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Testing a Perceptual Phenomenon Project – Data Analysis of the Stroop Effect

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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."

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

   The independent variable is the two different conditions in which the test is conducted, while the dependent variable is the amount of time in seconds it takes to read out loud the colors that are shown in equally-sized lists.

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

   The null hypothesis, H_0, is that there is no statistically significant difference between the average time in seconds for the congruent condition vs. the incongruent condition. When subtracting the population mean of the congruent condition, μ_c, from the population mean of the incongruent condition, μ_{ic}, the result is zero.
   Algebraically, H_0: $\mu_c - \mu_{ic} = 0$.

   The alternative hypothesis, H_a, would state that there is a significant difference between the averages of these two conditions. When subtracting the population mean of the congruent condition, μ_c, from the population mean of the incongruent condition, μ_{ic}, the result is not zero.
   Algebraically, H_a: $\mu_c - \mu_{ic} \neq 0$

For testing these hypotheses, t-test will be used based on the following assumptions:

- The population mean is represented by the sample mean and data was collected from a randomly selected portion of the total population. In our case, we have less than 30 samples.
- We do not know the population sample deviation; therefore, the sample standard deviation will be calculated using Bessel's correction.
- The data, when plotted, will be normally distributed.

Generally, if the values in one sample affect the values in the other sample, then the samples are dependent. Since the values in our analysis are taken from the same people and we are comparing two conditions (congruent and incongruent), we can conduct a dependent t-test for paired samples at $\alpha = 0.05$ in order to test the hypothesis.

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

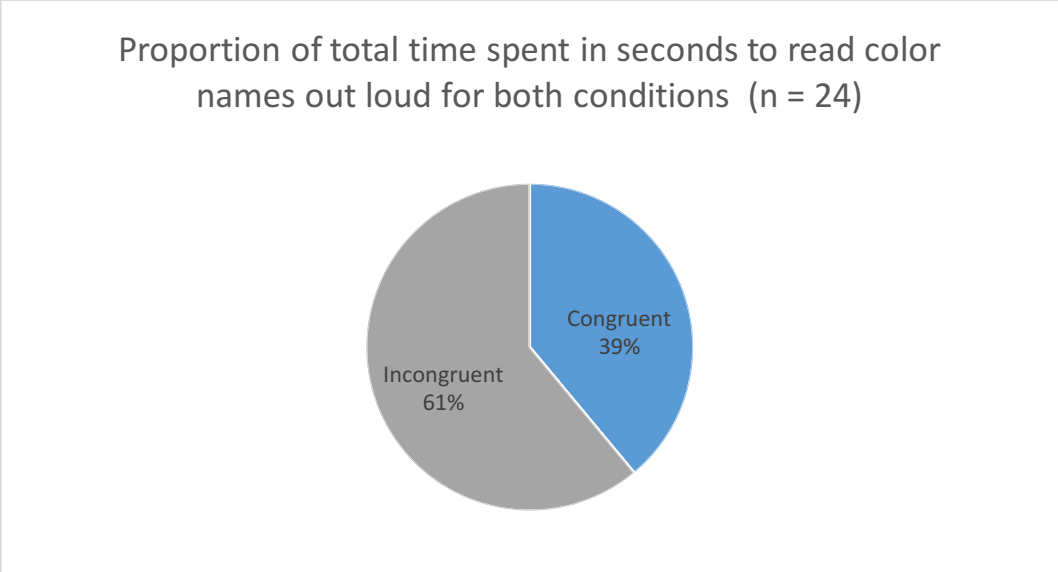
Our dataset contains 24 values for both the congruent and incongruent group, which is our sample size.
n = 24
degrees of freedom, df = 23

In the table below, there are some descriptive statistics:

Congruent			***Incongruent***
Mean	14.051125	Mean	22.01591667
Standard Error	0.726550901	Standard Error	0.979195185
Median	14.3565	Median	21.0175
Mode	#N/A	Mode	#N/A
Standard Deviation	3.559357958	Standard Deviation	4.797057122
Sample Variance	12.66902907	Sample Variance	23.01175704
Kurtosis	-0.205224823	Kurtosis	2.688900198
Skewness	0.416899874	Skewness	1.547590026
Range	13.698	Range	19.568
Minimum	8.63	Minimum	15.687
Maximum	22.328	Maximum	35.255
Sum	337.227	Sum	528.382
Count	24	Count	24

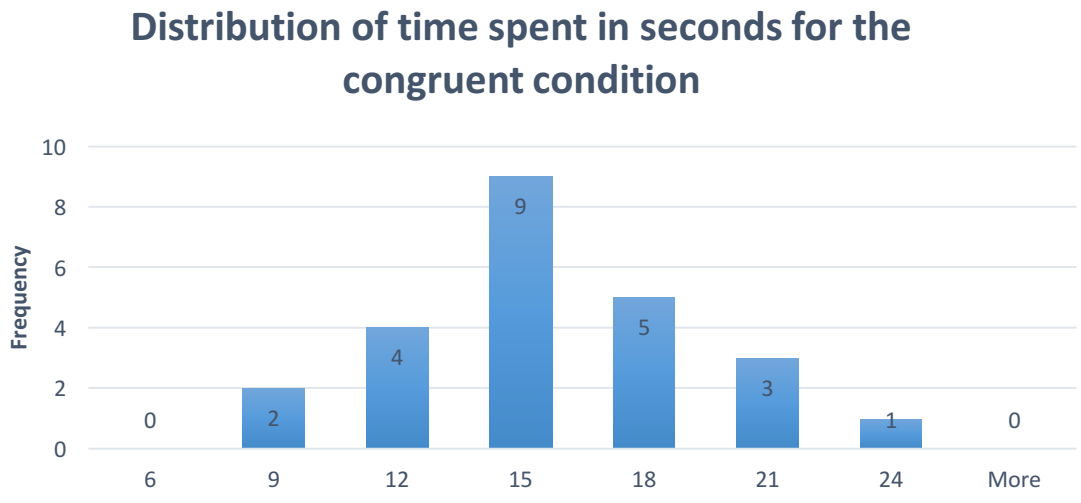
Therefore, $\mu_c = 14.0511$ and $\mu_{ic} = 22.0159$, with $s_c = 3.5594$ and $s_{ic} = 4.7971$.

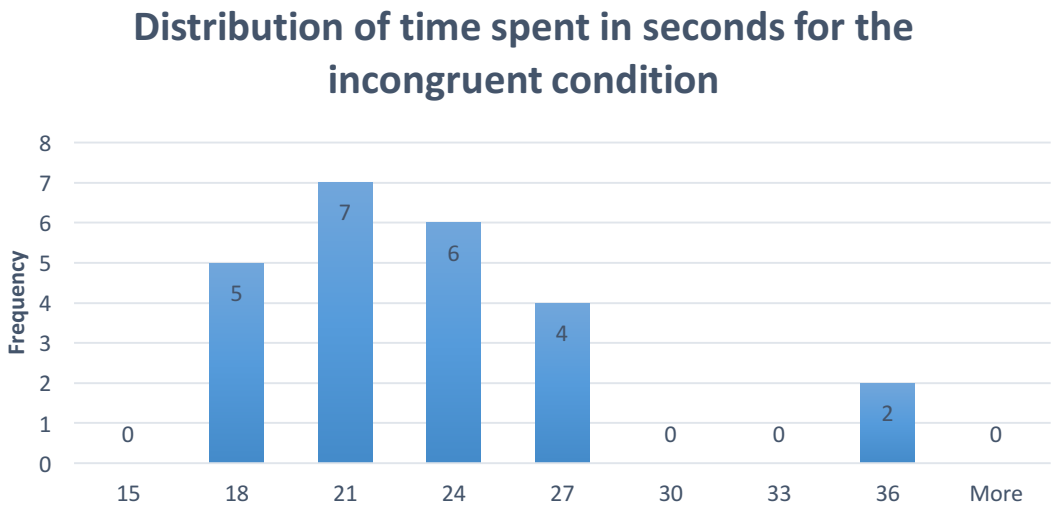
4. Provide one or two visualizations that show the distribution of the sample data. Write one or two sentences noting what you observe about the plot or plots.



The pie chart above shows the percentage of the total time spent in seconds for the two conditions. We can see, that people overall spent about 21% more time in seconds where the color words did match the colors in which they were printed.

The distribution of time spent can be visualized for both groups as such:





As we can see, the values of the time spent for the congruent condition are normally distributed. For the incongruent condition, there are two values that make the histogram positively skewed, however, those values are not too extreme to be considered as outliers and we will include them in the calculations.

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?

   The point estimate, or the mean difference in the two population, $\mu_d = \mu_c - \mu_{ic}$ equals to -7.965. The standard deviation of the difference, $s_d = 4.865$. Therefore, t = -8.021.

   The $t_{critical}$ value at $\alpha = 0.05$ for a two-tailed t-test is $\pm$ 2.069.

   Conclusion: By using the website of *Graphpad Software*, link in the References section, the p value is calculated to be less than 0.0001. Since the value of our t-test falls into the critical region with $p < \alpha$, we reject the null hypothesis. Therefore, there is a statistically significant difference between the average time in seconds between the congruent condition and the incongruent condition.

   Cohen's d is the appropriate effect size measure if two groups have similar standard deviations and are of similar size. Cohen's d, in this example, has a value of -1.637. This is considered a "large" effect size, and confirms the conclusion.

The 95% confidence interval for the mean difference is (-10.020, -5.910). This means that the difference in between the average time in seconds the for the congruent condition, or where people are presented with matching color names to read out loud, is from 5.910 to 10.020 seconds shorter than under the incongruent condition. This result would match my expectations, as it seems to be realistic to spend more time reading out loud color names where the word is not matching.

References:

1. Hypothesis testing explained from Minitab, http://support.minitab.com/en-us/minitab/17/topic-library/basic-statistics-and-graphs/hypothesis-tests/tests-of-means/how-are-dependent-and-independent-samples-different/
2. The Stroop effect from Wikipedia, https://en.wikipedia.org/wiki/Stroop_effect
3. Stroop Interactive Test, https://faculty.washington.edu/chudler/java/strvote.html
4. Udacity's Data Analyst Nanodegree Program Statistics lecture
5. Graphpad Software website, http://www.graphpad.com/quickcalcs