Statistics Project
The Stroop Effect

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This project examines the following data[1], which are the results of a Stroop task[2].

Congruent	Incongruent	Difference
12.079	19.278	7.199
16.791	18.741	1.95
9.564	21.214	11.65
8.63	15.687	7.057
14.669	22.803	8.134
12.238	20.878	8.64
14.692	24.572	9.88
8.987	17.394	8.407
9.401	20.762	11.361
14.48	26.282	11.802
22.328	24.524	2.196
15.298	18.644	3.346
15.073	17.51	2.437
16.929	20.33	3.401
18.2	35.255	17.055
12.13	22.158	10.028
18.495	25.139	6.644
10.639	20.429	9.79
11.344	17.425	6.081
12.369	34.288	21.919
12.944	23.894	10.95
14.233	17.96	3.727
19.71	22.058	2.348
16.004	21.157	5.153

Table 1: The time it took each participant to finish the congruent task, incongruent task and the time difference (incongruent time - congruent time). All values are in seconds.

Questions

1. The independent variable is the task condition, which could either be congruent or incongruent. The dependent variable is the time it took to finish the task in seconds.

2. As stated in the Wikipedia article[3], it is expected to take longer to finish the incongruent task than the congruent task. Therefore, the null hypothesis is that the mean of the incongruent times is less than or equal to the mean of the congruent times. And the alternative hypothesis is that the mean of the incongruent times is greater than the mean of the congruent times. Mathematically,

$$H_0 : \mu_i \leq \mu_c$$
$$H_A : \mu_i > \mu_c$$

where H_0 is the null hypothesis, H_A is the alternative hypothesis, μ_i is the mean of the incongruent times and μ_c is the mean of the congruent times. Furthermore, if we let $\mu_d = \mu_i - \mu_c$ be the mean of the differences, then we get the following equivalent hypotheses:

$$H_0 : \mu_d \leq 0$$
$$H_A : \mu_d > 0$$

The statistical test that will be performed is a one-tailed t test in the positive direction with an alpha level of 0.05. A t test is necessary since we are working with samples rather than the population. A one-tailed test in the positive direction is needed since we expect $\bar{x}_i$ to be greater than $\bar{x}_c$ or for $\bar{x}_d$ to be positive. Here, $\bar{x}_i$ is the mean of the sample of incongruent times, $\bar{x}_c$ is the mean of the sample of congruent times and $\bar{x}_d = \bar{x}_i - \bar{x}_c$ is the mean of the sample time differences. An alpha level of 0.05 is used as passing the test with this alpha level (or lower) would imply a statistically significant result (with 95% confidence).

This is a case of repeated measures design on dependent samples. The assumptions on a t test on dependent means are[4]:

- interval scale of measurement
- random sampling from a defined population
- samples used to produce the difference scores are linked in the population
- scores (and their differences) are normally distributed

Of these assumptions, the second and fourth do not necessarily hold. It is not known how the sample and population were chosen nor if they were normally distributed. However, we can see that the differences use an interval scale and that the samples used to produce the differences are linked in the population as they are the two times the same individual took to complete the two types of tasks.

3. (Note: All values are rounded to the nearest thousandth.) The mean of the sample of congruent times is $\bar{x}_c = 14.051$ seconds, the mean for the sample of incongruent times is $\bar{x}_i = 22.016$ seconds and the mean of the sample time differences is $\bar{x}_d = 7.964$ seconds. We will use $\bar{x}_d$ as the point estimate in the t test. The standard deviation of the time differences is $S = 4.865$ seconds, which yields a corresponding standard error of $SE = S/\sqrt{24} = 0.993$ seconds.

4. Below is a histogram of the time differences.

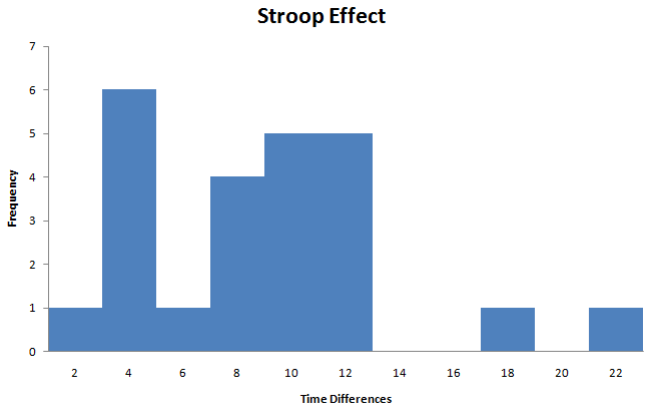


Figure 1: Histogram of time differences between congruent and incongruent Stroop tasks with a bin size of 2 seconds.

Most of the time differences are between 0 - 12 seconds with only 2 times above that. There appear to be two peaks: one between 2 - 4 seconds and one from 8 - 12 seconds. Also, looking at Table 1 we can see that every single difference is positive, so for this sample each individual took longer to finish the incongruent task than the congruent task.

5. The t-statistic for the mean is calculated using the formula $(\bar{x}_d - 0)/SE = 8.020$ rounded to the nearest thousandth. For an alpha level of 0.05, 23 degrees of freedom and a one-tailed t test we have a t-critical value of 1.714 from consulting a t-table[5]. The t-statistic is much larger than the t-critical value, so we can reject the null with 95% confidence. In fact, using GraphPad Softward[6] we can calculate the p-value to be less than 0.0001. This means the participants took significantly longer to finish the incongruent task than the congruent task. If this data came from an experimental setup we could further conclude that the type of task had a causal effect on the time needed to complete it.

Resources

1. https://drive.google.com/file/d/0B9Yf01UaIbUgQXpYb2NhZ29yX1U/view
2. https://faculty.washington.edu/chudler/java/ready.html
3. https://en.wikipedia.org/wiki/Stroop_effect
4. http://www.psychology.emory.edu/clinical/bliwise/Tutorials/TOM/meanstests/assump.htm
5. https://s3.amazonaws.com/udacity-hosted-downloads/t-table.jpg
6. http://www.graphpad.com/quickcalcs/