Statistics: Project

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.

Dependent and Independent Variables

In an experiment, an independent variable (also called as experimental or predictor variable) is manipulated in order to observe the effect on a dependent variable (also called an outcome variable).

We are taking control of the word color congruency condition and observing the time taken for an individual to name the color.

Dependent variable: The time received on the task is the Dependent variable.

Independent variable: The type of tasks, congruent words condition and incongruent word condition are the independent variables.

Hypothesis Introduction

An appropriate hypothesis for this task is to prove Semantic Interference. Semantic Interference states that naming the ink color of neutral stimuli is faster than in incongruent conditions.

Null hypothesis: There is no difference in time taken to name the ink color for congruent and incongruent conditions.

Alternative hypothesis: The time taken to name a color in congruent conditions is less than the time taken in incongruent conditions.

Null hypothesis: $H_0 : \mu_C = \mu_{IC}$
Alternative hypothesis: $H_a = \mu_C < \mu_{IC}$

where,
μ_C is the mean time received by the population on the task for a congruent word condition.
μ_{IC} is the mean time received by the population on the task for an incongruent word condition.

Assumptions

1. We do not have the population standard deviation. Hence we go for a t-test.
2. Central Limit Theorem holds good for large samples. Rule of thumb for large samples is n>30. In this case n=24, which is less than the minimum number of samples required to assume that the distribution of sample means is approximately normal.
3. T-tests for dependent means is considered typically robust for violations of normal distribution.
4. However, if we are conducting a one tailed t-test and the data are highly skewed, this will cause a lot of error to be introduced into our calculation of difference scores and this will bias the result. In this circumstance, a non-parametric test should be used.

So we make an assumption that the distribution is normal and proceed with a t-test.

Statistical Test Introduction

This is a repeated measures sample, where 2 conditions, congruent word and incongruent word are tested for the same sample. Hence we can use a **paired t-test** to determine if the mean of the differences between the 2 samples is equal to the target value.
In this case, $\mu_C - \mu_{IC} < 0$ or $\mu_C < \mu_{IC}$

Descriptive Statistics

$\bar{X}_C$ = 14.051 seconds
$Median_C$ = 14.356 seconds
S_C^2 = 12.70
S_C = 3.559 seconds

$\bar{X}_{IC}$ = 23.02 seconds
$Median_{IC}$ = 21.017
S_{IC}^2 = 23.01
S_{IC} = 4.797 seconds

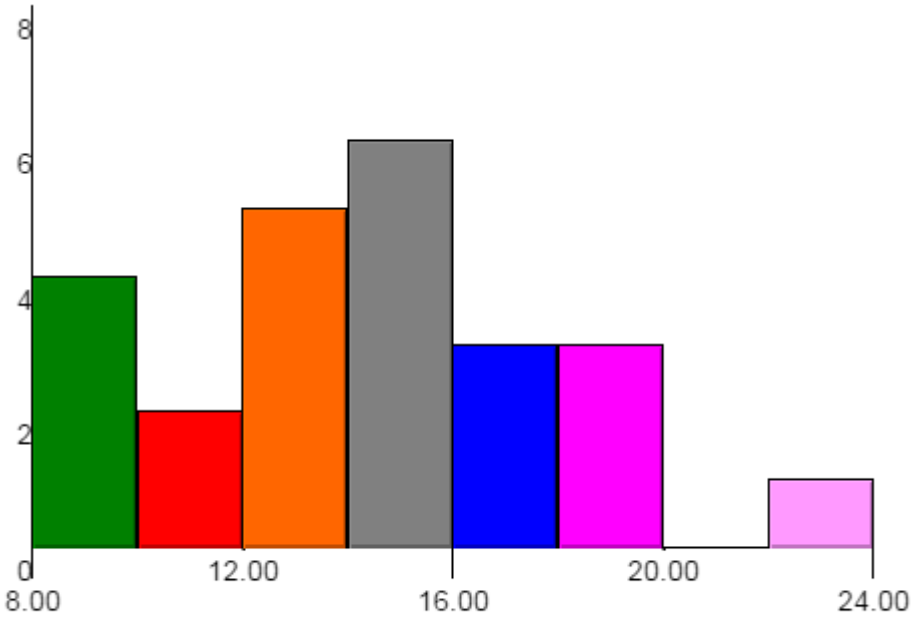
where

$\bar{X}_C$ is the mean time taken for the congruent word condition for the sample
$Median_C$ is the median time taken for the congruent word condition for the sample
S_C^2 is the variance of the time taken for the congruent word condition
S_C is the standard deviation of the time taken for the congruent word condition

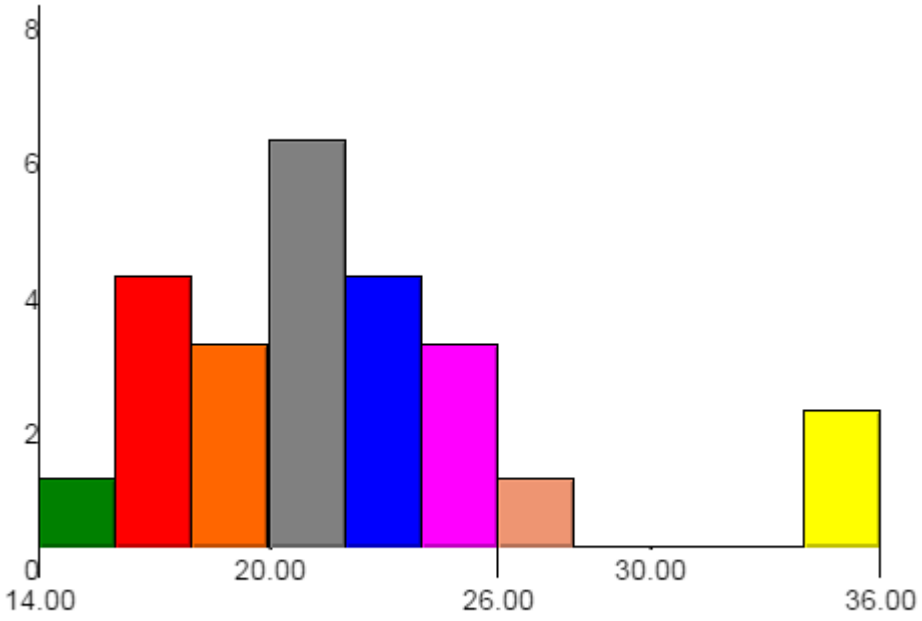
$\bar{X}_{IC}$ is the mean time taken for the incongruent word condition for the sample
$Median_{IC}$ is the median time taken for the incongruent word condition for the sample
S_{IC}^2 is the variance of the time taken for the incongruent word condition
S_{IC} is the standard deviation of the time taken for the incongruent word condition

Visualizations

Histogram



Congruent word condition



Incongruent word condition

Observations

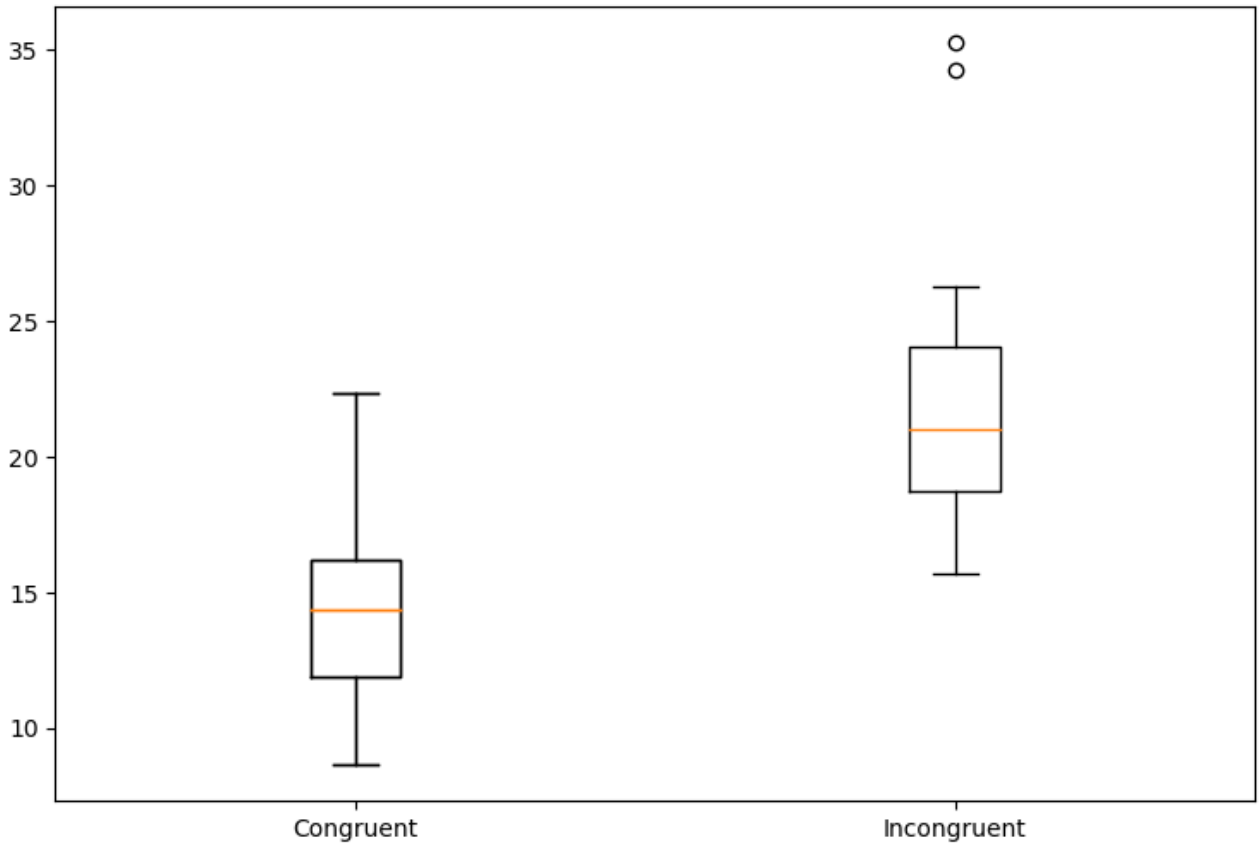
1. The histogram lets us identify the approximate shape of the distribution and understand if the data is skewed in any manner. Both congruent and incongruent word conditions seem to be approximately normally distributed.

2. The histogram gives us an idea about the spread of the data. We can see that the minimum and maximum values for the congruent condition are significantly lesser than the incongruent condition for this sample.

3. We can also see where the data is concentrated. For congruent condition at lot of people in the sample seem to receive a time between 12 and 16 seconds. Whereas for incongruent condition, this is wider, between 12 and 24 seconds.

4. We can also see that about 2 or 3 people seem to have received very high times for incongruent condition, between 34 and 36 seconds. This is a possible outlier.
(and upon further investigation, it indeed is an outlier)

Box Plot



Observations

1. The box plot clearly shows the 2 outliers in incongruent word condition sample.

2. We can see the range of the distribution from these box plots. We can again see that the Median of congruent word condition is about 14.5 seconds while the Median for incongruent word condition is much higher at around 21 seconds.

Statistical Analysis

We will perform a **one tailed t-test** for this sample.

The hypotheses again are:

Null hypothesis: $H_0 : \mu_C = \mu_{IC}$
Alternative hypothesis: $H_a : \mu_C < \mu_{IC}$

Confidence level = 95%
$\alpha = 0.05$

n = 24
DF = n-1 = 23

$t_{critical}$ (23), $\alpha = 0.05$ for a one tailed test is 1.714

$\bar{d} = \Sigma (X_C - X_{IC}) / n = 7.965$

$S_d = 4.865$

$SE(\bar{d}) = S_d/\sqrt{n} = 0.993$

$t = \bar{d} / SE(\bar{d}) = 8.021$

p is less than 0.00005

t(23) = 8.02, p < 0.00005, one tailed

This difference is considered to be extremely statistically significant.

Confidence Interval = $\bar{d} \pm t_{critical} * SE(\bar{d}) = (6.263,9.667)$

Confidence Interval on the mean difference; 95% CI = (6.263,9.667)

where

- n – Sample size
- DF – Degrees of freedom
- $\bar{d}$ - Mean difference
- S_d – Standard deviation of differences
- SE($\bar{d}$) - Standard error of the mean difference
- t – t-statistic
- p - p-value

Hence the result of the analysis is "**Reject the Null Hypothesis**". There is enough evidence that the time taken to name a color in congruent conditions is less than the time taken in incongruent conditions.

Conclusion

The results match with the expectations of this test. When presented a set of words, our brain automatically tends to read the words. Hence the congruent word conditions are easier on us. But in the incongruent word condition, we tend to still read the word first and train our brains to spell out the color of the text. This is much harder and hence it takes longer.

Additional discussion on this effect

I would like to refer to an example from Daniel Kahneman's book "Thinking Fast and Slow" to explore an additional example.

In the introductory chapter of the book Kahneman introduces the concept of System 1 and System 2 in our brains and this is accompanied by a small test which goes like this.

Column 1	**Column 2**
LEFT	upper
left	lower
right	LOWER
RIGHT	upper
RIGHT	UPPER
left	lower
LEFT	LOWER
right	upper

Task 1:
Go through both columns and call out if the letters are printed in uppercase or lowercase.

Task 2:
Go through both columns and call out if the word is printed to the left or right of center.

This exercise reveals similar insights as the Stroop effect test.

Task 1 – Column 1 is easy but column 2 slows us down.
Task 2 – Column 2 is easy but column 1 slows us down.

System 1 operates automatically and System 2 is called during intensive mental activities that require concentration. Kahneman reasons that when we set out on this task we program our memory so that the words upper and lower for task 1 are on the tip of our tongue. When we get to column 2 in task 1, we see the words upper and lower and are tempted to read them out. So we experience a conflict between a task we intended to carry out and an automatic response.

References and resources used in this project

Wikipedia
https://en.wikipedia.org/wiki/Stroop_effect

Assumptions for dependent t-test
https://statistics.laerd.com/spss-tutorials/dependent-t-test-using-spss-statistics.php

How to select a type of t-test
http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/hypothesis-tests/tests-of-means/types-of-t-tests/

https://discussions.udacity.com/t/questions-about-my-review/216926

http://www.psychology.emory.edu/clinical/bliwise/Tutorials/TOM/meanstests/assump.htm

Calculate P Value
http://www.graphpad.com/quickcalcs/distMenu/

Calculate t Value
https://s3.amazonaws.com/udacity-hosted-downloads/t-table.jpg

Histogram drawn using
http://www.shodor.org/interactivate/activities/Histogram/

Box plots drawn using
http://www.alcula.com/calculators/statistics/box-plot/

Thinking Fast and Slow, Daniel Kahneman
Chapter 1, page 25-26