Statistics: The Science of Decisions

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

Q1. What is our independent variable? What is our dependent variable?

Answer

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

Dependent Variable: The time in seconds it takes to name the ink colours, in equally-sized lists.

Q2. What is an appropriate set of hypotheses for this task? What kind of statistical test do you expect to perform? Justify your choices.

Answer

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.

Hypothesis Test

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:

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

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:

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

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 [1] [2]. 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.

Q3. Report some descriptive statistics regarding this dataset. Include at least one measure of central tendency and at least one measure of variability.

Answer

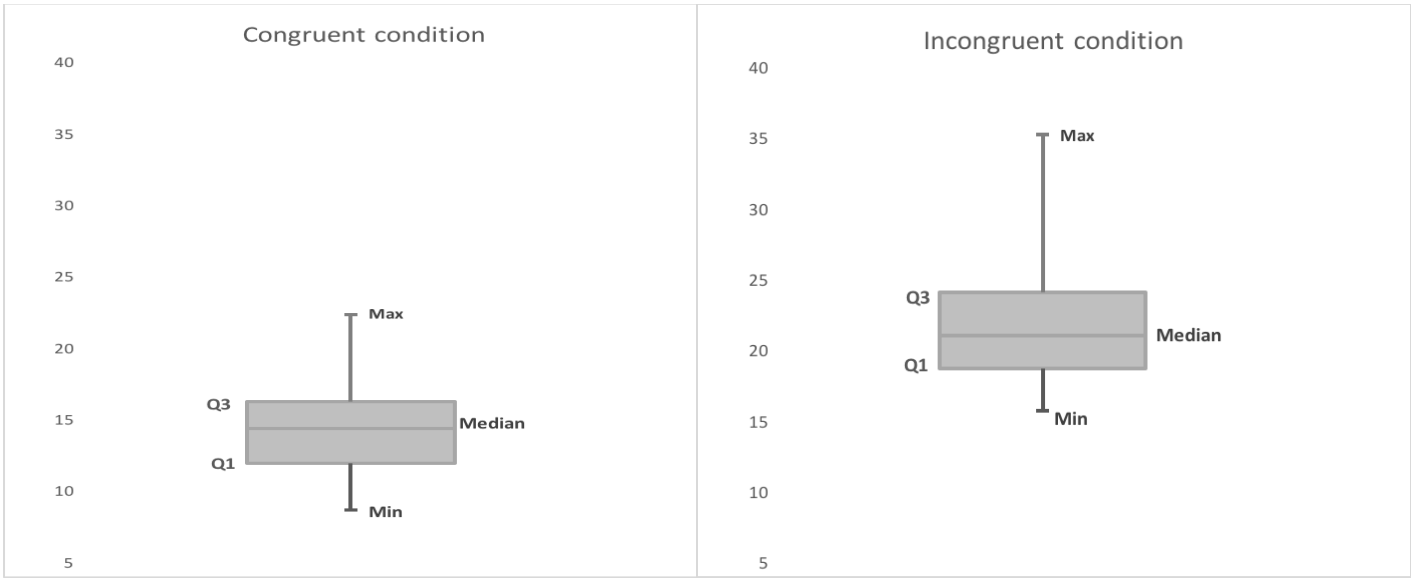
A. Measures of centrality for the dataset's groups		
	Mean	**Median**
Congruent Condition	14.05	14.36
Incongruent Condition	22.02	21.02

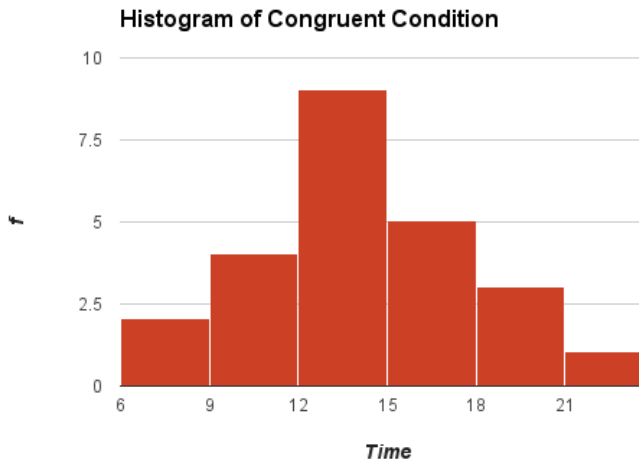
B. Measures of variability for the dataset's groups		
	Variance	**Standard Deviation**
Congruent Condition	12.67	3.56
Incongruent Condition	23.01	4.8
Paired Condition (D)	23.67	4.86

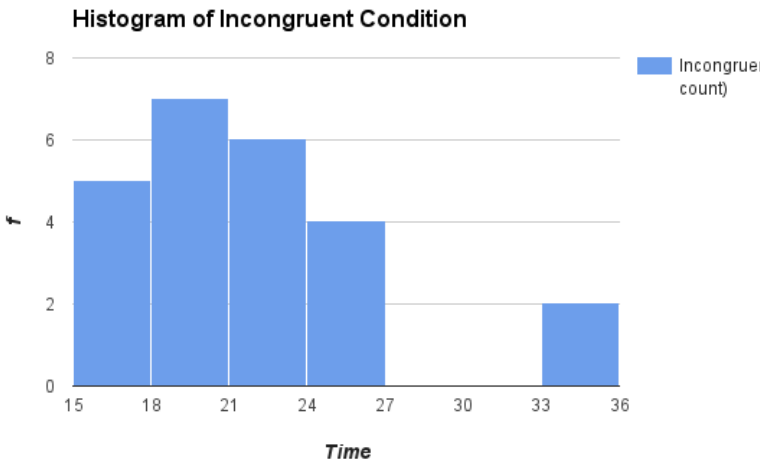
Q4. Provide one or two visualizations that show the distribution of the sample data. Write one or two sentences noting what you observe about the plot or plots.

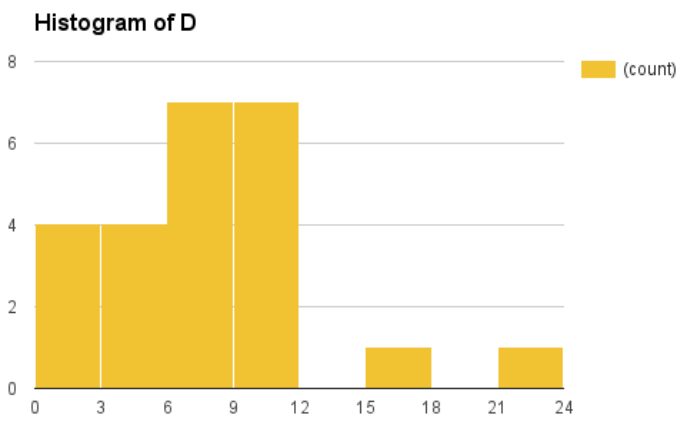
Answer

In the following series of figures we provide box plots and Histograms to visualise 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.









Q5. 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?

Answer

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 [3][4]. 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.

The Point estimate, is the difference between the two sample means:

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

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:

$$s = 4.86$$

Then we calculate 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]:

$$p \text{ value} < 0.0001$$

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.

Q6. 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!

Answer

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”. [7]

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). [7]

References

[1] Statistics How To. *When to use a t score*. Available at *http://www.statisticshowto.com/when-to-use-a-t-score-vs-z-score/* (Accessed 5th January 2016).

[2] Minitab 17. *Types of t-tests.* Available at http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/hypothesis-tests/tests-of-means/types-of-t-tests/(Accessed 5th January 2016).

[3] Udacity. *t-Tests*. Available at https://storage.googleapis.com/supplemental_media/udacityu/4578095863/Lesson10.pdf (Accessed 1st December 2015).

[4] Northern Arizona University. *Understanding the dependent-samples t test.* Available at http://oak.ucc.nau.edu/rh232/courses/EPS525/Handouts/Understanding%20the%20Dependent%20t%20Test.pdf (Accessed 12th December 2015).

[5] Amazon Simple Storage Service. *T distribution critical values.* Available at https://s3.amazonaws.com/udacity-hosted-downloads/t-table.jpg (Accessed 10th December 2015).

[6] GraphPad. *T Statistical distributions and interpreting P values.* Available at http://www.graphpad.com/quickcalcs/ (Accessed 15th December 2015).

[7] Rochester Institute of Technology. *Background on the Stroop effect.* Available at http://www.rit.edu/cla/gssp400/sbackground.html (Accessed 8th December 2015).