Paired t test requirements

Paired Samples t-test: Example Suppose we want to know whether or not a certain training program is able to increase the max vertical jump (in inches) of college basketball players. She must use the same exam for all students. Only 5% of the data overall is further out in the tails than 2.131. 2. We compare the value of our statistic (0.750) to the t value. The null hypothesis is written as: $ H_o: \mathrm{\mu_d} = 0 $ The alternative hypothesis is that the population mean of the differences is not zero. If the mean difference between scores for students is “close enough” to zero, she will make a practical conclusion that the exams are equally difficult. You can see that the test statistic (0.75) is not far enough “out in the tail” to reject the hypothesis of a mean difference of zero. Earlier, we decided that the distribution of exam score differences were “close enough” to normal to go ahead with the assumption of normality. Each of the paired measurements must be obtained from the same subject. … Paired t-test assumptions. For example, for the test scores data, the instructor knows that the underlying distribution of score differences is normally distributed. Each of the paired measurements are obtained from the same subject. Alternative hypothesis: The mean of the paired differences does not equal … Paired T-test is a test that is based on the differences between the values of a single pair, that is one deducted from the other. Under the null hypothesis, this statistic follows a t-distribution with n−1 degrees of freedom. The instructor can go ahead with her plan to use both exams next year, and give half the students one exam and half the other exam. The statistical test gives a common way to make the decision, so that everyone makes the same decision on the same data. She wants to know if the exams are equally difficult and wants to check this by looking at the differences between scores. Each student does their own work on the two exams. Subjects are independent. Figure 4: t-distribution with 15 degrees of freedom and α = 0.05 Since our test is two-sided and we set α = 0.05, the figure shows that the value of 2.131 “cuts off” 2.5% of the data in each of the two tails. The degrees of freedom (df) are based on the sample size and are calculated as: $ df = n - 1 = 16 - 1 = 15 $ Statisticians write the t value with α = 0.05 and 15 degrees of freedom as: $ t_{0.05,15} $ The t value with α = 0.05 and 15 degrees of freedom is 2.131. In both cases we are interested in comparing the mean measurement between two groups in which each observation in one sample can be paired with an observation in the other sample. These types of analyses do not depend on an assumption that the data values are from a specific distribution. You can use the test when your data values are paired measurements. Our alternative hypothesis is that the mean difference is not equal to zero. The t- distribution is similar to a normal distribution. Figure 5: Results of t-test – test statistic is smaller than |2.131| Putting it all together with software To perform the paired t-test in the real world, you are likely to use software most of the time. Paired Samples t-test: Assumptions For the results of a paired samples t-test to be valid, the following assumptions should be met: The participants should be selected randomly from the population. (Note that the statistics are rounded to two decimal places below. We can go ahead with the paired t-test. The test statistic is higher than the t value. We test the distribution of the score differences. Next year, she can use both exams and give half the students one exam and half the other exam. Additional Resources The following tutorials explain how to perform a paired samples t-test using different statistical programs: How to Perform a Paired Samples t-Test in Excel How to Perform a Paired Samples t-test in SPSS How to Perform a Paired Samples t-test in Stata How to Perform a Paired Samples t-test on a TI-84 Calculator How to Perform a Paired Samples t-test in R How to Perform a Paired Samples t-Test in Python How to Perform a Paired Samples t-Test by Hand A paired samples t-test is used to compare the means of two samples when each observation in one sample can be paired with an observation in the other sample. You reject the hypothesis that the mean difference is zero. A measurement is taken on a subject before and after some treatment – e.g. the max vertical jump of college basketball players is measured before and after participating in a training program. Most statistics books have look-up tables for the distribution. In a paired sample t-test, one … Or, you can perform a nonparametric test that doesn’t assume normality. Use tables of the t-distribution to … Paired T Test Hypotheses. To determine whether or not the training program actually had an effect on max vertical jump, we will perform a paired samples t-test at significance level α = 0.05 using the following steps: Step 1: Calculate the summary data for the differences. The differences between the pairs should be approximately normally distributed. Measurements for one subject do not affect … The paired sample t-test, sometimes called the dependent sample t-test, is a statistical procedure.Specifically, it determines whether the mean difference between two sets of observations is zero. We will perform the paired samples t-test with the following hypotheses: H0: μ1 = μ2 (the two population means are equal) H1: μ1 ≠ μ2 (the two population means are not equal) Step 3: Calculate the test statistic t. Or what if your sample size is large and the test for normality is rejected? According to the T Score to P Value Calculator, the p-value associated with t = -3.226 and degrees of freedom = n-1 = 20-1 = 19 is 0.00445. The two-sided test is what we want. Checking the data Let’s start by answering: Is the paired t-test an appropriate method to evaluate the difference in difficulty between the two exams? Our null hypothesis is that the population mean of the differences is zero. The paired t-test is also known as the dependent samples t-test, the paired-difference t-test, the matched pairs t-test and the repeated-samples t-test. xdiff: sample mean of the differences = -0.95 s: sample standard deviation of the differences = 1.317 n: sample size (i.e. number of pairs) = 20 Step 2: Define the hypotheses. Our test statistic is 0.750. Figure 3 below shows results of testing for normality with JMP. Paired Samples t-test: Motivation A paired samples t-test is commonly used in two scenarios: 1. This tutorial explains the following: The motivation for performing a paired samples t-test. For the exam score data, we decide that we are willing to take a 5% risk of saying that the unknown mean exam score difference is zero when in reality it is not. Figure 6: Paired t-test results for exam score data using JMP software The software shows results for a two-sided test (Prob > |t|) and for one-sided tests. We have sufficient evidence to say that the mean max vertical jump of players is different before and after participating in the training program. What if my data isn’t nearly normally distributed? We make a practical conclusion to consider exams as equally difficult. The most likely situation is that you will use software for your analysis and will not use printed tables.To find this value, we need the significance level (α = 0.05) and the degrees of freedom. This year, she gives both exams to the students. What are some other names for the paired t-test? The degrees of freedom (df) are based on the sample size. In our exam score data example, we set α = 0.05. For the exam score data, this is:$ df = n - 1 = 16 - 1 = 15 $The t value with α = 0.05 and 15 degrees of freedom is 2.131. The practical conclusion made by the instructor is that the tests are not of equal difficulty. Paired Samples t-test: Formula A paired samples t-test always uses the following null hypothesis: H0: μ1 = μ2 (the two population means are equal) The alternative hypothesis can be either two-tailed, left-tailed, or right-tailed: H1 (two-tailed): μ1 ≠ μ2 (the two population means are not equal) H1 (left-tailed): μ1 < μ2 (population 1 mean is less than population 2 mean) H1 (right-tailed): μ1> μ2 (population 1 mean is greater than population 2 mean) We use the following formula to calculate the test statistic t: t = xdiff / (sdiff/√n) where: xdiff: sample mean of the differences s: sample standard deviation of the differences n: sample size (i.e. number of pairs) If the p-value that corresponds to the test statistic t with (n-1) degrees of freedom is less than your chosen significance level (common choices are 0.10, 0.05, and 0.01) then you can reject the null hypothesis. We feel confident in our decision not to reject the null hypothesis. Figure 3: Testing for normality in JMP software What if my data are not from a normal distribution? Our null hypothesis is that the mean difference between the paired exam scores is zero. The standard deviation of the differences is sd. Additional Resources The following tutorials explain how to perform a paired samples t-test using different statistical programs: How to Perform a Paired Samples t-Test in Excel How to Perform a Paired Samples t-test in SPSS How to Perform a Paired Samples t-test in Stata How to Perform a Paired Samples t-test on a TI-84 Calculator How to Perform a Paired Samples t-test in R How to Perform a Paired Samples t-Test in Python How to Perform a Paired Samples t-Test by Hand The paired t-test is a method used to test whether the mean difference between pairs of measurements is zero or not. Statistical details Let’s look at the exam score data and the paired t-test using statistical terms. Measurements for one subject do not affect measurements for any other subject. The data are roughly bell-shaped, so our idea of a normal distribution for the differences seems reasonable. The figure below shows a t- distribution with 15 degrees of freedom. Other people might disagree. There should be no extreme outliers in the differences. We calculate our test statistic as: $ t = \dfrac{\text{Average difference}}{\text{Standard Error}} = \frac{1.31}{1.75} = 0.750 $ To make our decision, we compare the test statistic to a value from the t- distribution. When can I use the test? If your sample sizes are very small, you might not be able to test for normality. To accomplish this, we need the average difference, the standard deviation of the difference and the sample size. An example of how to perform a paired samples t-test. The software shows a p-value of 0.4650 for the two-sided test. These are shown in Figure 1 above. This activity involves four steps: We decide on the risk we are willing to take for declaring a difference when there is not a difference. In the formula for a paired t-test, this difference is notated as d. The assumptions that should be met to perform a paired samples t-test. What if you know the underlying measurements are not normally distributed? You can also find tables online. How to perform the paired t-test We'll further explain the principles underlying the paired t-test in the Statistical Details section below, but let's first proceed through the steps from beginning to end. Normal distributions are symmetric, which means they are equal on both sides of the center. Subjects must be independent. The figure below shows a normal quantile plot for the data and supports our decision. Because 0.750 < 2.131, we cannot reject our idea that the mean score difference is zero. The calculation is: $ \text{Standard Error} = \frac{s_d}{\sqrt{n}} = \frac{7.00}{\sqrt{16}} = \frac{7.00}{4} = 1.75 $ In the formula above, n is the number of students – which is the number of differences. Software will usually display more decimal places and use them in calculations.) The average score difference is: $ \overline{x_d} = 1.31 $ Next, we calculate the standard error for the score difference. A measurement is taken under two different conditions – e.g. the response time of a patient is measured on two different drugs. From the statistics, we see that the average, or mean, difference is 1.3. Is this “close enough” to zero for the instructor to decide that the two exams are equally difficult? Then, we may have each player use the training program for one month and then measure their max vertical jump again at the end of the month. In statistics-speak, we set the significance level, denoted by α, to 0.05. For example, you may use this test to … 4. This is written as: $ H_o: \mathrm{\mu_d} eq 0 $ We calculate the standard error as: $ Standard Error = \frac{s_d}{\sqrt{n}} $ The formula shows the sample standard deviation of the differences as sd and the sample size as n. Since this p-value is less than our significance level α = 0.05, we reject the null hypothesis. Before jumping into the analysis, we should plot the data. 5. Figure 1: Histogram and summary statistics for the difference in test scores From the histogram, we see that there are no very unusual points, or outliers. For example, you might have before-and-after measurements for a group of people. In this situation, you can use nonparametric analyses. Calculate the t-statistic, which is given by T = d¯ SE(d¯). You fail to reject the hypothesis that the mean difference is zero. Paired t tests have the following hypotheses: Null hypothesis: The mean of the paired differences equals zero in the population. Or not? Also, the distribution of differences between the paired measurements should be normally distributed. A paired samples t-test is used to compare the means of two samples when each observation in one sample can be paired with an observation in the other sample. Figure 2: Normal quantile plot for exam data You can also perform a formal test for normality using software. Understanding p-values Using a visual, you can check to see if your test statistic is a more extreme value in the distribution. Here is the data: Table 1: Exam scores for each student Student Exam 1 Score Exam 2 Score Difference If you look at the table above, you see that some of the score differences are positive and some are negative. For now, we will assume this is true. You can check these two features of a normal distribution with graphs. To test this, we may recruit a simple random sample of 20 college basketball players and measure each of their max vertical jumps. We calculate a test statistic. It's a good practice to make this decision before collecting the data and before calculating test statistics. For the paired t -test, a nonparametric test is the Wilcoxon signed-rank test. Figure 5 shows where our result falls on the graph. You might think that the two exams are equally difficult. Additional Resources The following tutorials explain how to perform a paired samples t-test using different statistical programs: How to Perform a Paired Samples t-Test in Excel How to Perform a Paired Samples t-test in SPSS How to Perform a Paired Samples t-test in Stata How to Perform a Paired Samples t-test on a TI-84 Calculator How to Perform a Paired Samples t-test in R How to Perform a Paired Samples t-Test in Python How to Perform a Paired Samples t-Test by Hand 1. The practical conclusion made by the instructor is that the two tests are equally difficult. To apply the paired t-test to test for differences between paired measurements, the following assumptions need to hold: Subjects must be independent. Your two groups must be sampled independently from one another. We start by calculating our test statistic. There are two possible results from our comparison: The test statistic is lower than the t value. The figure below shows results for the paired t-test for the exam score data using JMP. The measured differences are normally distributed. Step 5: Draw a conclusion. We cannot reject the hypothesis of a normal distribution. Note: You can also perform this entire paired samples t-test by simply using the Paired Samples t-test Calculator. t = xdiff / (sdiff/√n) = -0.95 / (1.317/√20) = -3.226 Step 4: Calculate the p-value of the test statistic t. We now have the pieces for our test statistic. To apply the paired t-test to test for differences between paired measurements, the following assumptions need to hold:. Testing for normality The normality assumption is more important for small sample sizes than for larger sample sizes. Paired t-test example An instructor wants to use two exams in her classes next year. We will test this later. Independent Samples t-test: Used when you have two independent groups that you would like to compare the means of. The formula to perform a paired samples t-test. The test statistic is calculated as: $ t = \frac{\mathrm{\mu_d}}{\frac{s}{\sqrt{n}}} $ We compare the test statistic to a t value with our chosen alpha value and the degrees of freedom for our data. We find the value from the t-distribution. We decide that we have selected a valid analysis method. For example, the before-and-after weight for a smoker in the example above must be from the same person. You might need to rely on your understanding of the data. If your sample size is very small, it is hard to test for normality. Even for a very small sample, the instructor would likely go ahead with the t-test and assume normality. This means that the likelihood of seeing a sample average difference of 1.31 or greater, when the underlying population mean difference is zero, is about 47 chances out of 100. Each student takes both tests. In this situation, you need to use your understanding of the measurements. The distribution of differences is normally distributed. The figure below shows a histogram and summary statistics for the score differences. Normal distributions do not have extreme values, or outliers.

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