

# Background Information

In a Stroop task, participants are presented with a list of words, with each word displayed in a color of ink. The participant's task is to say out loud the color of the ink in which the word is printed. The task has two conditions: a congruent words condition, and an incongruent words condition. In the congruent words condition, the words being displayed are color words whose names match the colors in which they are printed: for example RED, BLUE. In the incongruent words condition, the words displayed are color words whose names do not match the colors in which they are printed: for example PURPLE, ORANGE. In each case, we measure the time it takes to name the ink colors in equally-sized lists. Each participant will go through and record a time from each condition.

## Questions For Investigation

As a general note, be sure to keep a record of any resources that you use or refer to in the creation of your project. You will need to report your sources as part of the project submission.

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

Now it's your chance to try out the Stroop task for yourself. Go to [this link](#), which has a Java-based applet for performing the Stroop task. Record the times that you received on the task (you do not need to submit your times to the site.) Now, download [this dataset](#) which contains results from a number of participants in the task. Each row of the dataset contains the performance for one participant, with the first number their results on the congruent task and the second number their performance on the incongruent task.

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

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

- Independent variable: the words condition: congruent words / incongruent words
- Dependent variable: the time it takes to name the ink colors

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

$$H_0: \mu_C - \mu_I = 0$$

$$H_A: \mu_C - \mu_I \neq 0,$$

where  $\mu_C$  is the mean of the Congruent population and  $\mu_I$  is the mean of the Incongruent population

**H<sub>0</sub>:** there is no difference between the population's average time it takes to name the ink colors under congruent words condition and incongruent words condition

**H<sub>A</sub>:** there is a difference between the population's average time to name the ink colors under congruent words condition and incongruent words condition

We will compare the means of two samples that are dependent, subjects being involved in both treatments, and determine if there is a statistical significant difference between means (or that the result is not due to chance).

For this we can use a two-tailed t-test for dependent samples.

T test is appropriate because:

- the sample size is small (under 30)
- we don't know the population parameters
- data come from normally distributed populations

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

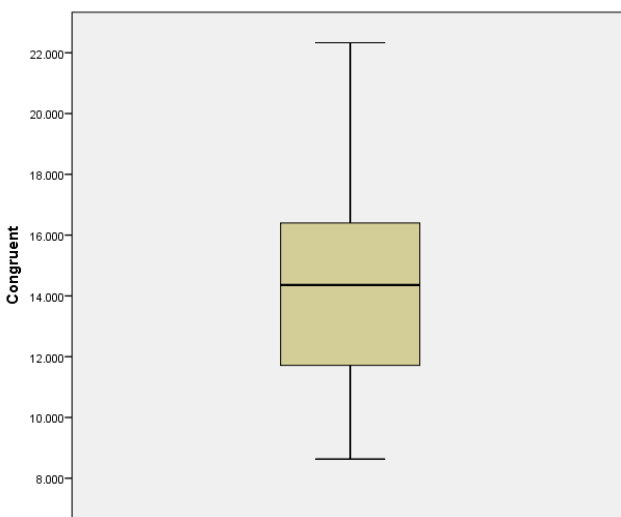
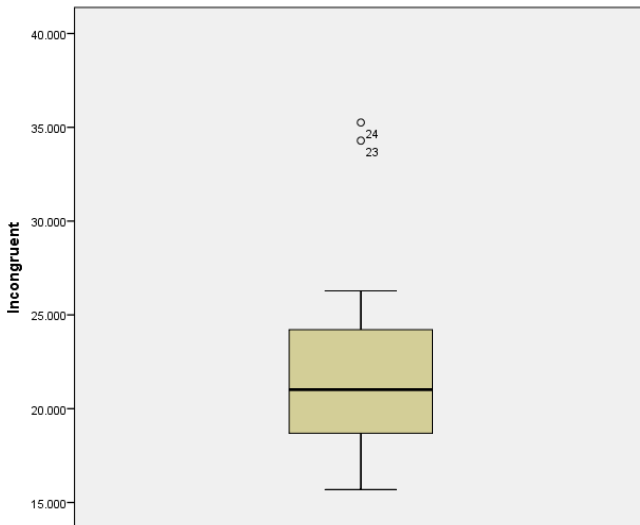
	Sample size	Mean	Variance	Standard deviation	25th percentile	Median	75th percentile
<b>Congruent</b>	24	14.05	12.67	3.56	11.9	14.36	16.2
<b>Incongruent</b>	24	22.02	23.01	4.80	18.72	21.02	24.05

*The congruent sample has a mean score of 14.05 (SD=3.56). Scores of 11.90, 14.36 and 16.20 represented the 25th, 50th and 75th percentiles, respectively.*

*The incongruent sample has a mean score of 22.02 (SD=4.80). Scores of 18.72, 21.02 and 24.05 represented the 25th, 50th and 75th percentiles, respectively.*

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.

#### Box-Plot



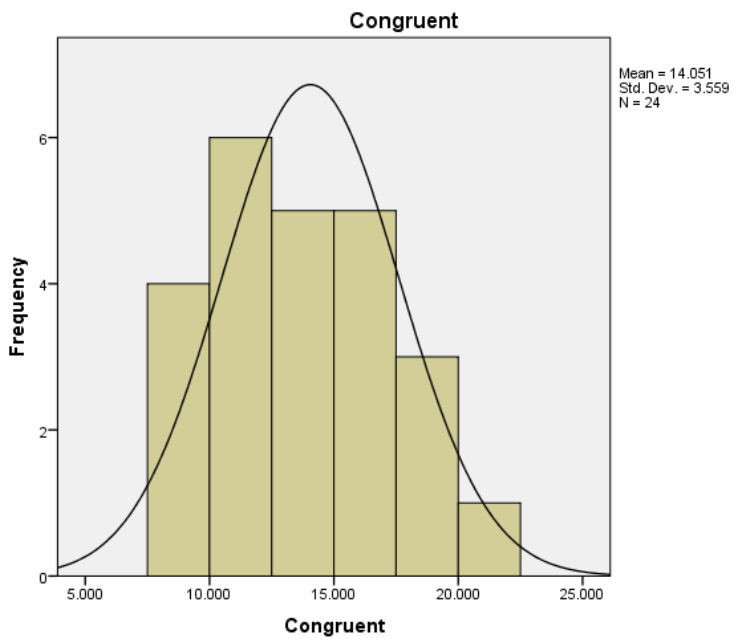
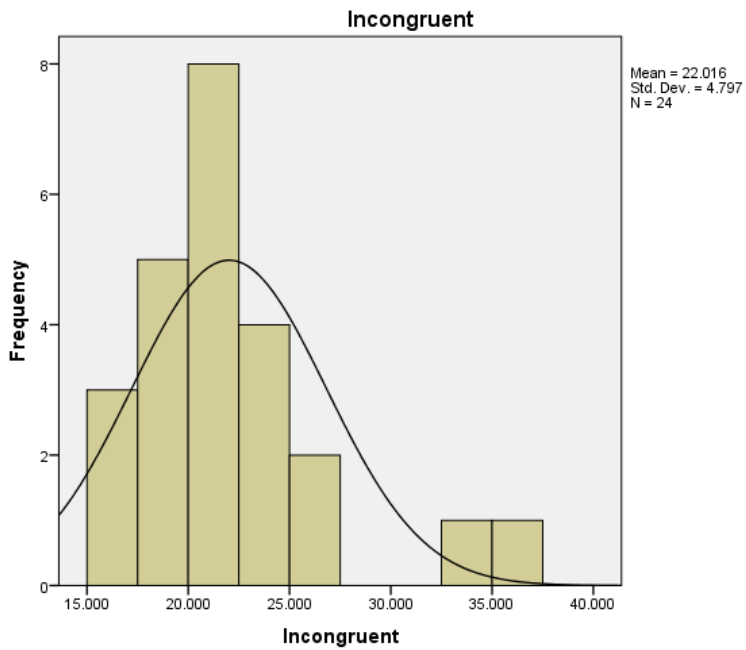
*Incongruent sample:*

- Data ranges between ~15 and ~ 26. There are 2 outliers: the 23th and 24th observations are beyond the upper whisker. The outliers indicate slightly positive skewness.

*Congruent sample:*

- Data ranges between ~8 and ~ 22; no outliers.

## Histograms



The histograms show a normal distribution for congruent sample and a slightly positive skewness for incongruent sample caused by the two outliers.

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?

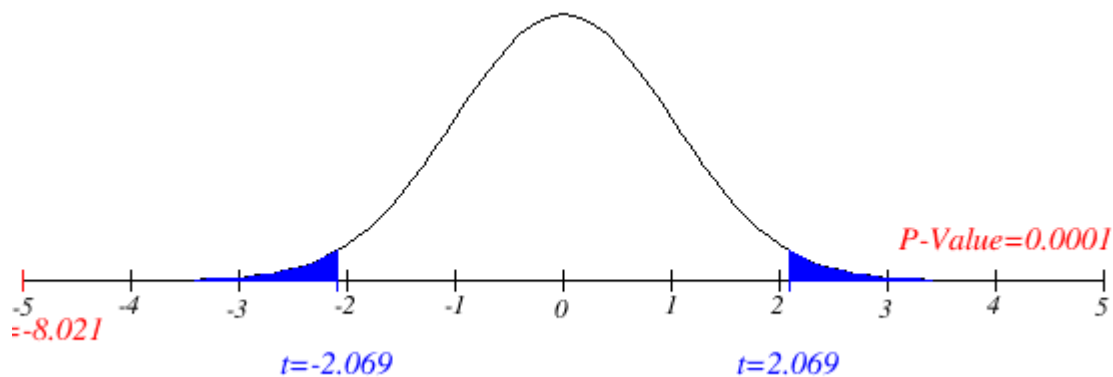
Congruent	Incongruent	Difference	----->	Point estimate for means difference	-7.965
12.079	19.278	-7.199		Variance	23.667
16.791	18.741	-1.95		S	4.865
9.564	21.214	-11.65		SEM	0.993
8.63	15.687	-7.057		t statistic	-8.021
14.669	22.803	-8.134		t critical value at $\alpha=0.05$	+/-2.069
12.238	20.878	-8.64		df	23
14.692	24.572	-9.88		Confidence level	95%
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			
<b>Mean</b>	<b>14.051</b>	<b>22.016</b>			
		<b>-7.965</b>			

The mean difference is negative. This shows that subjects tend to need more time to match the color under incongruent words condition.

A 95% confidence interval will be used for this t-test.

For  $\alpha=.05$  the t-value for the test is -8.02, which is associated with a P value less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.

## T distribution



The t-statistic falls in the critical region, so we can reject the null hypotheses for  $\alpha = 0.05$  and accept alternate-hypotheses: there is a statistical significant difference in average time to match the colors under the two words conditions.

**Cohen's d=-1.637** The congruent and incongruent means are 1.637 standard deviation units apart.

### Margin error for 95% CI=2.05

95% Confidence Interval of the Difference

- Lower Limit= -10.014
- Upper Limit= -5.915

**CI (-10.014,-5.915)** We are 95% confident that the difference between the congruence and incongruence average time to match the colors is between -10.014 and -5.915.

**R-squared=.737** Approximately 73.7% of the difference in time spent to match colors is due to the words condition.

***T test showed that the difference in time to match colors between congruent sample (N=24, M=14.05, SD=3.56) and the incongruent sample (N=24, M=22.02, SD=4.90) were statistically significant,  $t(23) = -8.02$ ,  $p = .0001$ , 95% CI [-10.014,-5.915],  $d = -1.64$ .***

The experiment shows that when the words displayed are color words whose names do not match the colors in which they are printed, naming the color of the word takes longer than when the color of the ink matches the name of the color.

The results match up with my expectations. I believe that the words whose names don't match the colors in which they are printed increase the time it takes to recognize the correct color.

**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 are few theories that may explain the Stroop effect:

Processing speed - the brain reads words faster than it recognizes colors.

Selective attention - color recognition as opposed to reading a word, requires more attention

Automaticity - recognizing colors is not an “automatic process” so there is hesitancy to respond; the brain automatically understands the meaning of words as a result of habitual reading.

An alternative task of Stroop effect: **Number Stroop Effect Experiment**. In this experiment you are required to count the number of words in each box, do not say what the word says. Example:

dog dog	You should say "Two" because the word <b><u>dog</u></b> is shown two times.
one one one	You should say "Three" because the word <b><u>one</u></b> is shown three times.

**Sources:** [https://en.wikipedia.org/wiki/Stroop\\_effect](https://en.wikipedia.org/wiki/Stroop_effect)  
<https://faculty.washington.edu/chudler/java/timescn.html>  
<http://www.graphpad.com/quickcalcs/pValue2/>