t(ea) for Two

Tests Between the Means of Different Groups

Difficulty Scale 😊😊😊 (not too hard—this is the first one of this kind, but you know more than enough to master it)

How much Excel? 📈📊📊 (lots)

What you’ll learn about in this chapter

• When the \( t \)-test for independent means is appropriate to use
• How to compute the observed \( t \) value
• How to use the T.TEST function
• How to use the \( t \)-Test Analysis ToolPak tool for computing the \( t \) value
• How to interpret the \( t \) value and understand what it means

INTRODUCTION TO THE \( t \)-TEST FOR INDEPENDENT SAMPLES

Even though eating disorders are recognized for their seriousness, little research has been done that compares the prevalence and intensity of symptoms across different cultures. John P. Sjostedt, John F. Schumaker, and S. S. Nathawat undertook this comparison with groups of 297 Australian and 249 Indian university students.
Each student was tested on the Eating Attitudes Test and the Goldfarb Fear of Fat Scale. The groups’ scores were compared with one another. On a comparison of means between the Indian and the Australian participants, Indian students scored higher on both of the tests. The results for the Eating Attitudes Test were $t_{(524)} = -4.19$, $p < .0001$, and the results for the Goldfarb Fear of Fat Scale were $t_{(544)} = -7.64$, $p < .0001$.

Now just what does all this mean? Read on.

Why was the $t$-test for independent means used? Sjostedt and his colleagues were interested in finding out whether there was a difference in the average scores of one (or more) variable(s) between the two groups, which were independent of one another. By independent, we mean that the two groups were not related in any way. Each participant in the study was tested only once. The researchers applied a $t$-test for independent means and arrived at the conclusion that for each of the outcome variables, the differences between the two groups were significant at or beyond the .0001 level. Such a small Type I error means that there is very little chance that the difference in scores between the two groups is due to something other than group membership, in this case representing nationality, culture, or ethnicity.


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**The Path to Wisdom and Knowledge**

To use Figure 11.1, the flowchart first introduced in Chapter 9, to select the appropriate test statistic, follow the highlighted sequence of steps. They take you to the $t$-test for independent means.

1. The differences between the groups of Australian and Indian students are being explored.
2. Participants are being tested only once.
3. There are two groups.
4. The appropriate test statistic is $t$-test for independent means.
Are you examining differences between one sample and a population?

I'm examining relationships between variables.

How many variables are you dealing with?

Two variables
- t-test for the significance of the correlation coefficient

More than two variables
- Regression, factor analysis, or canonical analysis

Are the same participants being tested more than once?

Yes
- t-test for dependent samples

No
- More than two groups
  - Related measures analysis of variance

Are you examining relationships between variables or examining the difference between groups on one or more variables?

I'm examining differences between groups on one or more variables.

Are the same participants being tested more than once?

Yes
- t-test for independent samples

No
- More than two groups
  - How many factors are you dealing with?
    - One
      - Simple analysis of variance
    - More than one
      - Factorial analysis of variance
Almost every statistical test has certain assumptions that underlie the use of the test. For example, the *t*-test has a major assumption that the amount of variability in each of the two groups is equal. This is the homogeneity of variance assumption. Although this assumption can be safely violated if the sample size is big enough, small samples and a violation of this assumption can lead to ambiguous results and conclusions. Although such assumptions are rarely violated, it is worth knowing that they do exist. Don’t knock yourself out worrying about these assumptions because they are beyond the scope of this book.

### COMPUTING THE TEST STATISTIC

The formula for computing the *t* value for the *t*-test for independent means is shown in Formula 11.1. The difference between the means makes up the numerator, and the amount of variation within and between each of the two groups makes up the denominator.

\[
t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2} \left[ \frac{n_1 + n_2}{n_1 n_2} \right]}}
\]  

(11.1)

where

- $\bar{X}_1$ is the mean for Group 1,
- $\bar{X}_2$ is the mean for Group 2,
- $n_1$ is the number of participants in Group 1,
- $n_2$ is the number of participants in Group 2,
- $s_1^2$ is the variance for Group 1, and
- $s_2^2$ is the variance for Group 2.

Nothing new here at all. It’s just a matter of plugging in the correct values.

### Here’s an Example

Here are some data reflecting the number of words remembered following a program designed to help Alzheimer’s patients remember
the order of daily tasks. Group 1 was taught using visuals, and Group 2 was taught using visuals and intense verbal rehearsal. We’ll use the data to compute the test statistic step-by-step.

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Here are the famous eight steps in the computation of the $t$-test statistic.

1. **State the null and research hypotheses.** As represented by Formula 11.2, the null hypothesis states that there is no difference between the means for Group 1 and Group 2. For our purposes, the research hypothesis, shown in Formula 11.3, states that there is a difference between the means of the two groups. The research hypothesis is a two-tailed, nondirectional research hypothesis because it posits a difference, but in no particular direction.

   The null hypothesis is as follows:

   $$H_0 : \mu_1 = \mu_2 \quad (11.2)$$

   And the research hypothesis is this:

   $$H_1 : \bar{X}_1 \neq \bar{X}_2 \quad (11.3)$$

2. **Set the level of risk (or the level of significance or Type I error) associated with the null hypothesis.** The level of risk or Type I error or level of significance (any other names?) is .05. This number is completely up to the researcher.

3. **Select the appropriate test statistic.** Using the flowchart shown in Figure 11.1, we determined that the appropriate test is a
Part IV ♦ Significantly Different

t-test for independent means. It is not a t-test for dependent means (a common mistake beginning students make) because the groups are independent of one another.

4. **Compute the test statistic value (called the obtained value).** Now’s your chance to plug in values and do some computation. The formula for the t value was shown in Formula 11.1. When the values in our example are plugged in, we get the equation shown in Formula 11.4. (We already computed the mean and standard deviation.)

\[
t = \frac{5.43 - 5.53}{\sqrt{\frac{30 - 1 \times 3.42^2 + (30 - 1) \times 2.06^2}{30 + 30 - 2}}}
\]

(11.4)

With the numbers plugged in, Formula 11.5 shows how we get the final value of –.1371. The value is negative because a larger value (the mean of Group 2, which is 5.53) is being subtracted from a smaller number (the mean of Group 1, which is 5.43).

Remember, though, that because the test is nondirectional and any difference is hypothesized, the sign of the difference is meaningless. In other words, you can ignore it!

\[
t = \frac{-0.1}{\sqrt{\frac{339.20 + 132.06}{58}}}
\]

(11.5)

When a nondirectional test is discussed, you may find that the t value is represented as an absolute value looking like this, |t|, which ignores the sign of the value altogether. Your teacher may even express the t value as such to emphasize that the sign is relevant for a one-directional test but surely not for a nondirectional one (and don’t call me Shirley).

5. **Determine the value needed for rejection of the null hypothesis using the appropriate table of critical values for the particular statistic.** Here’s where we go to Table B.2 in Appendix B, which lists the critical values for the t test. We can use this distribution to see if two independent means differ from one another by comparing what we would expect by chance (the tabled or critical value) to what we observe (the obtained value).
Our first task is to determine the degrees of freedom \((df)\), which approximates the sample size. For this particular test statistic, the degrees of freedom is \(n_1 - 1 + n_2 - 1\), or \(n_1 + n_2 - 2\). So for each group, add the size of the two samples and subtract 2. In this example, \(30 + 30 - 2 = 58\). This is the degrees of freedom for this test statistic, not necessarily for any other.

The idea of degrees of freedom means pretty much the same thing no matter what statistical test you use. But the way that the degrees of freedom is computed for specific tests can differ from teacher to teacher and from book to book. We tell you that the correct degrees of freedom for the above test is computed as \(n_1 - 1 + n_2 - 1\). However, some teachers believe that you use the smaller of the two \(n\)'s (a more conservative alternative you may want to consider).

Using this number (58), the level of risk you are willing to take (earlier defined as .05), and a two-tailed test (because there is no direction to the research hypothesis), you can use the \(t\)-test table to look up the critical value. At the .05 level, with 58 degrees of freedom for a two-tailed test, the value needed for rejection of the null hypothesis is \ldots oops! There's no 58 degrees of freedom in the table! What do you do? Well, if you select the value that corresponds to 55, you're being conservative in that you are using a value for a sample smaller than what you have (and the critical \(t\) value will be larger).

If you go for 60 degrees of freedom (the closest to your value of 58), you will be closer to the size of the population but a bit liberal in that 60 is larger than 58. Although statisticians have different opinions about what to do in this situation, let's go with the value that's closest to the actual sample size (which is 60). So, the value needed to reject the null hypothesis with 58 degrees of freedom at the .05 level of significance is 2.001.

6. **Compare the obtained value and the critical value.** The obtained value is \(-0.14\), and the critical value for rejection of the null hypothesis that Group 1 and Group 2 performed differently is 2.001. The critical value of 2.001 represents the value at which chance is the most attractive explanation for any of the observed differences between the two groups, given 30 participants in each group and the willingness to take a .05 level of risk.
7 and 8. Decision time!

If the obtained value is more extreme than the critical value (remember Figure 9.2?), the null hypothesis cannot be accepted. If the obtained value does not exceed the critical value, the null hypothesis is the most attractive explanation.

In this case, the obtained value (–0.14) does not exceed the critical value (2.001)—it is not extreme enough for us to say that the difference between Groups 1 and 2 occurred by anything other than chance. If the value were greater than 2.001, it would represent a value that is just like getting 8, 9, or 10 heads in a coin toss—so extreme that we believe something other than chance is going on. In the case of the coin, it would be an unfair coin; in this example, it would be that one way of teaching memory skills to people with Alzheimer's is better than the other.

So, to what can we attribute the small difference between the two groups? If we stick with our current argument, then we could say the difference is due to anything from sampling error to rounding error to simple variability in participants' scores. Most important, we're pretty sure (but, of course, not 100% sure) that the difference is not due to anything in particular that one group or the other experienced during the treatment.

### So How Do I Interpret \( t_{(58)} = -0.14, p > .05 \)?

- \( t \) represents the test statistic that was used.
- 58 is the number of degrees of freedom.
- –0.14 is the obtained value, calculated using the formula we showed you earlier in the chapter.
- \( p > .05 \) (the really important part of this little phrase) indicates that the probability is greater than 5% that on any one test of the null hypothesis, the two groups do not differ because of the way they were taught. Also note that \( p > .05 \) can also appear as \( p = \text{n.s.} \) for nonsignificant.

### And Now . . . Using Excel’s T.TEST Function

Interestingly, Excel does not have a function that computes the \( t \) value for the difference between two independent groups. Rather, \( \text{T.TEST} \) returns the probability of that value occurring. Very useful, but if you need the \( t \) value for a report, you may be out of luck.
(actually, not on your life—the Analysis ToolPak has a nifty function). Here are the steps.

1. Enter the individual scores into columns in a worksheet. Label one column as Group 1 and one as Group 2, as you see (partially) in Figure 11.2.

![Figure 11.2 Data for Using the T.TEST Function](image)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

2. Select the cell into which you want to enter the T.TEST function. In this example, we are going to have the T.TEST value returned to Cell D1 (and that location was not chosen for any particular reason).

3. Now click Formulas → More Functions → Statistical menu option and scroll down to select T.TEST. The function looks like this:

\[
= \text{T.TEST(array1, array2, tails, type)},
\]

where

- array1 is the cell addresses for the first set of data (in this case A2:A31);
- array2 is the cell addresses for the second set of data (in this case B2:B31);
- tails is 1 or 2 depending on whether this is a one-tailed (directional, which is a 1) or two-tailed (nondirectional, which is a 2) test; and
- type is 1 if it is a paired \( t \) test, 2 if it is a two-sample test (independent with equal variances), and 3 if it is a two-sample test with unequal variances.
4. For this example, shown in Figure 11.3, the finished function T.TEST looks like this:

\[ T.\text{TEST}(A2:A31,B2:B31,2,1) \]

Click OK, and you see the value returned: 0.877992.

**Figure 11.3** Using T.TEST to Compute the Probability of a \( t \) Value

<table>
<thead>
<tr>
<th>D1</th>
<th>=T.TEST(A2:A31,B2:B31,2,1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>1</td>
<td>Group 1</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Notice two important things about T.TEST.
First, it does not compute the \( t \) value.
Second, it returns the *likelihood* that the resulting \( t \) value is due to chance (given that the null hypothesis is true of course). As we said earlier, the interpretation of a \( t \) value with an associated probability of .88 (and remember, it can only go to 1 or 100%) is that it is pretty darn high.

Believe it or not, way back in the olden days, when your author and perhaps your instructor were graduate students, there were only huge mainframe computers and not a hint of such marvels as we have today on our desktops. In other words, everything that was done in our statistics class was done only by hand. The great benefit of that is, first, it helps you to better understand the process. Second, should you be without a computer, you can still do the analysis. So, if the computer does not spit out all of what you need, use some creativity. As long as you know the basic formula for the obtained value and have the appropriate tables, you’ll do fine.

Oops. If the first set of data (in array 1) and the second set of data (in array 2) have a different number of data points and you enter 1 (as the type of data), then the T.TEST function returns the #N/A error message. Why? Because you can’t have unequal numbers in your groups but have paired (or dependent) scores, as you will in Chapter 12.

There is a pretty dramatic difference between what you get when you compute the \( t \) value using the formula and when you use one of the functions. Remember that when you did it manually, you had to use a table to locate the critical value and then compare the observed value to that? Well, with T.TEST and the Analysis ToolPak discussion that follows later in this chapter, there’s no more “\( p < . \)” That’s because Excel computes the exact, exactamente, precise, one-of-a-kind probability. No need for tables—just get that number, which is the probability associated with the outcome.
USING THE AMAZING ANALYSIS TOOLPAK TO COMPUTE THE T VALUE

Once again, we’ll find that the ToolPak gives us all the information we need to make a very informed judgment about the value of \( t \) and its significance. The ToolPak tool also provides us with other information that, as you will see, is very helpful and saves us the effort of extra analyses as well.

1. Click Data → Data Analysis, and you will see the Data Analysis dialog box shown in Figure 11.4.

Figure 11.4  The Dialog Box That Gets Us Started With the Analysis ToolPak

2. Click t-Test: Two-Sample Assuming Equal Variances and then click OK, and you will see the Descriptive Statistics dialog box, as shown in Figure 11.5.

Figure 11.5  The t-Test Dialog Box

3. In the Variable 1 Range, enter the cell addresses for the first group of data. In our sample spreadsheet that you saw in Figure 11.2, the cell addresses are A1:A31 (this includes the label Group 1).
4. In the Variable 2 Range, enter the cell addresses for the second group of data. In our sample spreadsheet that you saw in Figure 11.2, the cell addresses are B1:B31 (this includes the label Group 2).

5. Click the Labels box so that labels are included in the output that Excel generates.

6. Click the Output Range button and enter an address on the same worksheet as the data where you want the output located. In this example, we are placing the output beginning in Cell D1.

7. Click OK, and as you can see in Figure 11.6, you get a tidy summary of important data (we cleaned it up a bit by reformatting so it fits nicely) relating to this analysis. Below that is a table listing the descriptions of what each statistic means.

Figure 11.6 Data Summary

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>The average score for each variable</td>
</tr>
<tr>
<td>Variance</td>
<td>The variance for each variable</td>
</tr>
<tr>
<td>Observations</td>
<td>The number of observations in each group</td>
</tr>
<tr>
<td>Pooled Variance</td>
<td>The variance for both groups</td>
</tr>
<tr>
<td>Hypothesized Mean Difference</td>
<td>What you may have indicated to be the difference you expect (back in the dialog box)</td>
</tr>
<tr>
<td>df</td>
<td>The degrees of freedom</td>
</tr>
<tr>
<td>t Stat</td>
<td>The value of the $t$ statistic</td>
</tr>
<tr>
<td>$P(T&lt;=t)$ one-tail</td>
<td>The probability of $t$ occurring by chance for a one-tailed test</td>
</tr>
<tr>
<td>$t$ Critical one-tail</td>
<td>The critical value one needs to exceed for a one-tailed test (Remember those critical values from Chapter 8?)</td>
</tr>
<tr>
<td>$P(T&lt;=t)$ two-tail</td>
<td>The probability of $t$ occurring by chance for a two-tailed test</td>
</tr>
<tr>
<td>$t$ Critical two-tail</td>
<td>The critical value one needs to exceed for a two-tailed test (Remember those critical values from Chapter 8?)</td>
</tr>
</tbody>
</table>
More Excel

Remember that it takes only a moment to pretty up the ToolPak output, copy it from Excel, and paste it (or whatever you need from it) into another document.

Results

The results of the analysis show that although Group 2 did have a higher score than Group 1, that score was not significantly different. The $t$ value for a two-tailed test was $-0.14$, with an associated $p$ value of $0.89$. Here’s a summary:

<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>5.43</td>
<td>5.53</td>
</tr>
<tr>
<td>Variance</td>
<td>11.70</td>
<td>4.26</td>
</tr>
<tr>
<td>Observations</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Degrees of freedom</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>$t$ statistic</td>
<td>$-0.14$</td>
<td></td>
</tr>
<tr>
<td>$p$ value</td>
<td>0.89</td>
<td></td>
</tr>
</tbody>
</table>

Special Effects: Are Those Differences for Real?

Okay, now you have some idea how to test for the difference between the averages of two separate or independent groups. Good job. But that’s not the whole story.

You may have a significant difference between groups, but the $64,000 question is not only whether that difference is (statistically) significant but also whether it is meaningful. We mean, is there enough separation between the distribution that represents each group that the difference you observe and the difference you test is really a difference? Hmm . . . Welcome to the world of effect size. **Effect size** (ES) is a measure of how different two groups are from one another, and it’s not just about how big the difference is—it’s a measure of the magnitude of the treatment. It’s kind of like asking, “How big is big?” And what’s especially interesting about computing effect size is that sample size is not taken into account.

Calculating effect size, and making a judgment about it, adds a whole new dimension to understanding significant outcomes.
Let’s take the following example. A researcher tests the question of whether participation in community-sponsored services (such as card games, field trips, etc.) increases the quality of life (as rated from 1 to 10, with 1 being a higher quality of life than 10) for older Americans. The researcher implements the treatment over a 6-month period and then, at the end of the treatment period, measures quality of life in the two groups. Each group consists of 50 participants over the age of 80, and one group got the services and the other group did not. Here are the results:

<table>
<thead>
<tr>
<th></th>
<th>No Community Services</th>
<th>Community Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.46</td>
<td>6.90</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>1.03</td>
<td>1.53</td>
</tr>
</tbody>
</table>

And the verdict is that the difference is significant at the .034 level (which is $p < .05$, right?). So there’s a significant difference. But what about the magnitude of the difference?

The great Pooh-Bah of effect size was Jacob Cohen, who wrote some of the most influential and important articles on this topic. He authored a very important and influential book (your stats teacher has it on his or her shelf) that instructs researchers how to figure out the effect size for a variety of different questions that are asked about differences and relationships between variables. Here’s how you do it.

**Computing and Understanding the Effect Size**

Just as with many other statistical techniques, there are many different ways to compute effect size. We are going to show you the most simple and straightforward. You can learn more about effect sizes by consulting some of the references we’ll be giving you in a minute.

By far, the most direct and simple way to compute effect size is to simply divide the difference between the means by any one of the standard deviations. Danger, Will Robinson—this does assume that the standard deviations (and the amount of variance) between groups are equal to one another. For our example above, we’ll do this:

$$ES = \frac{\bar{X}_1 - \bar{X}_2}{s},$$

(11.6)
where

\[ ES = \frac{\bar{X}_1 - \bar{X}_2}{s} \]

is effect size,

\[ \bar{X}_1 \] is the mean for Group 1,

\[ \bar{X}_2 \] is the mean for Group 2, and

\[ s \] is the standard deviation from either group.

So, in our example . . .

\[ ES = \frac{7.46 - 6.90}{1.53} = .366 \]  \hspace{1cm} (11.7)

So, the effect size for this example is .37.

What does it mean? One of the very cool things that Cohen (and others) figured out was just what a small, medium, or large effect size is. They used the following guidelines:

A small effect size ranges from 0 to .2.

A medium effect size ranges from .2 to .5.

A large effect size is any value above .5.

Our example, with an effect size of .37, is categorized as medium. But what does it really mean?

Effect size gives us an idea about the relative positions of one group to another. For example, if the effect size is zero, that means that both groups tend to be very similar and overlap entirely—there is no difference between the two distributions of scores. On the other hand, an effect size of 1 means that the two groups overlap about 45% (having that much in common). And, as you might expect, as the effect size gets larger, it reflects the increasing lack of overlap between the two groups.

Jacob Cohen’s book, *Statistical Power Analysis for the Behavioral Sciences*, first published in 1967 with the latest edition (1988) published by Lawrence Erlbaum Associates, is a must for anyone who wants to go beyond the very general information that is presented here. It is full of tables and techniques for allowing you to understand why a statistically significant finding is only half the story—the other half is the magnitude of that effect.
So, you really want to be cool about this effect size thing. You can do it the simple way, as we just showed you (by subtracting means from one another and dividing by either standard deviation), or you can really wow that good-looking classmate who sits next to you. The grown-up formula for the effect size uses the pooled variance in the denominator of the ES equation that you saw above. The pooled standard deviation is sort of an average of the standard deviation from Group 1 and the standard deviation from Group 2. Here’s the formula:

\[ ES = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}}} \]

where

- \( ES \) is effect size,
- \( \bar{X}_1 \) is the mean of Group 1,
- \( \bar{X}_2 \) is the mean of Group 2,
- \( \sigma_1^2 \) is the variance of Group 1, and
- \( \sigma_2^2 \) is the variance of Group 2.

If we applied this formula to the same numbers we showed you above, you’d get a whopping effect size of .43—not very different from .37, which we got using the more direct method shown earlier. Both results are in the medium-size category, but this formula is a more precise method and one that is well worth knowing about.

**A Very Cool Effect Size Calculator**

Why not take the A train and go right to www.uccs.edu/~faculty/lbecker/, where statistician Lee Becker from the University of Colorado–Colorado Springs has developed an effect size calculator? With this calculator, you just plug in the values, click Compute, and the program does the rest, as you see in Figure 11.7. Thanks, Dr. Becker!

![Figure 11.7](image-url)
**Summary**

Learning about the *t* test is your first introduction to performing a real statistical test and trying to understand the whole matter of significance from an applied point of view. Be sure that you understand what's in this chapter before you move on. And be sure you can do by hand the few calculations that were asked for. Next, we move on to using another form of the same test, only this time, there are two measures taken from one group of participants rather than one measure taken from two separate groups.

**Time to Practice**

1. Using the data in the file named Chapter 11 Data Set 1, test the research hypothesis at the .05 level of significance that boys raise their hands in class more often than girls. Do this practice problem by hand using a calculator. What is your conclusion regarding the research hypothesis? Remember to first decide whether this is a one- or two-tailed test.

2. Using the same data set (Chapter 11 Data Set 1), test the research hypothesis at the .01 level of significance that there is a difference between boys and girls in the number of times they raise their hands in class. Do this practice problem by hand using a calculator. You use the same data for this problem as for Question 1, but you have a different hypothesis (one is directional and the other is nondirectional). What is your conclusion regarding the research hypothesis? How do the results differ, and why?

3. Using the data in the file named Chapter 11 Data Set 2, test the null hypothesis that urban and rural residents have the same attitudes toward gun control. Use the T.TEST function to test the hypothesis.

4. For your Friday afternoon report to the boss, you need to let her know if the two stores in Newark, Delaware, are selling at the same weekly rate or a different rate. Use the data in the file named Chapter 11 Data Set 3 and the Analysis ToolPak to let her know. Better hurry.

5. What would it mean if a difference were statistically significant and the effect size were not meaningful?