

Statistics: The Science of Decisions Project

1. What is our independent variable? What is our dependent variable?

In this problem, the independent variable is the task condition, i.e., congruent and incongruent word condition. The dependent variable is the time taken by a participant to state the ink color.

2. What is an appropriate set of hypotheses for this task? What kind of statistical test do you expect to perform? Justify your choices.

A possible aspect of interest for this task can be whether the average time taken by a population to perform the incongruent task is significantly different from the average time taken by the population to perform the congruent task. In order to validate this, appropriate hypotheses are framed. In framing these, the study is extended to consider the performance of a population who take both the tests, and not simply the given samples.

The null hypothesis would be that the average time taken to perform the incongruent task ($\mu_{incongruent}$) is comparable to the average time taken to perform the congruent task ($\mu_{congruent}$), i.e., the average difference between the time taken to complete the two types of tasks is zero. The difference is defined as $\mu_{difference} = \mu_{congruent} - \mu_{incongruent}$. The null hypothesis is expressed as shown below.

$$H_0 : \mu_{difference} = 0$$

The alternate hypothesis states that the average time taken to perform the congruent and incongruent tasks are significantly different from each other, i.e., the average difference is not zero.

$$H_A : \mu_{difference} \neq 0$$

As the dataset consists of samples where the same set of participants take both the tests, the values are paired and dependent. Therefore, the **dependent t-test for paired samples** could be used to evaluate these hypotheses. The provided dataset also complies with the assumptions for the test [3].

- The dependent variable, i.e., the values of time taken, are continuous.
- The independent variable, the task condition, consists of two categorical “matched pairs,” the congruent and incongruent conditions undertaken by the same set of participants.
- From the histogram of the differences between the two related groups, there appear to be no significant outliers.
- While the histogram does not reveal anything about the normality of the distribution of the differences between the two related groups, we assume this to be the case as the sample size is more than 20 [1].

3. Report some descriptive statistics regarding this dataset. Include at least one measure of central tendency and at least one measure of variability.

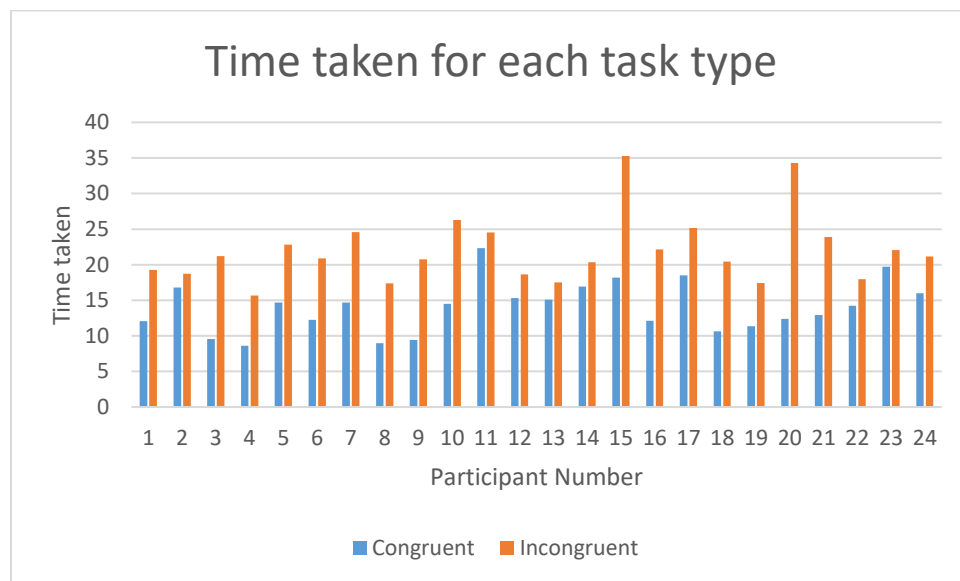
The following descriptive statistics were computed using in-built functions in Excel. All of these are with regard to the time taken by participants to complete the relevant task type.

Descriptive Statistics			
Measures of centrality	Mean	Congruent task condition	14.051
		Incongruent task condition	22.016
		Paired Difference	-7.965
	Median	Congruent task condition	14.357
		Incongruent task condition	21.018
		Paired Difference	-7.667
Measures of variability	Variance	Congruent task condition	12.669
		Incongruent task condition	23.012
		Paired Difference	23.667
	Standard Deviation	Congruent task condition	3.559
		Incongruent task condition	4.797
		Paired Difference	4.865

4. Provide one or two visualizations that show the distribution of the sample data. Write one or two sentences noting what you observe about the plot or plots.

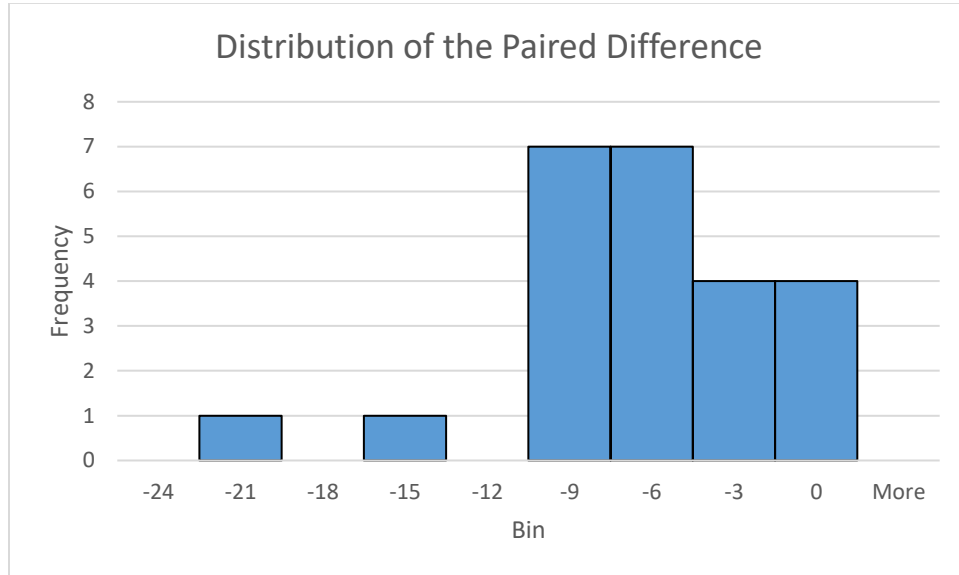
Visualization 1: Bar chart showing the time taken to complete each task type

The time taken by each participant to state the color was plotted as a bar chart. It is observed that, in each instance, the time taken to complete the incongruent task was higher than the time taken to complete the congruent task.



Visualization 2: Histogram to visualize distribution of paired difference

Next, the distribution of the difference between the time taken to complete the congruent and incongruent tasks was visualized to check for normality. This was achieved by computing the difference for each participant, classifying them into bins (size of 3 has been assumed here), and plotting a histogram for this data [2].



5. Now, perform the statistical test and report your results. What is your confidence level and your critical statistic value? Do you reject the null hypothesis or fail to reject it? Come to a conclusion in terms of the experiment task. Did the results match up with your expectations?

The following parameters were used in the dependent t-test for paired samples.

Number of samples

$$n = 24$$

Degrees of freedom

$$df = n - 1 = 23$$

Mean of paired difference

$$\mu_{\text{difference}} = -7.965$$

Standard error, i.e., standard deviation of the paired difference

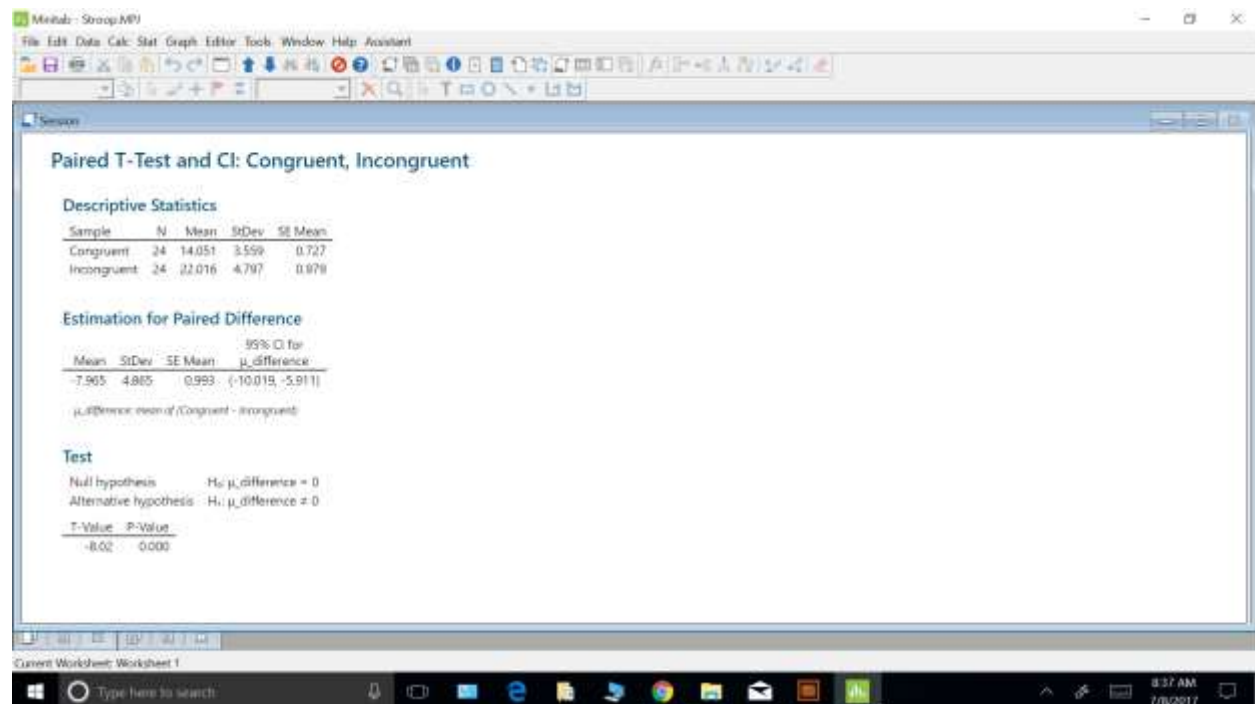
$$s = 4.865$$

The t-statistic was computed by substituting these values in the formula

$$\frac{\mu_{\text{difference}} - 0}{s/\sqrt{n}} = \frac{-7.965}{4.865/\sqrt{24}} = -8.021$$

For a confidence level of 95%, i.e., $\alpha = 0.05$, the corresponding t-critical values are ± 2.069 . As the computed t-statistic is outside the t-critical region, we reject the null hypothesis. This implies that there is a significant difference between the average time taken to perform congruent and incongruent tasks. This is in accordance with the observations from the bar chart. The confidence interval is computed as $(-10.019, -5.910)$. According to the GraphPad calculator, the two-tailed P value is less than 0.0001.

In order to double check my work, I performed the paired t-test on this dataset using Minitab [3]. The output from this matches with my findings and is shown below.



6. Optional: What do you think is responsible for the effects observed? Can you think of an alternative or similar task that would result in a similar effect? Some research about the problem will be helpful for thinking about these two questions!

Although there are several explanations online about the neurological and psychological reasons behind this effect, I have described the explanation that seems most logical to me. In the congruent task, the print ink color and the color word both reinforce the same color and hence the color can be stated in less time. In contrast, in the incongruent task, the two aspects are in conflict and there is a time lag before the participant can process this information and state the appropriate color. This is why it takes longer to complete an incongruent task.

A similar task would involve two components; one being a visual cue and the other being a word. Some possibilities are listed below.

- Enclose a word related to shapes inside a shape that is the same or different, such as “circle” inscribed inside a circle and “square” inscribed within a triangle. An example is shown in [4].

- Provide a multi-colored word that spells out a number and ask participants to state the number of colors.

References

- [1] <http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/introductory-concepts/normality/what-to-do-with-nonnormal-data/>
- [2] <https://support.microsoft.com/en-us/help/214269/how-to-use-the-histogram-tool-in-excel>
- [3] <https://statistics.laerd.com/minitab-tutorials/paired-t-test-using-minitab.php>
- [4] http://www.sciencebuddies.org/science-fair-projects/project_ideas/HumBeh_p028_StroopShapeWords.pdf