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Statistics Package Exercise: Carrying Out the Paired t-test

Learning Objective: In a given context, carry out the inferential method for comparing groups and draw the appropriate conclusions.

The purpose of this activity is to give you guided practice in carrying out the paired t-test and to teach you how to obtain the paired t-test output using statistical software. Here is some background for the historically important data that we are going to work with in this activity.

Background: Gosset's Seed Plot Data

William S. Gosset was employed by the Guinness brewing company of Dublin. Sample sizes available for experimentation in brewing were necessarily small, and new techniques for handling the resulting data were needed. Gosset consulted Karl Pearson (1857-1936) of University College in London, who

told him that the current state of knowledge was unsatisfactory. Gosset undertook a course of study under Pearson and the outcome of his study was perhaps the most famous paper in statistical literature, "The Probable Error of a Mean" (1908), which introduced the t distribution.

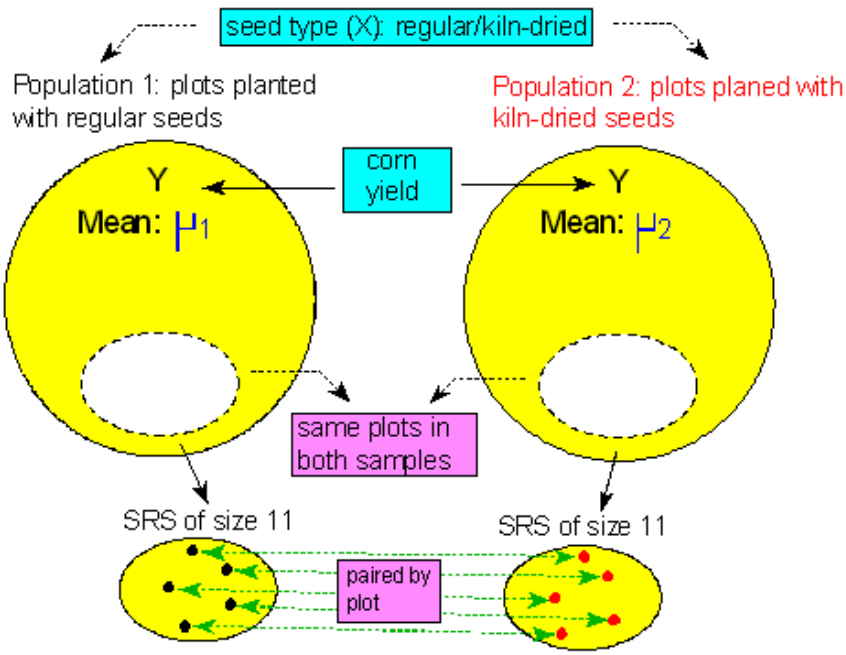
Since Gosset was contractually bound by Guinness, he published under a pseudonym, "Student," hence the t distribution is often referred to as Student's t distribution.

As an example to illustrate his analysis, Gosset reported in his paper on the results of seeding 11 different plots of land with two different types of seed: regular and kiln-dried. There is reason to believe that drying seeds before planting will increase plant yield. Since different plots of soil may be naturally more fertile, this confounding variable was eliminated by using the matched pairs design and planting both types of seed in all 11 plots.

The resulting data (corn yield in pounds per acre) are as follows:

Plot	Regular seed	Kiln-dried seed
1	1903	2009
2	1935	1915
3	1910	2011
4	2496	2463
5	2108	2180
6	1961	1925
7	2060	2122
8	1444	1482
9	1612	1542
10	1316	1443
11	1511	1535

We are going to use these data to test the hypothesis that kiln-dried seed yields more corn than regular seed. Here is a figure that summarizes this problem:



Because of the nature of the experimental design (matched pairs), we are testing the difference in yield.

Plot	Regular seed	Kiln-dried seed	Difference
1	1903	2009	**-106**
2	1935	1915	**20**
3	1910	2011	**-101**
4	2496	2463	**33**
5	2108	2180	**-72**
6	1961	1925	**36**
7	2060	2122	**-62**
8	1444	1482	**-38**
9	1612	1542	**70**
10	1316	1443	**-127**
11	1511	1535	**-24**

Note that the differences were calculated: regular − kiln-dried.

- R StatCrunch TI Calculator Minitab Excel

R Instructions

To open R with the data set preloaded, right-click here and choose "Save Target As" to download the file to your computer. Then find the downloaded file and double-click it to open it in R.

The data have been loaded into the data frame

```
seed
```

. Enter the command

```
seed
```

to see the data. The variables in the data frame are

```
regular.seed
```

and

```
kiln.dried.seed
```

.

To carry out the paired t-test, use the following command:

- ```
  t.test(seed$regular.seed, seed$kiln.dried.seed,
  alternative="less", paired=TRUE)
  ```

The mean of the differences is provided in the output in addition to the other pertinent information. Notice that the order of the variables indicates the order of the difference calculation (

```
position 1 - position 2
```

).
```

Learn By Doing (1/1 point)

Carry out the paired t-test, state the test statistic and p-value, and state your conclusion in context.

Your Answer:

t = -1.6905, p-value = 0.06091

p-value means that getting a t-statistic of -1.7 is not statistically significant. But as the previous lesson said, it can be low enough to warrant personal interpretation.

Our Answer:

RStatCrunch TI CalculatorMinitabExcel R Here is the R output: The test statistic is -1.69 and the p-value is .061, indicating that there is a 6.1% chance of obtaining data like those observed (or even more extremely in favor of the alternative hypothesis) had there really been no difference between regular and kiln-dried seeds (as the null hypothesis claims). Even though the p-value is quite small, it is not small enough if we use a significance level (cut-off probability) of .05. This means that even though the data show some evidence against the null hypothesis, it isn't quite strong enough to reject it. We therefore conclude that the data do not provide enough evidence that kiln-dried seeds yield more corn than regular seeds. Comment: While it is true that at the .05 significance level, our p-value is not small enough to reject Ho, it is "almost small enough." In other words, this is sort of a "borderline case" where personal interpretation and/or judgment is in order. You can stick to the .05 cut-off as we did above in our conclusion, but you might decide that .061 is small enough for you, and that the evidence that the data provide is strong enough for you to believe that indeed kiln-dried seeds yield more corn. This is the beauty of statistics ... there is no "black or white," and there is a lot of room for personal interpretation. StatCrunch Here is the StatCrunch output: The test statistic is -1.69 and the p-value is .061, indicating that there is a 6.1% chance of obtaining data like those observed (or even more extremely in favor of the alternative hypothesis) had there really been no difference between regular and kiln-dried seeds (as the null hypothesis claims). Even though the p-value is quite small, it is not small enough if we use a significance level (cut-off probability) of .05. This means that even though the data show some evidence against the null hypothesis, it isn't quite strong enough to reject it. We therefore conclude that the data do not provide enough evidence that kiln-dried seeds yield more corn than regular seeds. Comment: While it is true that at the .05 significance level, our p-value is not small enough to reject Ho, it is "almost small enough." In other words, this is sort of a "borderline case" where personal interpretation and/or judgment is in order. You can stick to the .05 cut-off as we did above in our conclusion, but you might decide that .061 is small enough for you, and that the evidence that the data provide is strong enough for you to believe that indeed kiln-dried seeds yield more corn. This is the beauty of statistics ... there is no "black or white," and there is a lot of room for personal interpretation. TI Calculator Here is the output: The test statistic is -1.69 and the p-value is .061, indicating that there is a 6.1% chance of obtaining data like those observed (or even more extremely in favor of the alternative hypothesis) had there really been no difference between regular and kiln-dried seeds (as the null hypothesis claims). Even though the p-value is quite small, it is not small enough if we use a significance level (cut-off probability) of .05. This means that even though the data show some evidence against the null hypothesis it isn't quite strong enough to reject it. We therefore conclude that the data do not provide enough evidence that kiln-dried seeds yield more corn than regular seeds. Comment: While it is true that at the .05 significance level, our p-value is not small enough to reject Ho, it is "almost small enough". In other words, this is sort of a "borderline case" where personal interpretation and/or judgment is in order. You can stick to the .05 cut-off as we did above in our conclusion, but you might decide that .061 is small enough for you, and that the evidence that the data

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