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

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

Independent variable :	Color
Dependant variable :	Time it takes to name the ink colors

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

Null hypothesis :	There is no difference in time when name the ink colors for congruent and incongruent words is the same.
Alternative hypothesis :	There is a time difference when naming the ink colors for congruent or incongruent words.

$H_0 : \mu_{cong} = \mu_{inc}$
$H_A : \mu_{cong} \neq \mu_{inc}$

We will use the Student's t-test because it can be used to determine if two sets of data are significantly different from each other.

Based on the hypothesis, we are interested to know if statistically there is a significant difference between the time to name the ink color of congruent words or incongruent words. We are therefore not interested by a direction (positive or negative), we just want to know if there is a difference. The two-tailed test is therefore the most appropriate kind of test to perform. This is a non-directional test.

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. 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.

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

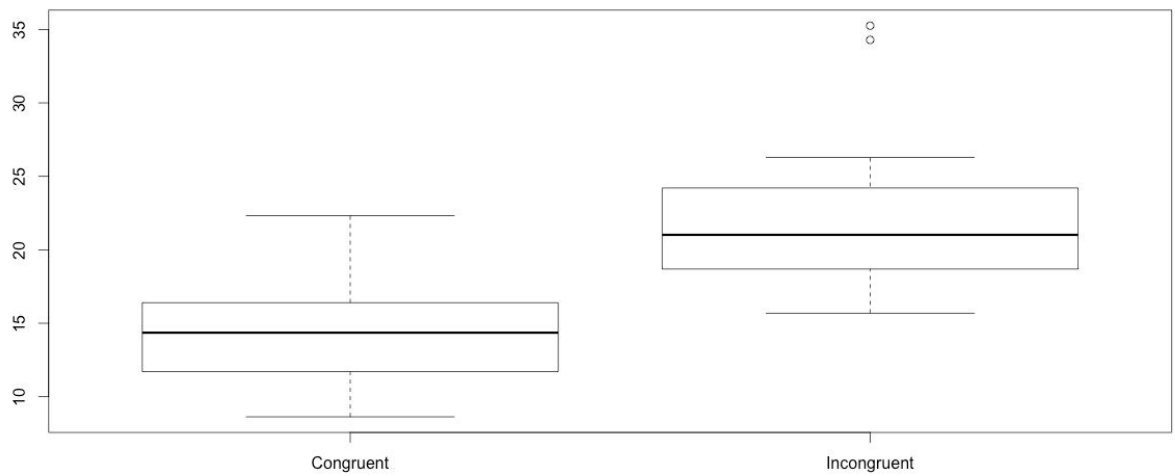
Measure of central tendency:

Measure	Congruent	Incongruent
Mean	14.05	22.02
Median	14.36	21.02

Measure of variability:

Measure	Congruent	Incongruent
Max	22.33	35.26
Min	8.63	15.69
Standard Deviation	3.56	4.8

To visualise if we have outlier we can use boxplot diagram.



Here are some observations we can already draw from this graph :

- The whisker are almost at the same length then, the distribution is symmetrical (the range of the top and bottom 25% of scores is the same)
- For the incongruent words, we see two dots above the whiskers therefore we can say that we have two outliers.
- We can see that the median is a bit higher than the mean for the congruent words which tells us that the middle time scored higher than the mean. The opposite is true for the incongruent words.

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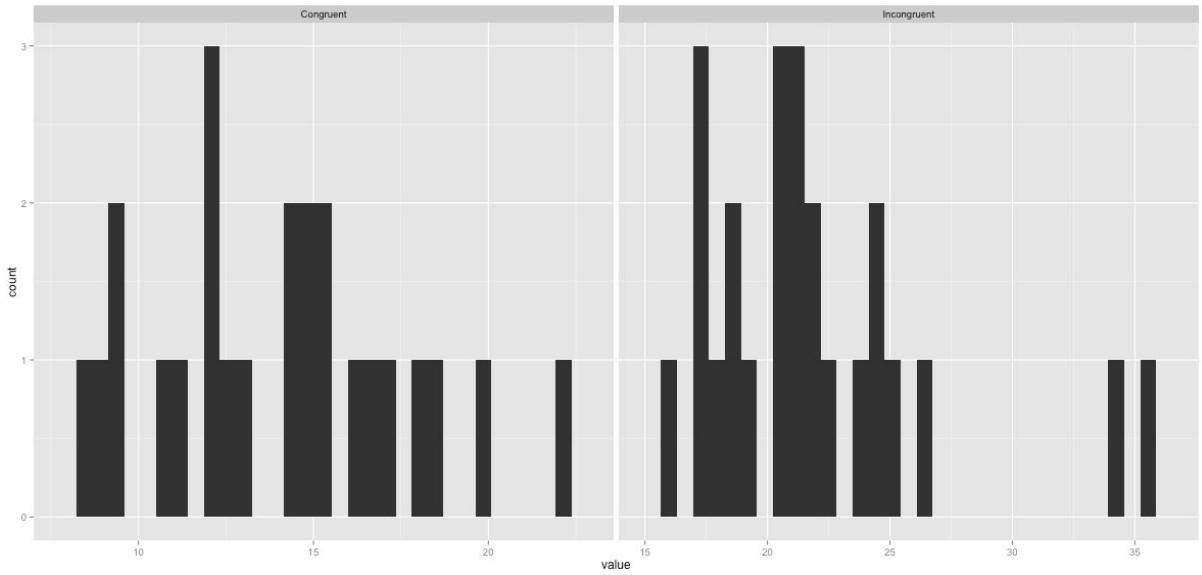
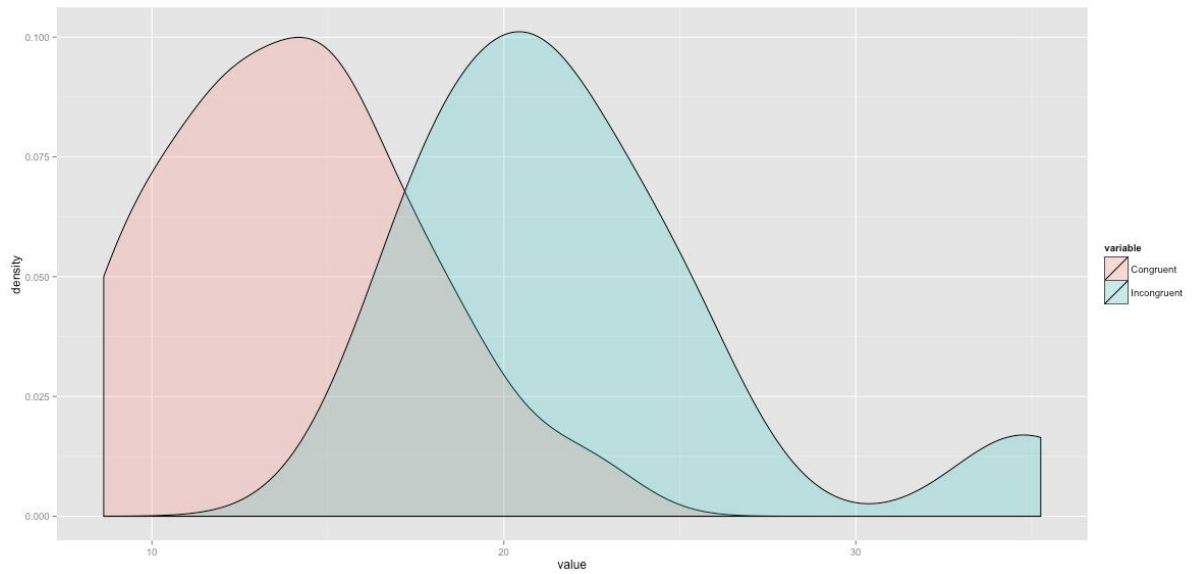
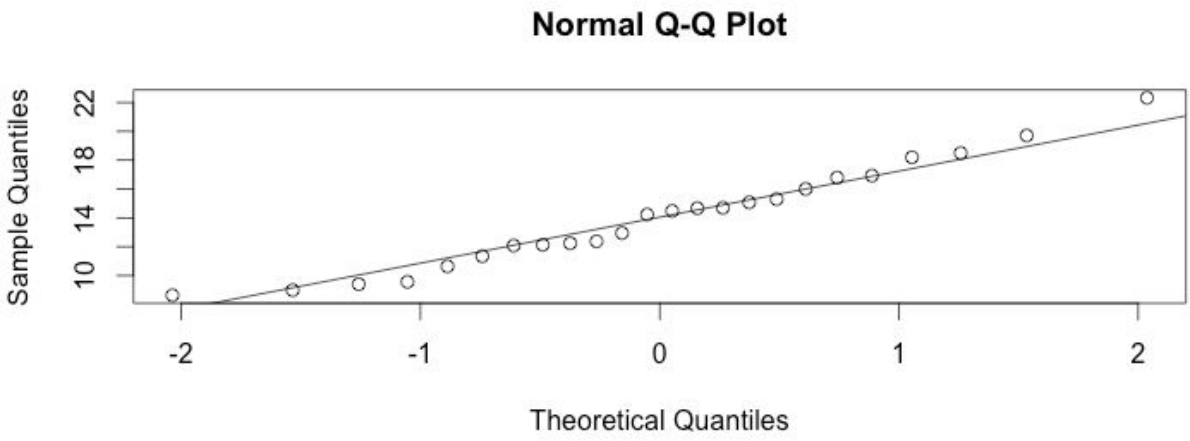
4. Provide one or two visualizations that show the distribution of the sample data. Write one or two sentences noting what you observe about the plot or plots.



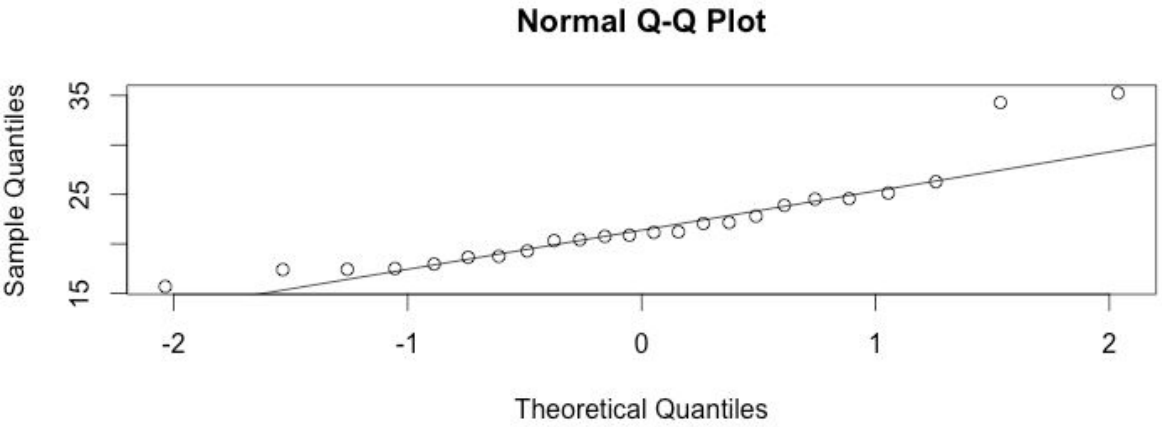


This last density curve is showing the effect on inference on naming colors.

qq-plot for Congruent



qq-plot for Incongruent words



The Q-Q plot for both feature shows that normality is probably a reasonably good approximation. The Q-Q plot clearly show the two outliers for the incongruent words. The same reasoning goes for the histograms. The histogram for the incongruent words is slightly left skewed because of the outliers.

As a result of the discovery of the outliers, we will ignore these value from the dataset for our significant test.

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5. Now, perform the statistical test and report your results. 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?

`independent 2-group t-test`

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> t.test(data$Congruent, data$Incongruent)

        Welch Two Sample t-test

data:  data$Congruent and data$Incongruent
t = -7.1571, df = 43.35, p-value = 7.299e-09
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -8.722289 -4.888098
sample estimates:
mean of x mean of y
 14.05113  20.85632
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We obtained p-value less than 0.05, then we can conclude that the averages of two groups are significantly different.

This confirms that we can reject the null hypothesis H_0 of equality of the means.

While playing with the java applet, I clearly noticed the significant difference in time when I was naming the words. It was quicker for me to name the congruent words than incongruent words.

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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!

The interference was explained by the automation of reading, where the mind automatically determines the semantic meaning of the word (it reads the word "red" and thinks of the color "red"), and then must intentionally check itself and identify instead the color of the word (the ink is a color other than red), a process that is not automated.

Several theories are used to explain the Stroop effect :

- *Processing speed* : there is a lag in the brain's ability to recognize the color of the words since the brain reads words faster than it recognizes.
- *Selective attention* : color recognition as opposed to reading words, requires more attention.

- *Automaticity* : since recognizing colors is not an “automatic process” there is hesitancy to respond; whereas, the brain automatically understands the meaning of words as a result of habitual reading.
- *Parallel distributed processing* : as the brain analyses information, different and specific pathways are developed for different tasks. Some pathways, such are reading, are stronger than others, therefore, it is the strength of the pathway and not the speed of the pathway that is important.

Variations of the Stroop test :

- *Warped words* : Much like the Stroop task, the printed word's color is different from the ink color of the word; however, the words are printed in such a way that it is more difficult to read.
- *Emotional* : In an emotional Stroop task, an individual is given negative emotional words like "grief," "violence," and "pain" mixed in with more neutral words like "clock," "door," and "shoe". Just like in the original Stroop task, the words are colored and the individual is supposed to name the color.
- *Spatial* : An up or down-pointing arrow appears randomly above or below a central point. Despite being asked to discriminate the direction of the arrow while ignoring its location, individuals typically make faster and more accurate responses to congruent stimuli than to incongruent ones.
- *Numerical* : A digit can be presented as big or small, irrespective of its numerical value. Comparing digits in incongruent trials is slower than comparing digits in congruent trials and the difference in reaction time is termed the numerical Stroop effect.
- *Reverse* : individuals are shown a page with a black square with an incongruent colored word in the middle — for instance, the word "red" written in the color green — with four smaller colored squares in the corners. One square would be colored green, one square would be red, and the two remaining squares would be other colors. Studies show that if the individual is asked to point to the color square of the written color (in this case, red) they would present a delay. Thus, incongruently-colored words significantly interfere with pointing to the appropriate square.

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7. References

Wikipedia article
R script used for this project