.05	0.025	0.005	0.0005
	Bi-directional		0.05	0.01	0.001
Degree of freedom					
4		2.13	2.78	4.60	8.61
5		2.02	2.57	4.03	6.87
6		1.94	2.45	3.71	5.96
7		1.89	2.36	3.50	5.41
8		1.86	2.31	3.36	5.04
9		1.83	2.26	3.25	4.78
10		1.81	2.23	3.17	4.59
11		1.80	2.20	3.11	4.44
12		1.78	2.18	3.05	4.32
13		1.77	2.16	3.01	4.22
14		1.76	2.14	2.98	4.1
15		1.75	2.13	2.95	4.07
16		1.75	2.12	2.92	4.01
17		1.74	2.11	2.90	3.97
18		1.73	2.10	2.88	3.92
19		1.73	2.09	2.86	3.88
20		1.72	2.09	2.85	3.85
21		1.72	2.08	2.83	3.82

Probability p	Directional	0.05	0.025	0.005	0.0005
22		1.72	2.07	2.82	3.79
23		1.71	2.07	2.81	3.77
24		1.71	2.06	2.80	3.75
25		1.71	2.06	2.79	3.73
26		1.71	2.06	2.78	3.71
27		1.70	2.05	2.77	3.69
28		1.70	2.05	2.76	3.67
29		1.70	2.05	2.76	3.66
30		1.70	2.04	2.75	3.65
35		1.69	2.03	2.72	3.59
40		1.68	2.02	2.70	3.55
45		1.68	2.01	2.69	3.52
50		1.68	2.01	2.68	3.50
55		1.67	2.00	2.67	3.48
60		1.67	2.00	2.66	3.46
65		1.67	2.00	2.65	3.45
70		1.67	1.99	2.65	3.43
75		1.67	1.99	2.64	3.42
80		1.66	1.99	2.64	3.42
85		1.66	1.99	2.63	3.41
90		1.66	1.99	2.63	3.40
95		1.66	1.99	2.63	3.40
100		1.66	1.98	2.63	3.39

Once you have entered the relevant values you can click on the 'Enter' button on your computer and the t -test will run its calculation and show you whether the null hypothesis can be rejected (Figure 7) on the grounds of statistical reliability.

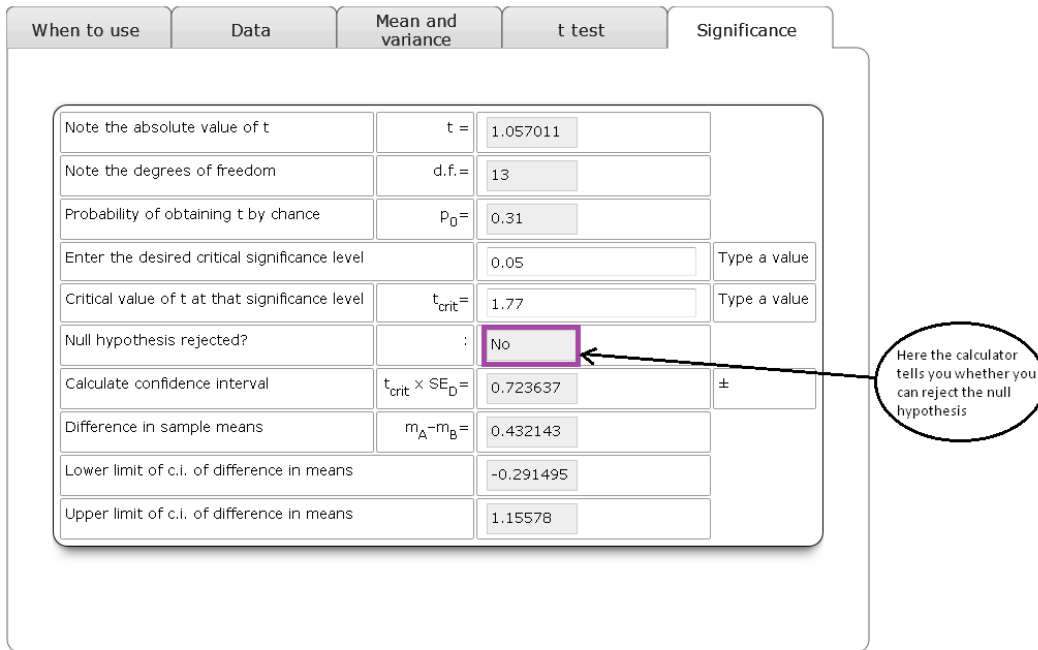


Figure 7 Deciding if the null hypothesis can be rejected

Finally you should go to the ‘Mean and variance’ tab and note down the calculated values of the means and variance from the t-test calculator, and use the variance to work out what your standard deviations are (Figure 8).

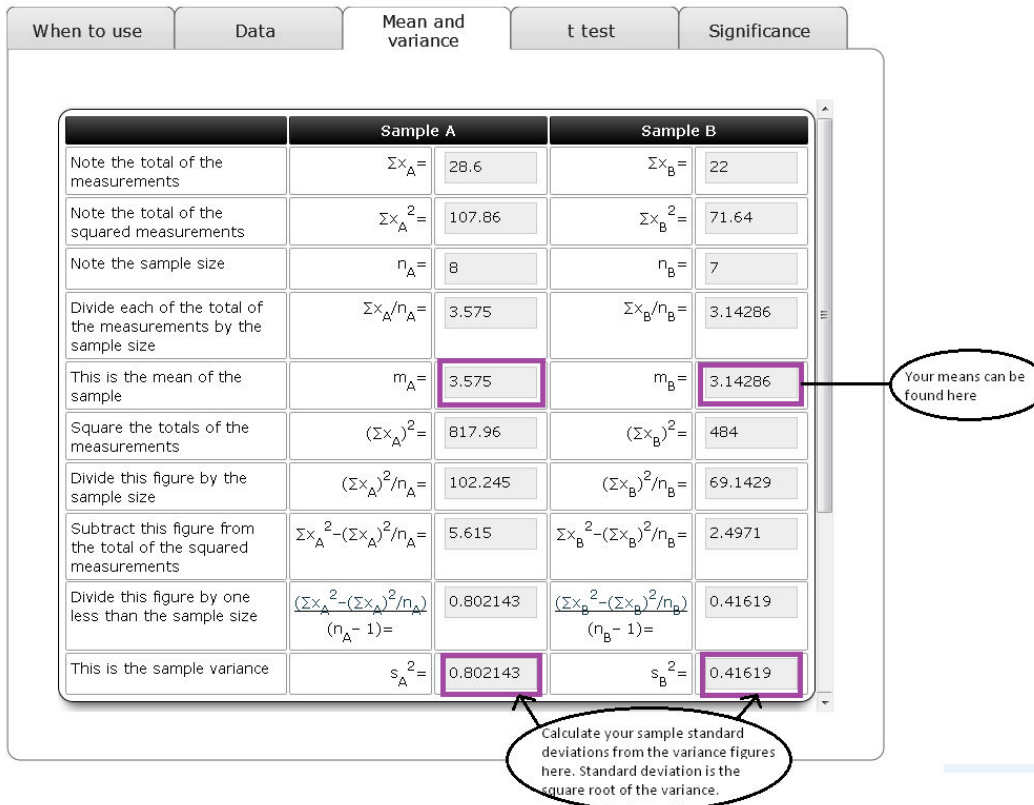


Figure 8 Working out your group means and standard deviations

You must piece all of this information together for each measure in your investigations in order to reach a suitable conclusion on your original experimental question. Can the null hypothesis be accepted or rejected?