

Project: Test a Perceptual Phenomenon

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

The independent variable in this case is condition if the word name and the font color were same or different.

The dependent variable is represented by the time it takes to name the ink colors in equally-sized lists or the reaction time.

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

We expect a hypothesis that should tell us that there is no difference in reaction time in both conditions (congruent & incongruent). In other words, if there is no Stroop Effect [1].

If we could assume that the population data is approximately normally distribution, and for the reasons listed below, we suppose to perform a One Sample Paired t-test, which is carried out when two different treatments are applied to the same subjects. [2][3]

1. The variance of the population is unknown.
2. The sample size is small ($n=24$).
3. The same participants are asked to perform the task under both the congruent words condition and the incongruent words condition.

A suitable set of hypotheses is:

$$H(0): \mu_c - \mu_i = 0$$

$$H(A): \mu_c - \mu_i < 0$$

The null hypothesis $H(0)$ is that the mean of the population reaction time of the task under the incongruent words condition is not significantly greater than that of the congruent words condition.

The alternative hypothesis $H(A)$ is that the mean of the population reaction time of the task under the incongruent words condition is significantly greater than that of the congruent words condition.

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

Let x = congruent condition, y = incongruent condition

\bar{x} = the average times of the 24 participants performing the task under the congruent words condition

\bar{y} = the average times of the 24 participants performing the task under the incongruent words condition

$$\bar{d} = \bar{x} - \bar{y}$$

S(x) = Sample standard deviations of the congruent words condition

S(y) = Sample standard deviations of the incongruent words condition

S(d) = standard deviation of the differences of mean i.e. \bar{d}

Calculation # 1

Congruent	mean	congruent - mean	Square of (congruent - mean)	Sum of column D/ n-1	Std deviation
12.079	14.0415	-1.9625	3.85140625	12.66912574	3.559371537
16.791		2.7495	7.55975025		
9.564		-4.4775	20.04800625		
8.63		-5.4115	29.28433225		
14.669		0.6275	0.39375625		
12.238		-1.8035	3.25261225		
14.692		0.6505	0.42315025		
8.987		-5.0545	25.54797025		
9.401		-4.6405	21.53424025		
14.48		0.4385	0.19228225		
22.328		8.2865	68.66608225		
15.298		1.2565	1.57879225		
15.073		1.0315	1.06399225		
16.929		2.8875	8.33765625		
18.2		4.1585	17.29312225		
12.13		-1.9115	3.65383225		
18.495		4.4535	19.83366225		
10.639		-3.4025	11.57700625		
11.344		-2.6975	7.27650625		

12.369		-1.6725	2.79725625		
12.944		-1.0975	1.20450625		
14.233		0.1915	0.03667225		
19.71		5.6685	32.13189225		
16.004		1.9625	3.85140625		

Illustration Table 1

After calculating from the values given in the dataset, the results are

$$\bar{x} = 14.05113s$$

$$S(x) = 3.559358$$

Calculation # 2

Incongruent	mean	incongruent - mean	Square of (incongruent - mean)	Sum of column D/ n-1	Std deviation
19.278	22.01591667	-2.73791667	7.496187692	23.01175704	4.797057122
18.741		-3.27491667	10.7250792		
21.214		-0.80191667	0.6430703456		
15.687		-6.32891667	40.05518622		
22.803		0.78708333	0.6195001684		
20.878		-1.13791667	1.294854348		
24.572		2.55608333	6.53356199		
17.394		-4.62191667	21.3621137		
20.762		-1.25391667	1.572307015		
26.282		4.26608333	18.19946698		
24.524		2.50808333	6.29048199		
18.644		-3.37191667	11.36982203		
17.51		-4.50591667	20.30328504		
20.33		-1.68591667	2.842315018		
35.255		13.23908333	175.2733274		
22.158		0.14208333	0.02018767266		
25.139		3.12308333	9.753649486		

20.429		-1.58691667	2.518304518		
17.425		-4.59091667	21.07651587		
34.288		12.27208333	150.6040293		
23.894		1.87808333	3.527196994		
17.96		-4.05591667	16.45046003		
22.058		0.04208333	0.001771006664		
21.157		-0.85891667	0.737737846		

Illustration Table 2

After calculating from the values given in the dataset, the results are

$$\bar{y} = 22.01592s$$

$$S(y) = 4.797057$$

Calculation # 3

Congruent	Incongruent	congruent - incongruent	mean of column C			
12.079	19.278	-7.199	-7.964791667	0.76579	0.5864343241	23.66654087
16.791	18.741	-1.95		6.01479	36.17769874	4.86482691
9.564	21.214	-11.65		-3.68521	13.58077274	Std deviation
8.63	15.687	-7.057		0.90779	0.8240826841	
14.669	22.803	-8.134		-0.16921	0.0286320241	
12.238	20.878	-8.64		-0.67521	0.4559085441	
14.692	24.572	-9.88		-1.91521	3.668029344	
8.987	17.394	-8.407		-0.44221	0.1955496841	
9.401	20.762	-11.361		-3.39621	11.53424236	
14.48	26.282	-11.802		-3.83721	14.72418058	
22.328	24.524	-2.196		5.76879	33.27893806	
15.298	18.644	-3.346		4.61879	21.33322106	
15.073	17.51	-2.437		5.52779	30.55646228	
16.929	20.33	-3.401		4.56379	20.82817916	
18.2	35.255	-17.055		-9.09021	82.63191784	

12.13	22.158	-10.028		-2.06321	4.256835504	
18.495	25.139	-6.644		1.32079	1.744486224	
10.639	20.429	-9.79		-1.82521	3.331391544	
11.344	17.425	-6.081		1.88379	3.548664764	
12.369	34.288	-21.919		13.95421	194.7199767	
12.944	23.894	-10.95		-2.98521	8.911478744	
14.233	17.96	-3.727		4.23779	17.95886408	
19.71	22.058	-2.348		5.61679	31.5483299	
16.004	21.157	-5.153		2.81179	7.906163004	

Illustration Table 3

After calculating from the values given in the dataset, the results are

$$\bar{d} = -7.96479s$$

$$S(d) = 4.864827$$

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.

The distribution of the sample data can be visualized with the bar chart as shown below. The chart below suggests that the reaction time of the performing the given task under incongruent words condition seems to be greater than that of the congruent words condition.

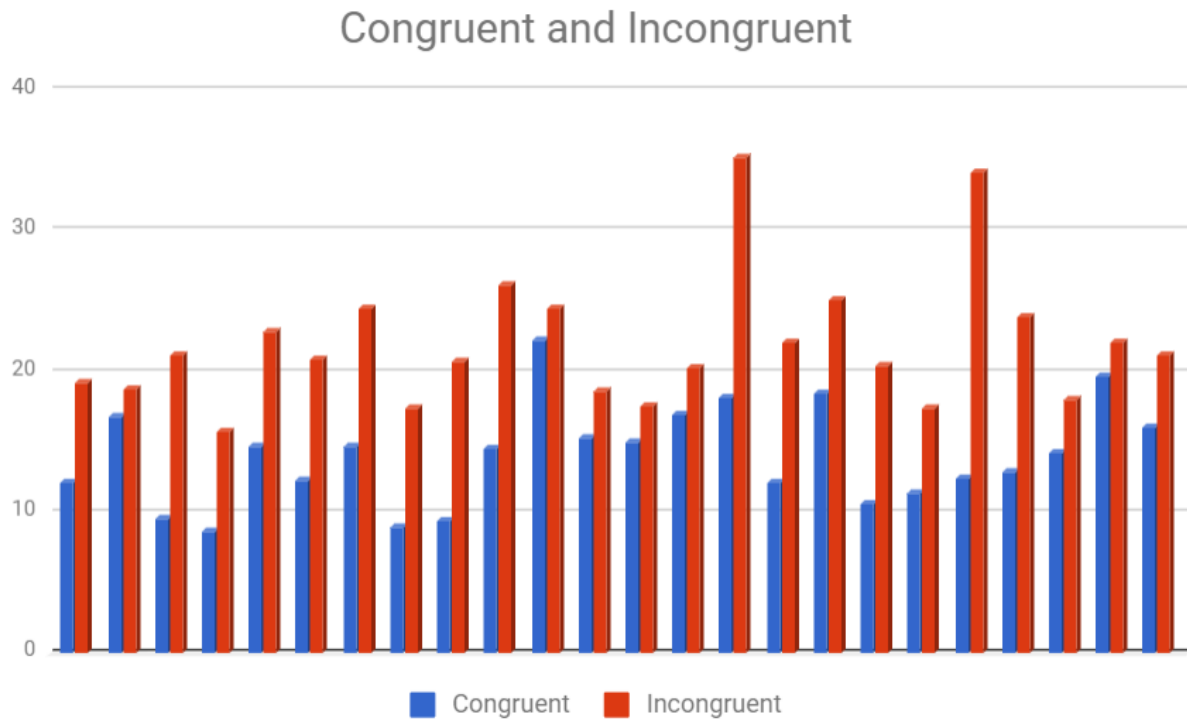


Figure 1

Let us visualize the same data with box plot as shown below.

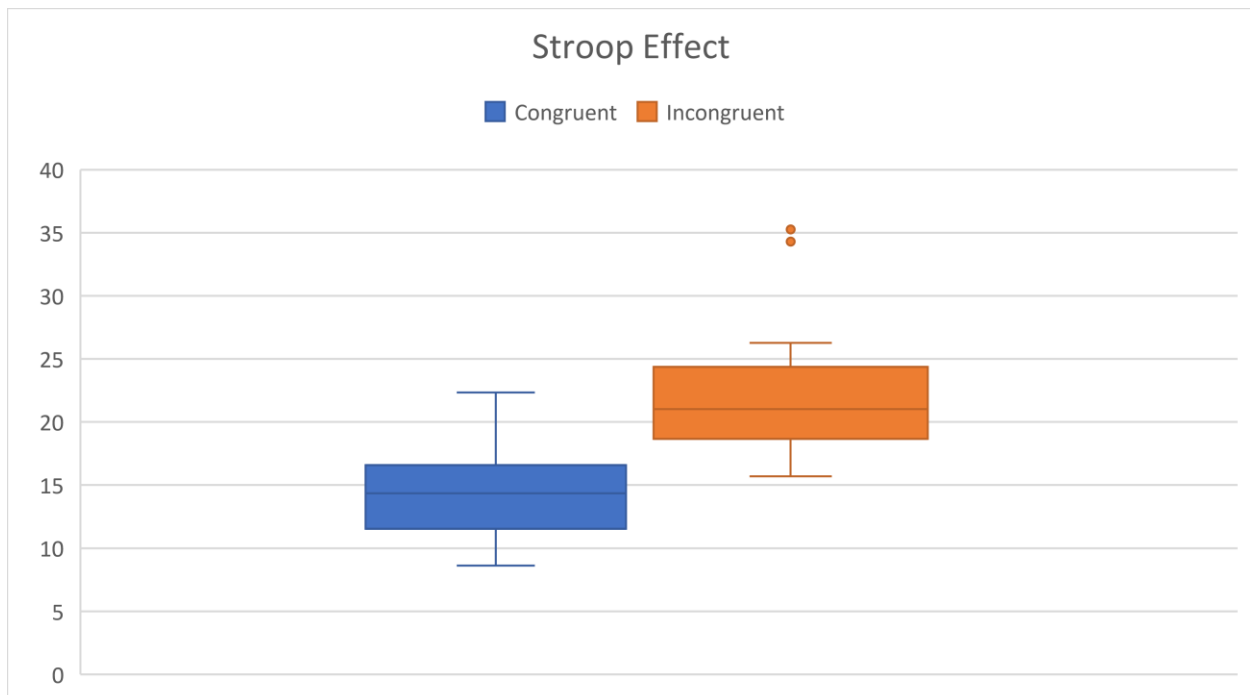


Figure 2

We also notice that there are 2 outliers (35.255,34.288) for incongruent word conditions. Let us plot the histogram for incongruent condition data to observe the effect of the 2 outliers.

Histogram of Incongruent Condition

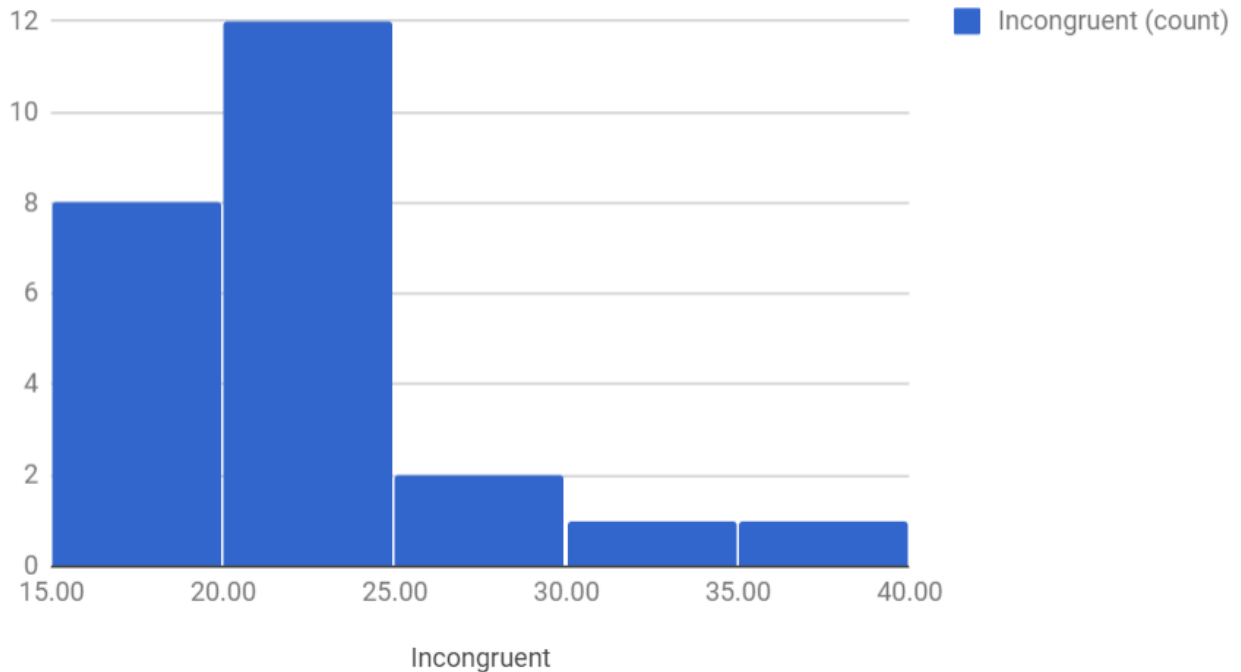


Figure 3

After plotting the data for incongruent condition, we notice that the 2 outliers could make the distribution positively skewed.

Below is the histogram for congruent condition

Histogram of Congruent

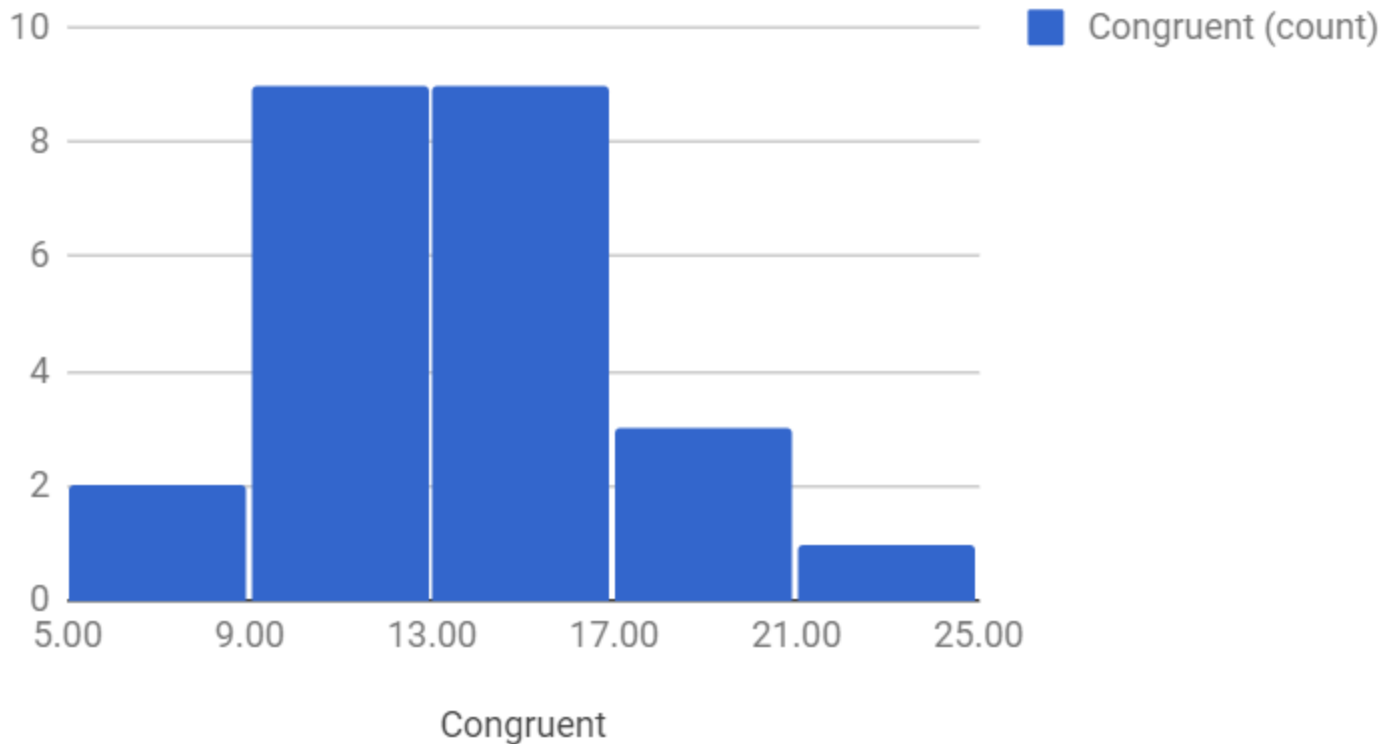


Figure 4

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?

Calculation of T-statistics

$SE(\bar{d})$ is the standard error of the mean difference.

$$SE(\bar{d}) = S(\bar{d}) / \sqrt{n}$$

$$SE(\bar{d}) = 4.8648 / \sqrt{24} = 0.993$$

$$t\text{-statistic (T)} = \bar{d} / SE(\bar{d})$$

$$t\text{-statistic (T)} = -7.96479 / 0.993 = -8.02$$

Calculation of T-critical [3]

$$\text{Alpha } (\alpha) = 0.05$$

Degree of freedom (df) = $n-1 = 23$

t-critical = ± 1.714 (on a right tailed)

Observation # 1

Based on the above calculation for the paired t-test, with an **alpha** level of 0.05, the t-statistics is equal to -8.02, which has conceded the t-critical value (-1.714).

Observation # 2

The p-value corresponding to the degree of freedom (df) = 23 and t-statistics (T) = -8.02 is 0.0001. By conventional criteria, this difference is extremely statistically significant

Hence, based on both the above observations, we reject the null hypothesis H_0 in favor of the alternative hypothesis H_A and conclude that the participants' reaction time of the task under the incongruent words condition is significantly lengthier than that of the congruent words condition.

My own results of the Stroop effect experiment are the following.

- Reaction time in congruent word conditions = 13.4 s
- Reaction time in incongruent word conditions = 39.4 s

It appears that the Stroop effect exists and indeed interferes people's reaction time of a task with a confidence interval of 95%.

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!

There seems to be a lag in the cognitive ability to recognize the color of the word since the brain reads words faster than it recognizes colors [4]

Another variation of the Stroop effect is numerical Stroop effect [5]. It demonstrates the relationship between numerical values and physical sizes.

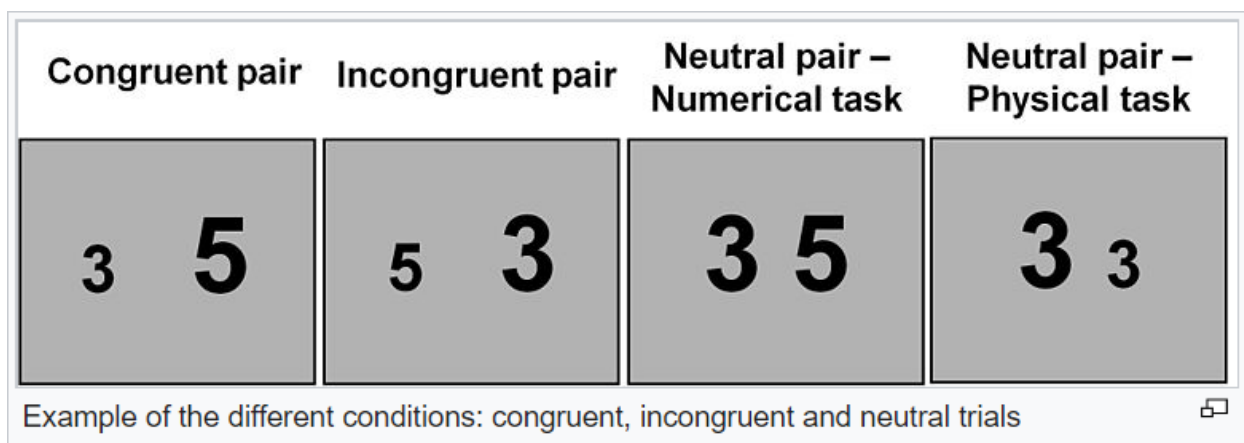


Figure 5 [5]

As seen above, when digits are presented visually, they can be physically large or small, irrespective of their actual values.

References:

- [1] https://en.wikipedia.org/wiki/Stroop_effect
- [2] <https://statistics.laerd.com/stata-tutorials/paired-t-test-using-stata.php>
- [3] <http://www.statstutor.ac.uk/resources/uploaded/paired-t-test.pdf>
- [4] <https://www.graphpad.com/quickcalcs/distMenu/>
- [5] <http://www.wisegeek.org/what-is-the-stroop-effect.htm>
- [6] https://en.wikipedia.org/wiki/Numerical_Stroop_effect