Statistics: The Science of Decisions

1. 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.

2. Investigation

Independent Variable

Congruent and incongruent words conditions (i.e. color congruency).

Dependent Variable

The time in seconds it takes to name the ink colors, in equally-sized lists.

Hypothesis Test

We want to see if there is a significant difference between the time it takes to name the ink colors in each condition. While we are trying to infer hypotheses about the populations, the datasets provided are samples of the two populations, therefore we are going to perform a hypothesis test about whether or not the population means are the same for congruent and incongruent word conditions.

Our **Null Hypothesis** (H0) is that there is not a significant difference between the two populations, meaning that the two samples are different by chance:

H0: $\mu Co = \mu In$ or $\mu Co - \mu In = 0$,

where μCo stands for the population mean of the Congruent condition and μIn stands for the population mean of the Incongruent one.

Our **Alternative Hypothesis** (Ha) is that there exists a significant difference between the two populations and population means:

Ha: $\mu Co \neq \mu In$ or $\mu Co - \mu In \neq 0$

Statistical Test

In order to prove the Null Hypothesis true or false we need to perform a statistical test. Looking in the provided dataset we can notice that we have less than 30 samples, we don't know the population's standard deviation, our samples are dependent (t paired) samples and we assume that the distributions are Gaussian. Based on the above mentioned, the most fitting statistical test to perform is a paired-sample t-test. In other words, we will consider the provided paired samples as similar to a one-sample t-test, based on the differences of the two populations. Since our alternative hypothesis is whether $\mu Co \neq \mu In$ or not, we are going to use a two-tailed paired-sample t-test.

3. Descriptive statistics

Measures of centrality

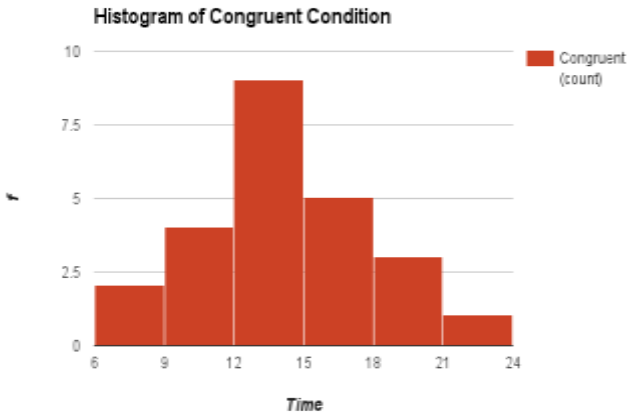
	Mean	Median
Congruent Condition	**14.05**	**14.36**
Incongruent Condition	**22.02**	**21.02**

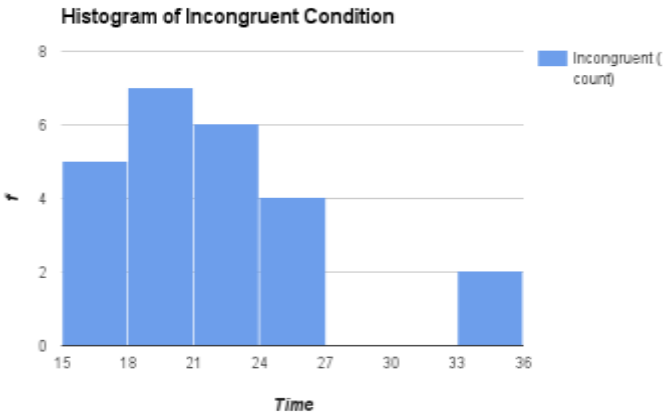
Measures of variability

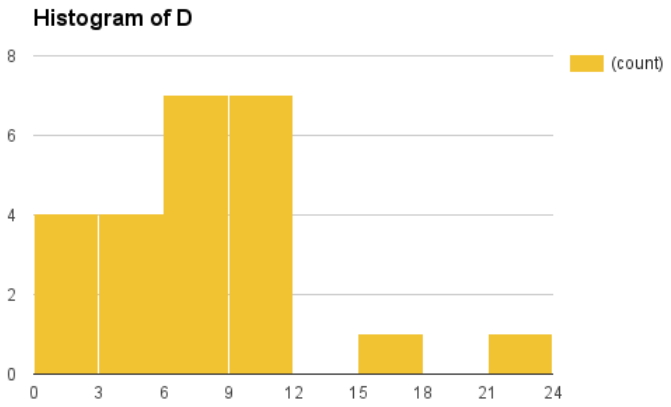
	Variance	Standard Deviation
Congruent Condition	**12.67**	**3.56**
Incongruent Condition	**23.01**	**4.8**
Paired Condition (D)	**23.67**	**4.86**

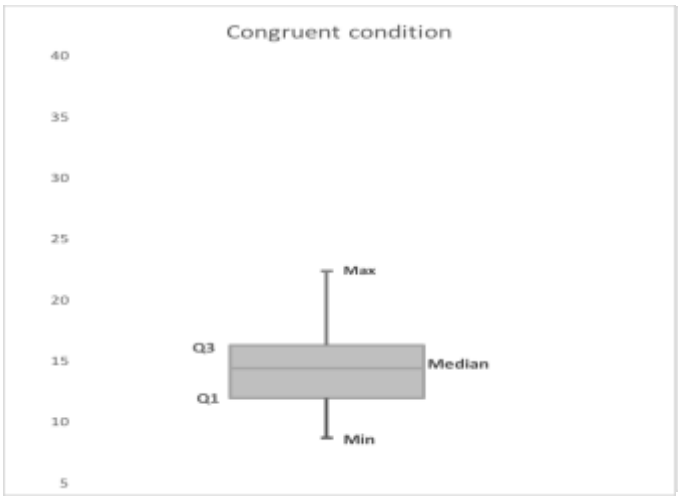
4. Data distributions

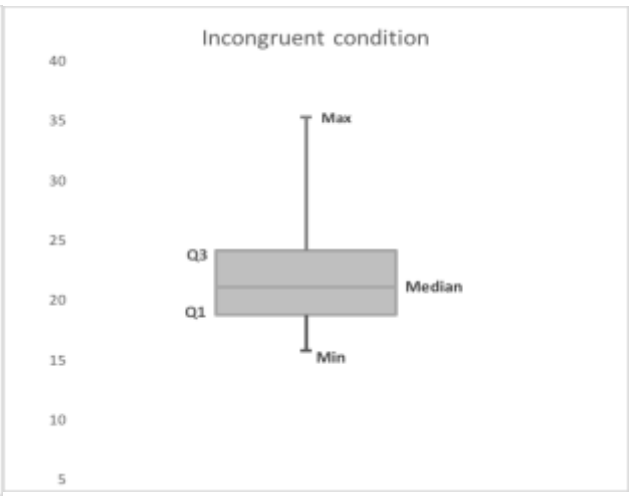
In the following series of figures, we provide box plots and Histograms to visualize the data distribution for Congruent and Incongruent conditions as well as their difference (D). The graphs demonstrate that there exists a clear tendency to higher response times concerning the Incongruent condition.


Histogram of Congruent Condition
Congruent (count)
10
7.5
5
2.5
0
6
9
12
15
18
21
24
Time


Histogram of Incongruent Condition
Incongruent (count)
8
6
4
2
0
15
18
21
24
27
30
33
36
Time


Histogram of D
(count)
8
6
4
2
0
0
3
6
9
12
15
18
21
24


Congruent condition
40
35
30
25
20
15
10
5
Max
Q3
Median
Q1
Min


Incongruent condition
40
35
30
25
20
15
10
5
Max
Q3
Median
Q1
Min

5. Statistical Test

We want to see whether there is a significant difference between the time it takes to name the ink colors in each condition. The given data set is dependent t-paired samples so we perform a two-tailed paired-sample t-test . We can think of a dependent samples (paired) t-test as being similar to a one-sample t-test on the differences of the two populations.

Point estimate

The difference between the two sample means:

$\mu Co - \mu In = -7.96$

Standard deviation

We want to know how this compares to other differences, so we need to find the Standard deviation (s) of the difference of the sample means:

$s = 4.86$

Standard error

$SE = \sigma / \sqrt{n} \Rightarrow SE = -8.02$, where n the sample population equal to 24.

Following we calculate the t-statistic:

$t = \mu Co - \mu In / SE \Rightarrow t = -8.02$

Now is there a significant difference between μCo & μIn? We use a confidence level of 95%, therefore an alpha level α=0.05, with 0.025 in each tail and so we use t-table [5] in order to calculate the t critical value for n-1= 23 degrees of freedom:

$t\ critical = \pm 2.069$

Finally, we calculate the p-value, which indicates the probability of obtaining the given t value by chance alone [6]:

$p\ value < 0.0001$

Comparing the two-tailed P value and our alpha level, the difference is considered to be extremely statistically significant.

To summarize, since the t-statistic equal to -8.02 lies not only within the critical regions but is far beyond the t-critical, we reject the null hypothesis H0. Therefore, the test results indicate that participants made significant different average time to name the ink colour, between the two examined conditions, in other words the dependent variable (to name the ink colours) has significantly changed due to the applied treatment. Clearly the test results match up our own expectations, that significant more time is needed to name the colours in the second incongruent condition.

6. Conclusions

One reason responsible for the effects observed could be the "Speed of Processing" hypothesis, where this model suggests that humans can process words much faster than they process colors. In this case, testing “a situation of incongruency between words and colors, when the task is to report the color, the word information arrives at the decision process stage earlier than the color information and results in processing confusion. On the other hand, when the task is to report the word, because the color information lags behind the word information, a decision can be made before the conflicting color information arrives”. The Stroop effect extends to an alternative task which presents similar effect, when words are replaced with non-words that sound like color words (e.g. wred and bloo).