

P1: Test a Perceptual Phenomenon - Statistics: The Science of Decisions Project

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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. QUESTIONS FOR INVESTIGATION

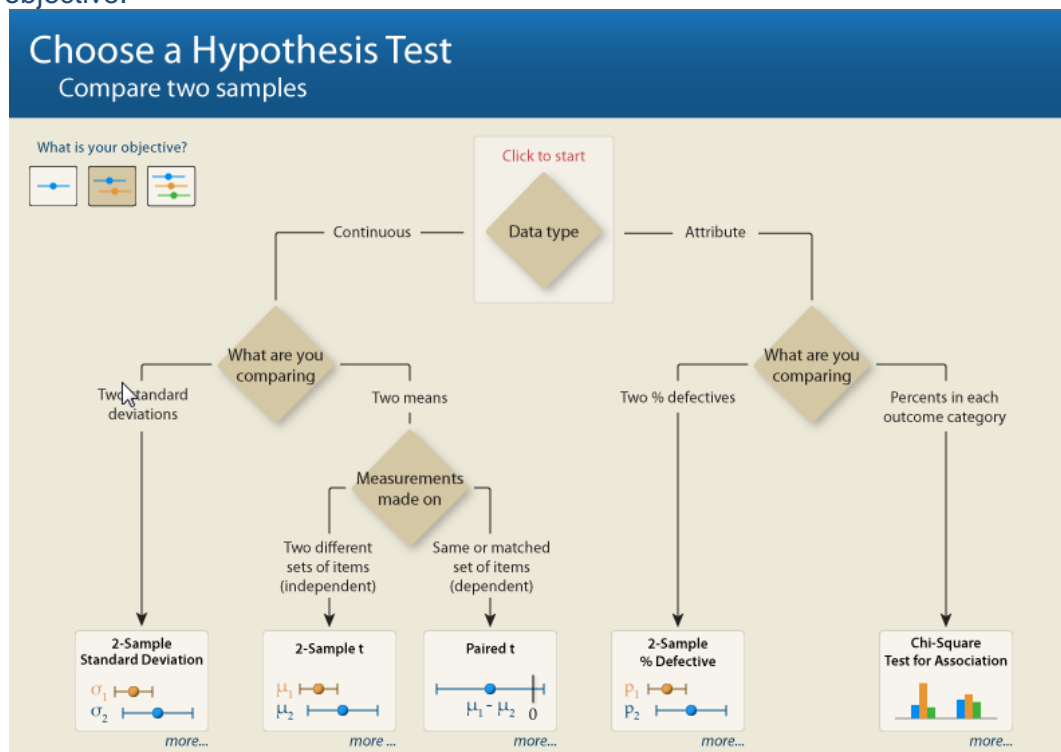
As a general note, be sure to keep a record of any resources that you use or refer to in the creation of your project. You will need to report your sources as part of the project submission.

2.1 WHAT IS OUR INDEPENDENT VARIABLE? WHAT IS OUR DEPENDENT VARIABLE?

An independent (input) variable is the variable of the experiment that is manipulated by the researcher. In our case the independent variable is the congruent and incongruent conditions. A dependent (output) variable is the variable of an experiment with which the researcher can measure changes. The dependent variable is the time of performing the test measured in seconds.

2.2 WHAT IS AN APPROPRIATE SET OF HYPOTHESES FOR THIS TASK? WHAT KIND OF STATISTICAL TEST DO YOU EXPECT TO PERFORM? JUSTIFY YOUR CHOICES.

In my day to day work I use the Minitab software. The assistant helps you make decisions based on your objective.



"In psychology, the Stroop effect is a demonstration of **interference in the reaction time of a task**. When the name of a color (e.g., "blue", "green", or "red") is printed in a color that is not denoted by the name (e.g., the word "red" printed in blue ink instead of red ink), **naming the color of the word takes longer and is more prone to errors** than when the color of the ink matches the name of the color." (Source: Wikipedia)

Therefore with the set of data provided I want to test the hypothesis made by John Ridley Stroop and demonstrate that the means of the two samples (μ) are different.

I will compare the two samples of continuous data of same set of items because I understand that each row of the data is made of two values obtained by the same person.

Therefore if I want to see the difference of reading of the two conditions I will perform the "Pair-t test" and as optional the "2-Sample Standard deviation test". In this way I can identify:

- if the mean (μ) for the two dependent populations are different. A paired t-test is appropriate for testing the mean difference between paired observations when the paired differences follow a normal distribution. A paired t-test matches responses that are dependent or related in a pairwise manner.

The null hypothesis for a paired t-test is: $H_0: \mu_d = \mu_0$, where:

- μ_d = the population mean of the differences
- μ_0 = the hypothesized mean of the differences

I can choose any one of three alternative hypotheses:

- $H_1: \mu_d > \mu_0$ One-tailed test
- $H_1: \mu_d < \mu_0$ One-tailed test
- $H_1: \mu_d \neq \mu_0$ Two-tailed test

(source: Minitab help).

The statistical parameter that will help me decide is: P- Value that in my case must be lower than 0,05 and the t-Value (test statistic) will give me the indication of which mean is greater and if it is different from zero.

$$t = (\bar{d} - \mu_0) / (sd / \sqrt{n})$$

- μ_0 = the hypothesized population mean of the differences
- \bar{d} = the mean of the paired sample differences
- sd = is the sample standard deviation of the paired sample differences
- n = the sample size.

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 (you do not need to submit your times to the site.) 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.

My results: Congruent: 14.447 and Incongruent 32.06

2.3 REPORT SOME DESCRIPTIVE STATISTICS REGARDING THIS DATASET. INCLUDE AT LEAST ONE MEASURE OF CENTRAL TENDENCY AND AT LEAST ONE MEASURE OF VARIABILITY.

The statistics parameters that describe:

- the central tendency are the mean (\bar{X}) and median
- the spread (variability) are the variance(σ^2) and standard deviation (σ)

With this we can compare the two data sets.

Descriptive Statistics: Congruent; Incongruent

Variable	N	Mean	SE Mean	St Dev	Minimum	Q1	Median	Q3	Maximum
Congruent	24	14,051	0,727	3,559	8,630	11,528	14,357	16,594	22,328
Incongruent	24	22,016	0,979	4,797	15,687	18,668	21,017	24,367	35,255

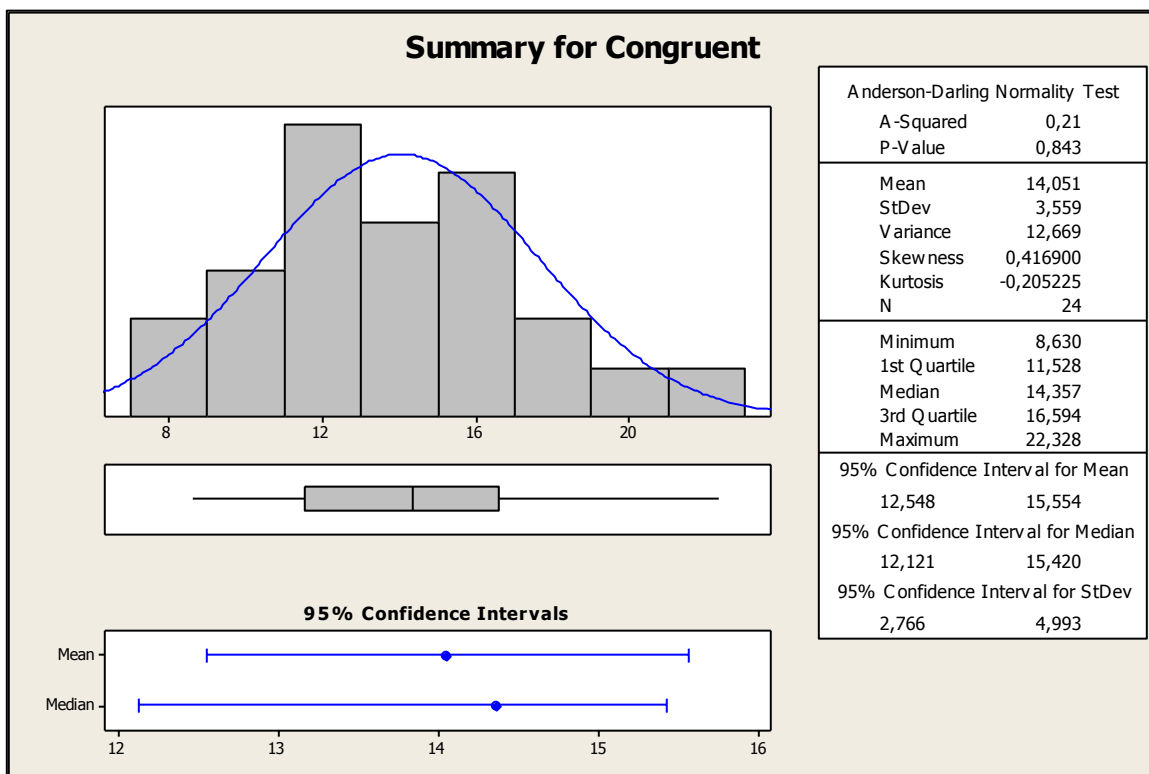
Where:

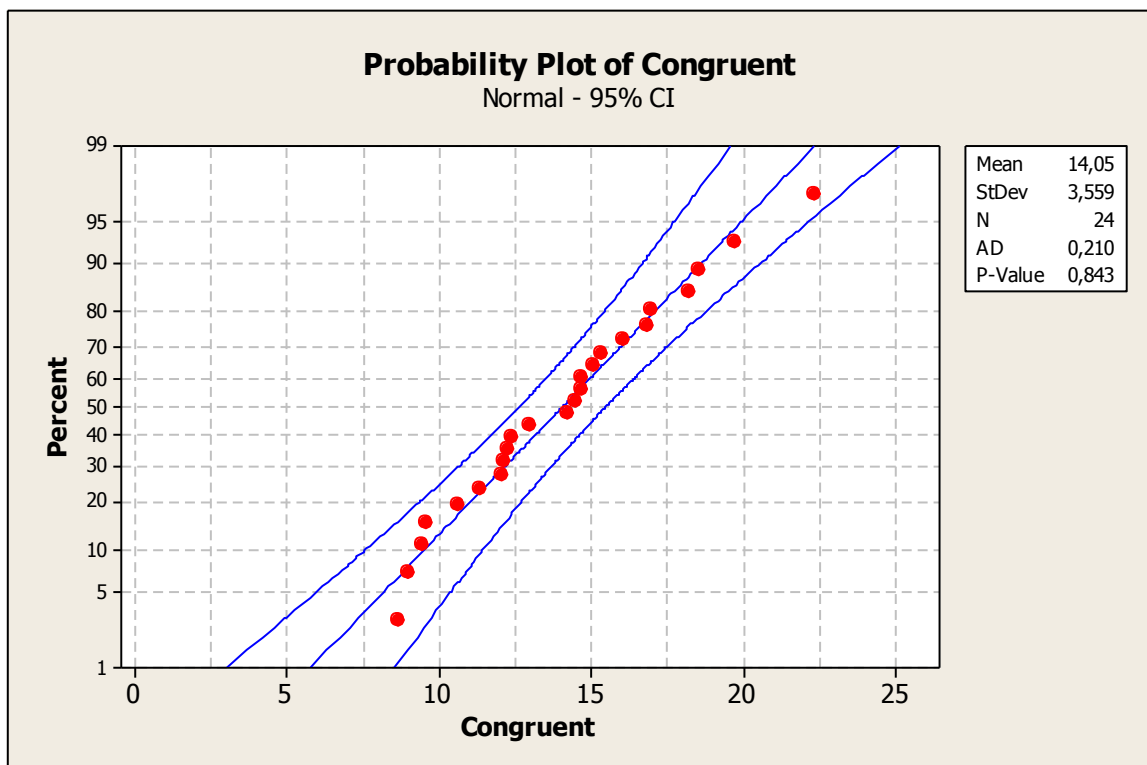
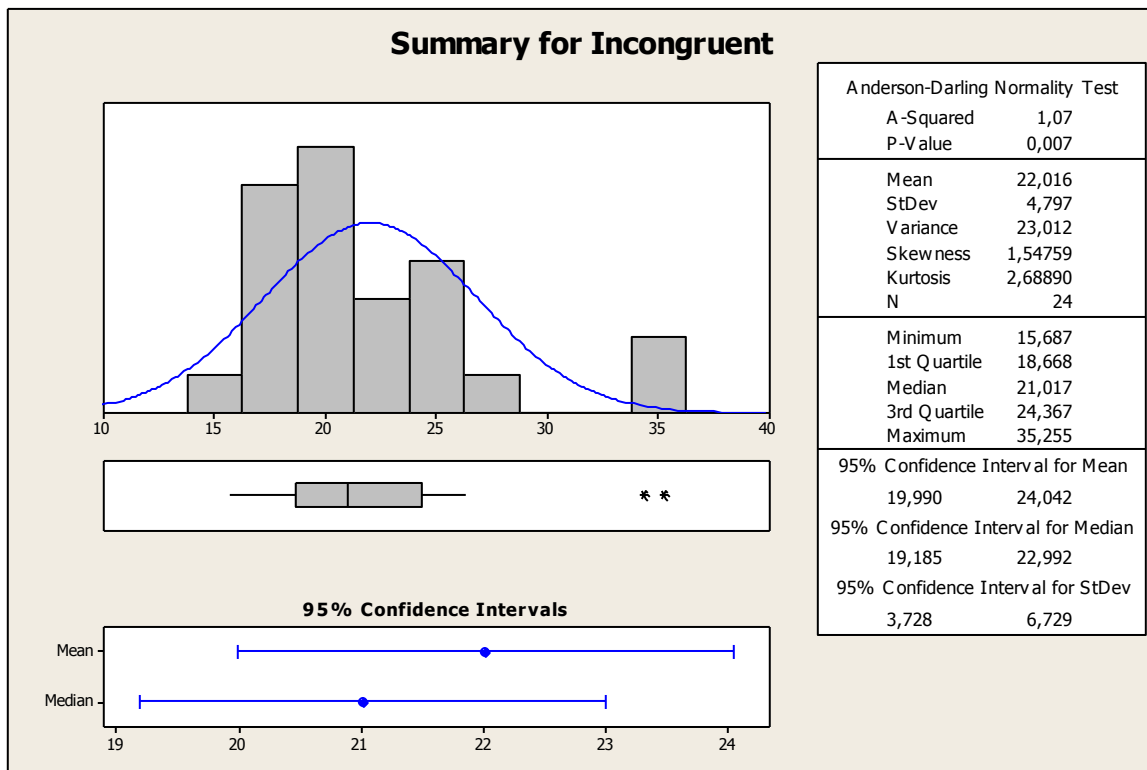
- N = sample size
- Mean value of the sample size ($\sum X_i/N$)
- Standard error of the mean (σ/\sqrt{N})
- Standard deviation
- Minimum and Maximum value
- Quartiles Q1(25% of data), Q2= median (50% of data) and Q3 (75% of data).

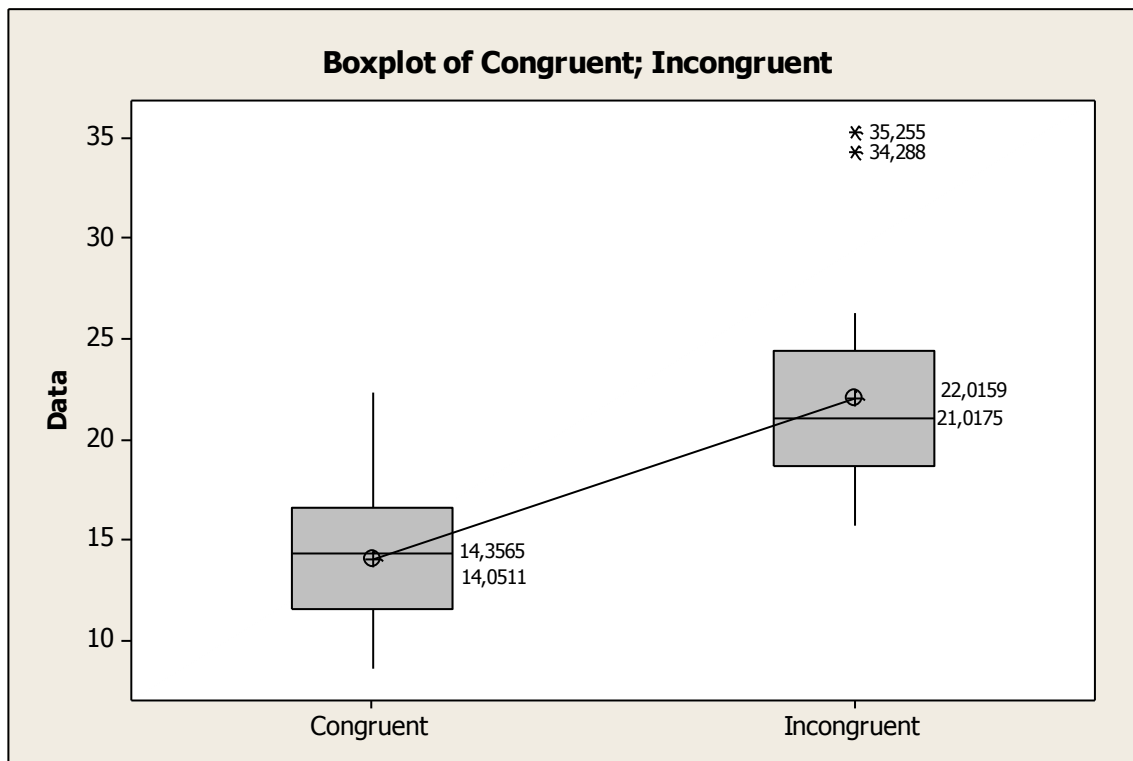
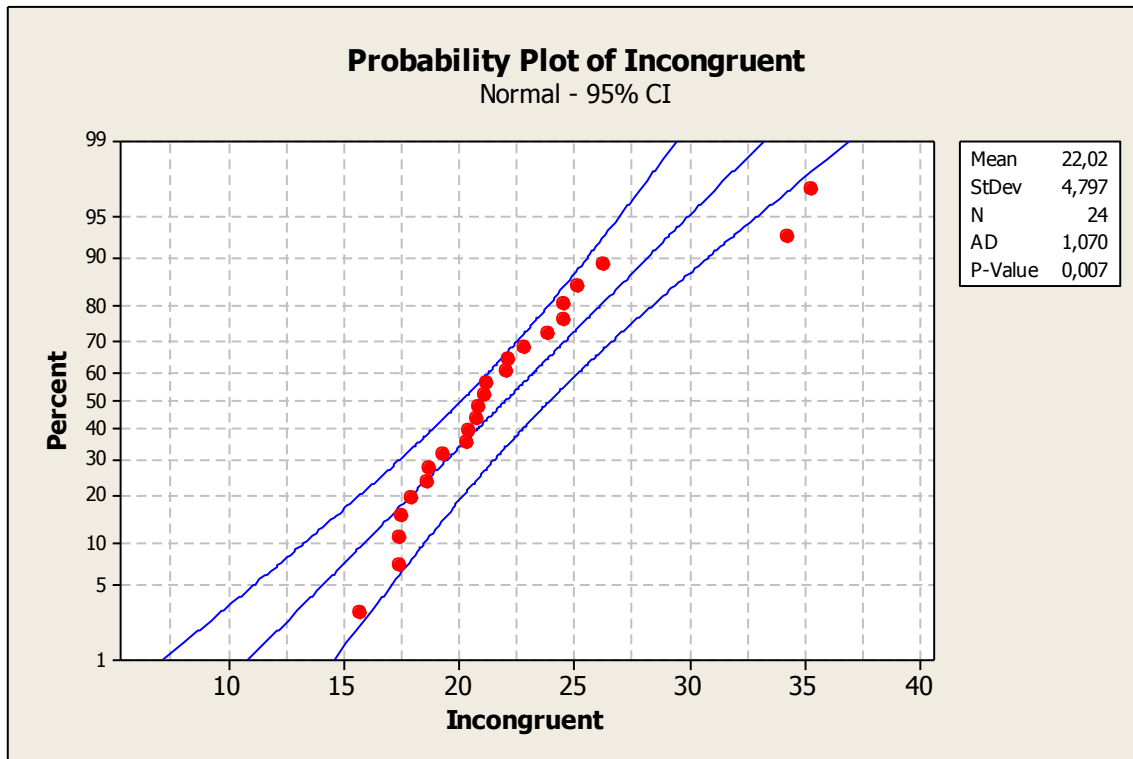
2.4 PROVIDE ONE OR TWO VISUALIZATIONS THAT SHOW THE DISTRIBUTION OF THE SAMPLE DATA. WRITE ONE OR TWO SENTENCES NOTING WHAT YOU OBSERVE ABOUT THE PLOT OR PLOTS.

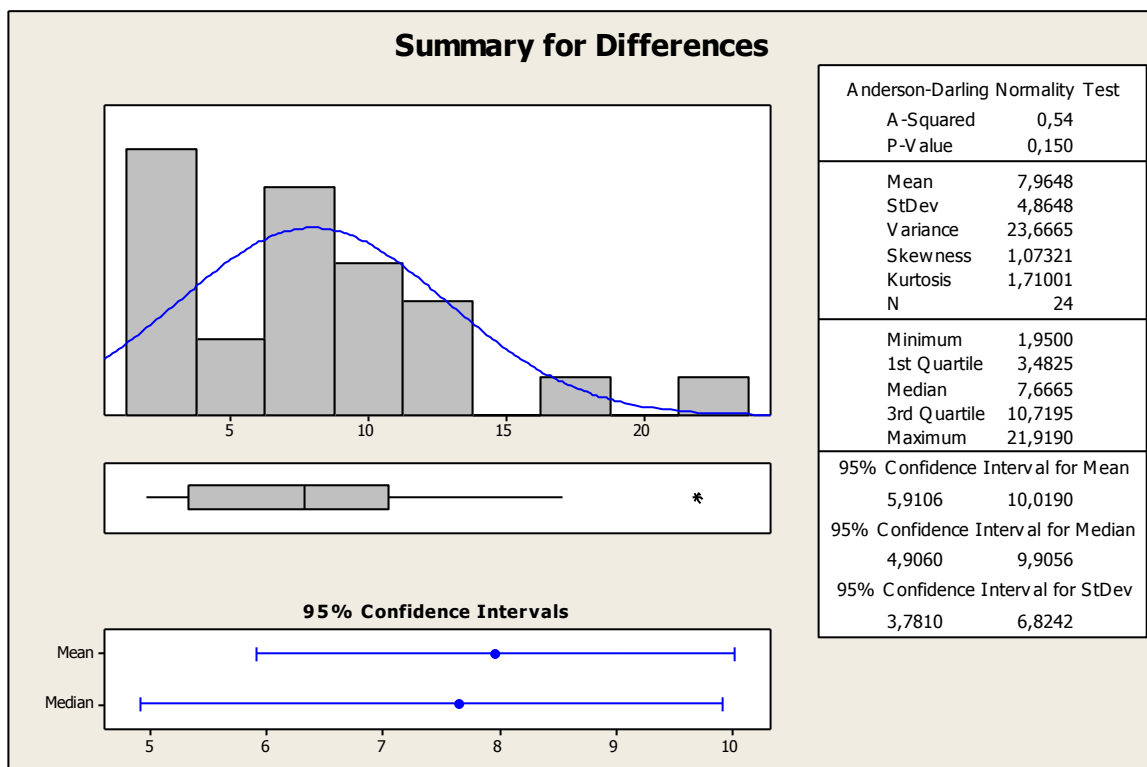
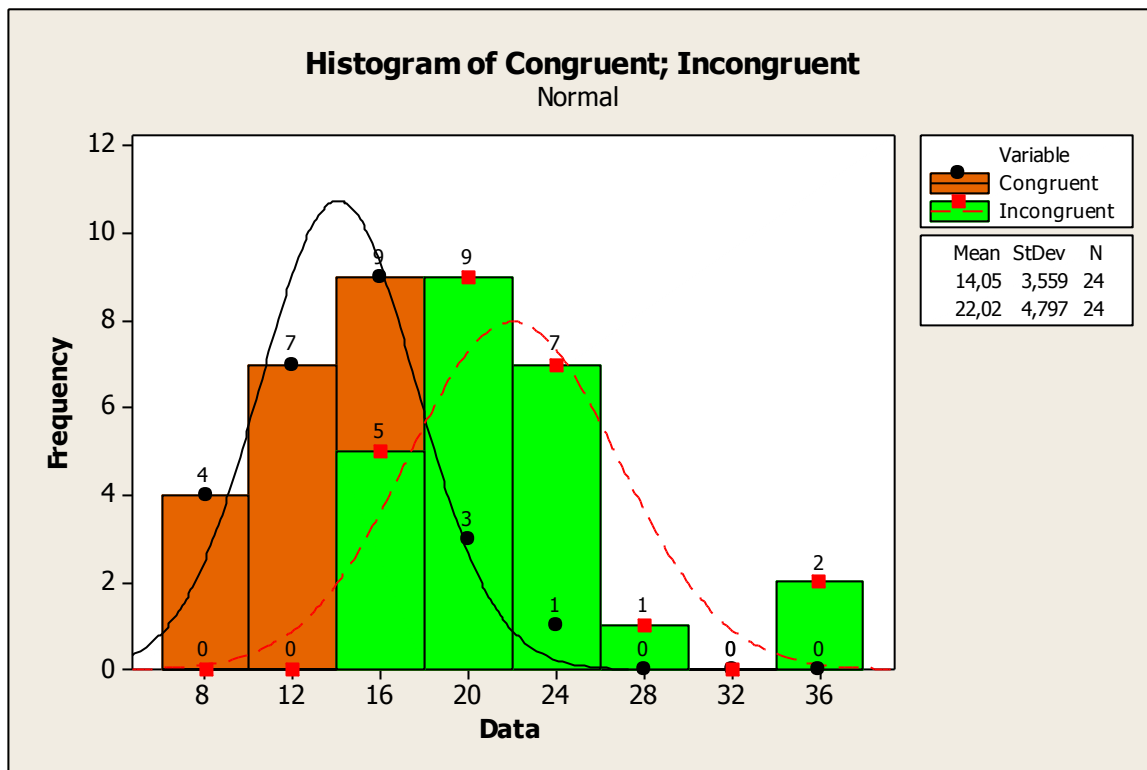
When I have a data set I usually start with the descriptive statistics and the distribution plot offered in Minitab. With the summary plot (histogram, boxplot and confidence interval for mean and median) I can immediately observe that the means are different and the processes have similar spreads. The congruent distribution is normal and the incongruent distribution is not normal (see P-Value). The normality is again confirmed / unconfirmed by the Probability plot where I can see the 2 outliers of the incongruent distribution.

The Plots I liked most are the two histograms in the same graphic and the boxplot of the two. With the two box plots in the same graphic I can visually observe the differences between the means that I will test later on. The data labels help me have also the values of the outliers, mean and medians. I plotted the distribution of the differences of the Congruent and Incongruent to check the normality.












The assumption of the normality of the differences is fulfilled (P-Value= 0,150 – greater than 0,05)

2.5 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?

Assumption:

Paired t Test for the Mean of Congruent and Incongruent Report Card		
Check	Status	Description
Unusual Data		One of the paired differences (row 20) is unusual compared to the others. Because unusual data can have a strong influence on the results, you should try to identify the cause of its unusual nature. Correct any data entry or measurement errors. Consider removing data that are associated with special causes and repeating the analysis.
Normality		Because your sample size is at least 20, normality is not an issue. The test is accurate with nonnormal data when the sample size is large enough.
Sample Size		The sample is sufficient to detect a difference between the means.

Paired T for Congruent – Incongruent result & stats:

	N	Mean	StDev	SEMean
Congruent	24	14,051	3,559	0,727
Incongruent	24	22,016	4,797	0,979
Difference	24	-7,965	4,865	0,993

95% CI for mean difference: (-10,019; -5,911)

T-Test of mean difference = 0 (vs not = 0): T-Value = -8,02 P-Value = 0,000

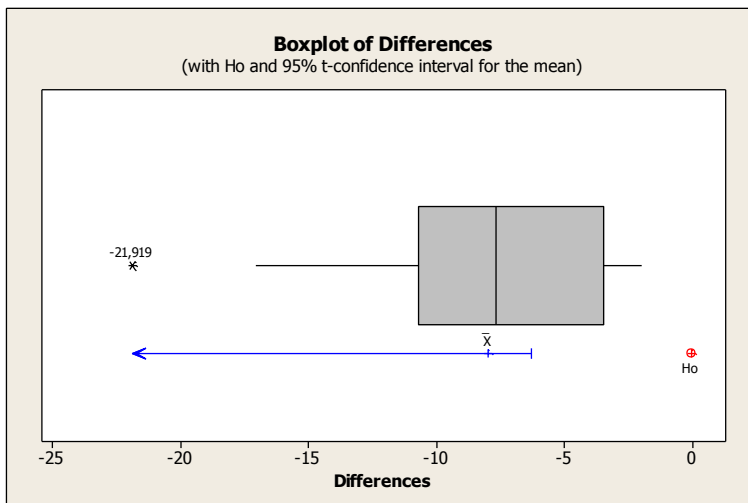
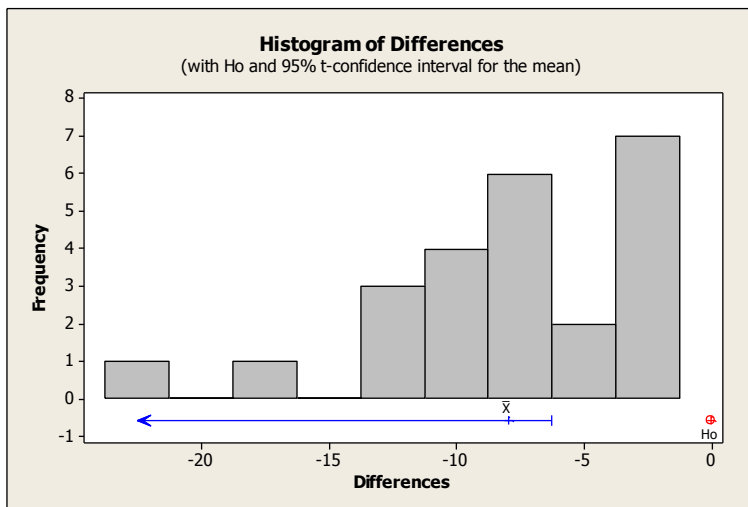
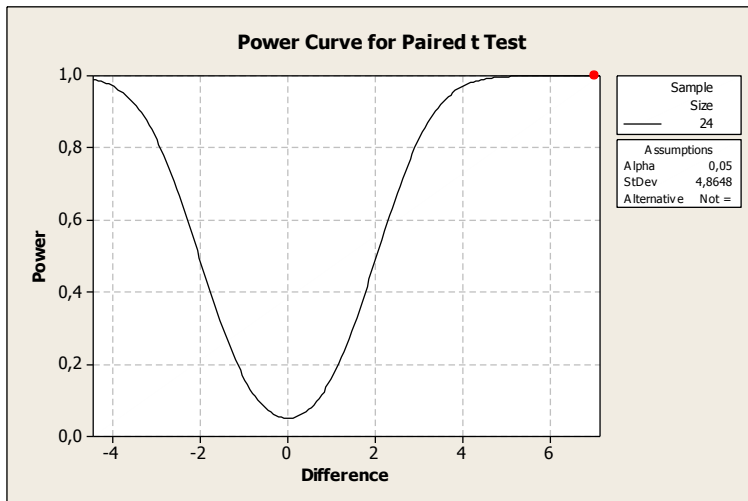
-- Test: I can conclude that the means differ at the 0,05 level of significance (P-Value < 0, 05). The mean of the paired differences is less than zero ($t \neq 0$, $t = -8,02$).

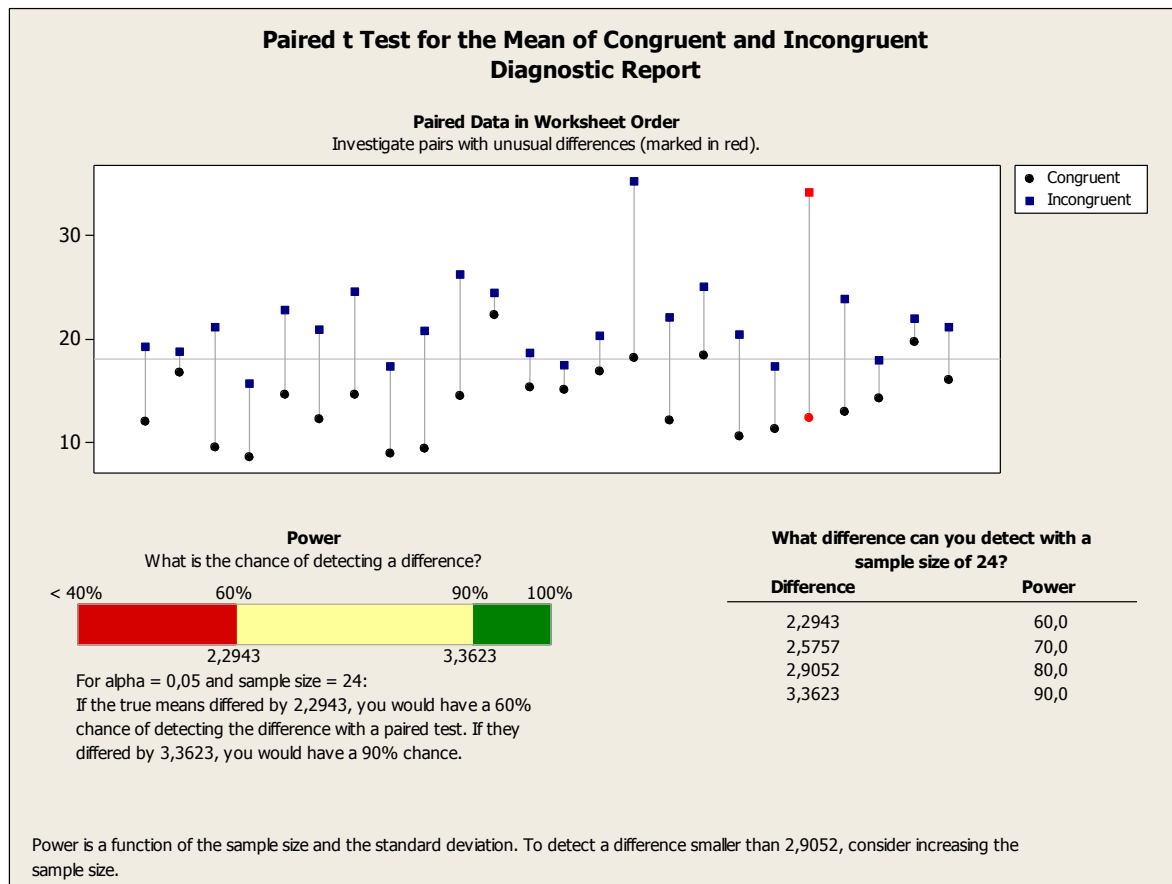
-- Confidence Interval: Quantifies the uncertainty associated with estimating the difference from sample data. I can be 95% confident that the true difference is between -10,019 and -5,9106.

-- Distribution of differences: The location of the distribution is shifted to the left compared with zero, so the mean of Incongruent is greater than the mean of congruent.

-Power test of sample size: 100%

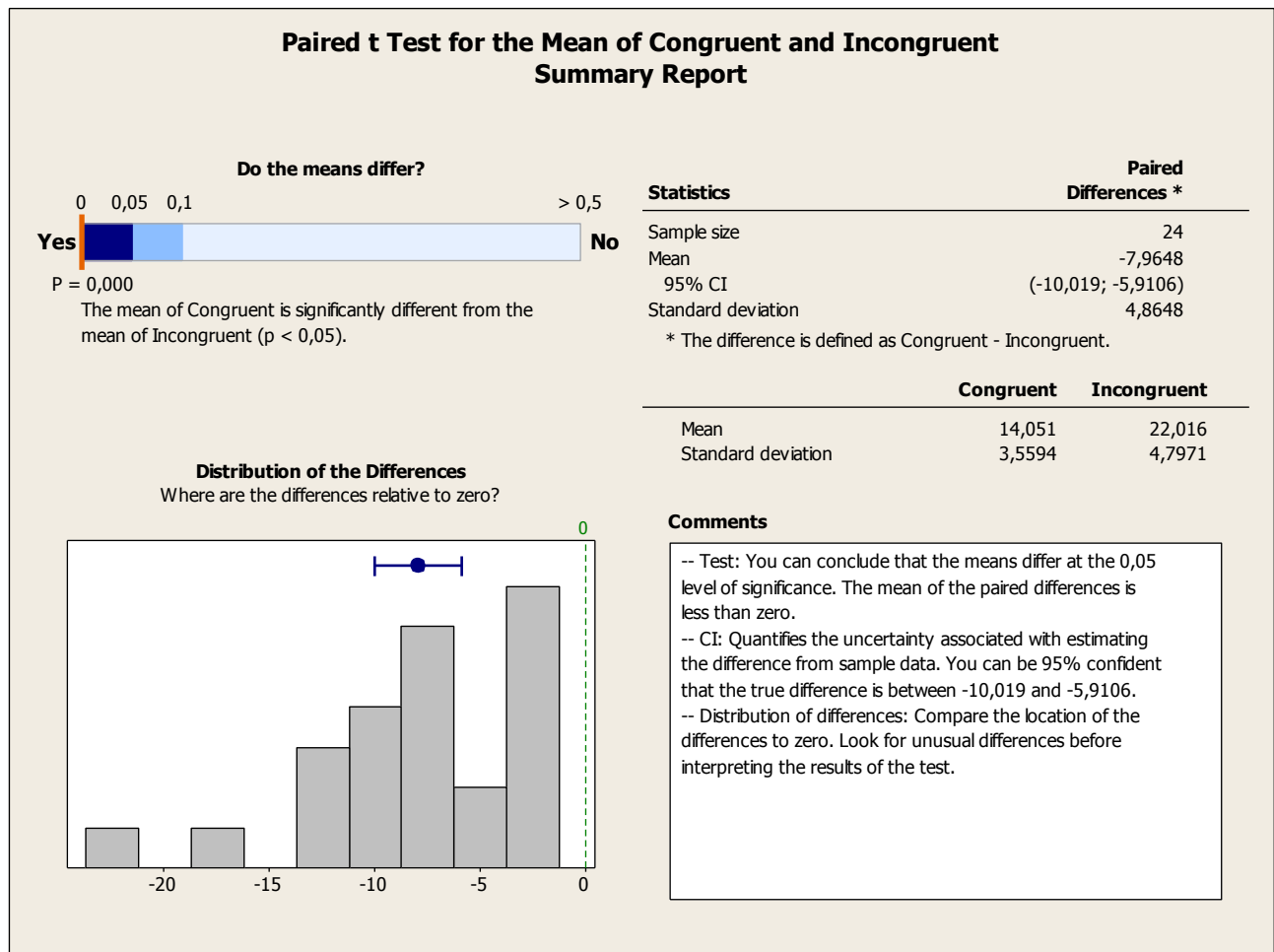
Therefore I can conclude that it takes more time to perform the test under the incongruent condition. This demonstrates Stroop effect.





An outlier can be observed. If I was the one performing the experiment I will check if the person number 20 has any annotation or exceptions.

↓	C1	C2	C3	C4
	Congruent	Incongruent	Differences	
1	12,079	19,278	7,199	
2	16,791	18,741	1,950	
3	9,564	21,214	11,650	
4	8,630	15,687	7,057	
5	14,669	22,803	8,134	
6	12,238	20,878	8,640	
7	14,692	24,572	9,880	
8	8,987	17,394	8,407	
9	9,401	20,762	11,361	
10	14,480	26,282	11,802	
11	22,328	24,524	2,196	
12	15,298	18,644	3,346	
13	15,073	17,510	2,437	
14	16,929	20,330	3,401	
15	18,200	35,255	17,055	
16	12,130	22,158	10,028	
17	18,495	25,139	6,644	
18	10,639	20,429	9,790	
19	11,344	17,425	6,081	
20	12,369	34,288	21,919	
21	12,944	23,894	10,950	
22	14,233	17,960	3,727	
23	19,710	22,058	2,348	
24	16,004	21,157	5,153	



2.6 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!

As we read almost automatically it takes more time to process an incongruent message; other influences might be tested such as: the mother tongue (if participants do not speak the language), adults vs. kids (different ability in reading), etc. Tests have been performed that tackle similar assessments:

- Different results in terms of number of practice sessions (practice) and time between practice sessions (interval); [Characterizing simultaneous time effects on practice for flight simulator performance among middle-aged and older pilots](#)
- Different results (in term of score) depending on the familiarity with the test: [“Scoring higher the second time around: meta-analyses of practice effects in neuropsychological assessment”](#).

3. APPENDIX – SOURCE REFERENCES

Minitab help (software from <https://www.minitab.com>)
https://en.wikipedia.org/wiki/Stroop_effect
<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4556540/#R5>
<https://www.ncbi.nlm.nih.gov/pubmed/22540222/>

4. APPENDIX - PROJECT SPECIFICATION

Test a Perceptual Phenomenon
 Responses to Project Questions

Criteria	Meets Specifications
Question 1: Identify variables in the experiment	Q1: Question response correctly identifies the independent and dependent variables in the experiment.
Question 2a: Establish hypotheses	Q2a: Null and alternative hypotheses are clearly stated in words and mathematically. Symbols in the mathematical statement are defined.
Question 2b: Establish a statistical test	Q2b: A statistical test is proposed which will distinguish the proposed hypotheses. Any assumptions made by the statistical test are addressed.
Question 3: Report descriptive statistics	Q3: Descriptive statistics, including at least one measure of centrality and one measure of variability, have been computed for the dataset's groups.
Question 4: Plot the data	Q4: One or two visualizations have been created that show off the data, including comments on what can be observed in the plot or plots.
Question 5: Perform the statistical test and interpret your results	Q5: A statistical test has been correctly performed and reported, including test statistic, p-value, and test result. The test results are interpreted in terms of the experimental task performed.
Question 6: Digging deeper and extending the investigation <i>Question 6 is optional and does not need to be answered in order to meet project specifications.</i>	Q6: Hypotheses regarding the reasons for the effect observed are presented. An extension or related experiment to the performed Stroop task is provided, that may produce similar effects.