THE STROOP EFFECT

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ABSTRACT

An experiment was conducted to see if stimuli conflicted with response time. This experiment was modeled after Stroop's experiment in 1935. Participants consisted of 24 students at Covenant University. Students were of various ethnicities and were of ages 18 and above.

Participants were shown 2 lists of the same eighteen words, spelling out colours. The participants were asked to read the colour of the ink and not the word. The first list showed words written in colours congruent to each word. The second showed words written in colours incongruent to each word. The independent variable was the ink colour used. The dependent variable was the time taken for the student to say the colour ink. Post-test only with control group design was used. Scores were analysed to find the range, mean, median, mode and standard deviation for each list. It was found that participants had trouble reading the list of incongruent coloured ink due to a conflict in stimuli.

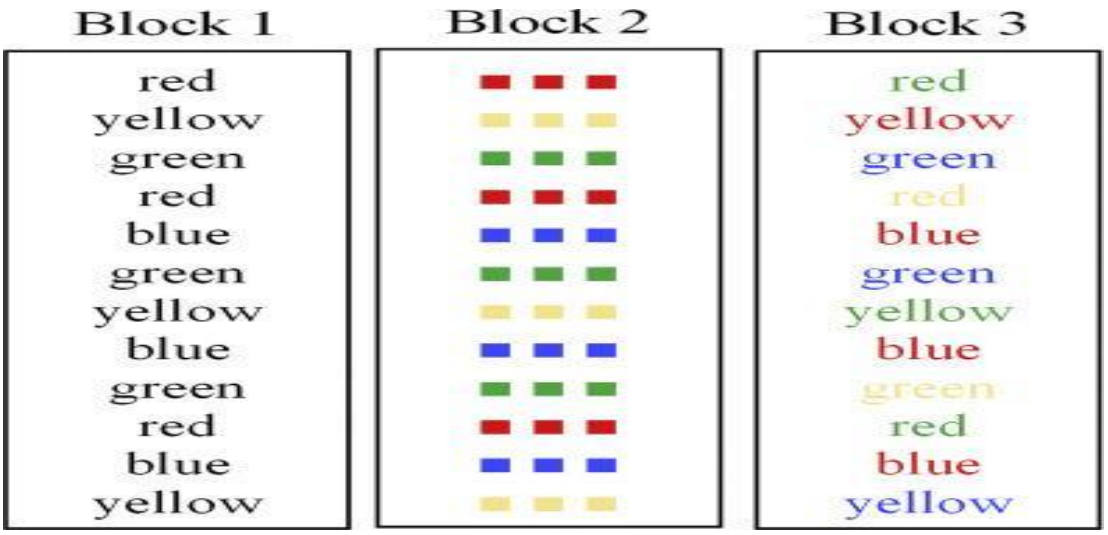
The Stroop task teaches us that when reading becomes an automatic process, simple tasks such as identifying the font color of a word that spells a color can be very difficult.

INTRODUCTION

Psychologist John Ridley Stroop first identified the phenomenon called the “Stroop Effect” in his PhD work in the 1930s. The Stroop effect is simply defined as a phenomenon which gives information on how the human brain processes certain information based on the delayed reactions between congruent and incongruent stimuli. (Macleod, 1991).

This led to the creation of the “Stroop Test” which is commonly used as a neuropsychological test in both clinical and experimental psychology. It is a relatively simple and engaging experiment to examine how the brain recognizes images while being distracted.

There have been various variations of this test and ways in which the performance is evaluated but the most basic idea of the test involves a list of neutral conditions (same word symbols, same neutral colour), a list of congruent conditions with words having same association with it’s colour and a list of incongruent conditions with words being mismatched with its associated colour then experiments are carried out to evaluate if people can name the colour associated with the words under certain time constraints.



In order for participants to effectively follow the process of these experiments, they are expected to have some knowledge in reading. Reading is a process that occurs almost automatically and much faster than the process of colour naming which requires more cognitive effort.

When a cognitive task, such as reading, becomes so practiced that it does not require conscious effort to be completed, the task is automatized (Francis, Neath, & Vanhorn, 2008).

Most people begin to learn to read at a young age. At these beginning stages, reading is effortful, requiring conscious attempts at sounding out each letter of each word. As people repeat and practice reading skills, they eventually learn to read without trying. Minimal conscious effort must be put into the task of reading. When a cognitive task, such as reading, becomes so practiced that it does not require conscious effort to be completed, the task is automatized (Francis, Neath, & Vanhorn, 2008).

OPERATIONAL DEFINITION OF TERMS

The terminologies and variables used in Stroop Effect Experiment:

- Congruent: the term means to be exactly equal in shape and size. In this case it means to agree or to be in harmony.
- Incongruent: to be in disharmony or disagreement with an affecting component
- Stimuli: a thing or event that evokes a specific functional reaction in something or someone
- Independent variable (IV): Nature of stimuli, i.e. congruent and incongruent
- Dependent variable (DV): reaction time taken and score based on errors committed.

BACKGROUND

A study was conducted by J.R. Stroop (1935) to test the effects of automaticity, specifically on reading. In one condition, Stroop presented his participants with 100 words, each of which spelled out a color, but the ink of the word was a different color than what the word spelled. The participants were asked to report the color of the ink the word was presented in. Reaction times were recorded. In addition, he showed participants 100 sets of squares, each presented in certain colors, and asked them to report these colors. Again, the reaction times were recorded. Stroop found that it took an average of 47 total seconds longer for participants to get through the condition where word names were spelled out. Based on this study and these results, we get Stroop tasks and the Stroop Effect. When the participant is asked to report the color of a word that spells out a color different from the color of the ink/font, they are completing a Stroop task. The trend to have longer reaction times when words and word colors do not match is known as the Stroop Effect. (Stroop, 1935)

The researchers believed that their findings supported the idea of a continuum of automaticity. This means that there is not just one level of automaticity. Cognitive functions, based on the level of repetition and practice they receive, can vary as to how automatic they are. For example, for a 2nd grader, reading is moderately automatic, whereas, for a college junior, reading is very automatic.

LITERATURE REVIEW

Many other studies have been conducted in response to Stroop's original study and findings. One such study was completed by MacLeod and Dunbar (1988), where the researchers looked at the possibility of a continuum of automaticity. Participants went through 4 phases

of learning, in which they essentially learned to associate colors with shapes. For example, in one of the phases, the participants might have learned that when they saw a square, they were to think of the color red. These phases were taught for 3 different experimental groups, the first group being taught for 2 hours, the second group being taught for 5 hours, and the third group being taught for 20 hours. The results showed that on average, the more time that was spent on the training, the faster the reaction times of the task. The researchers believed that their findings supported the idea of a continuum of automaticity. This means that there is not just one level of automaticity. Cognitive functions, based on the level of repetition and practice they receive, can vary as to how automatic they are. For example, for a 2nd grader, reading is moderately automatic, whereas, for a college junior, reading is very automatic.

This experiment was a partial replica of J Ridley Stroop's. Based on these studies and findings, the aim of this experiment was to investigate how the effects of response time can interfere and conflict with the stimuli of a person and how they react to the given situation.

Zimmermann, N., Cardoso, C. D. O., Trentini, C. M., Grassi-Oliveira, R., and Fonseca, R. P. (2015) analyzed and presented the performance of three (3) different methods: The Modified Wisconsin Card Sorting Test (MWCST), Stroop Color and Word Test (SCWT) and Digit Span test for adults between the ages of 19 and 75. The effects of these methods were used to assess how age and education affected executive function during a series of neurological and psychiatric evaluations. Using the 2-way ANOVA and ANCOVA analyses, they found that the effect of education was more prominent in all three (3) tasks especially in the automatic abilities for reading while the effect of age was only observed in the colour and colour-word naming speed of the SCWT method.

Scarpina F. and Tagini S. (2017) discussed their findings on the various normative scoring methods which have been used in theory to measure the Stroop effect. The research claimed

none of the methods which were reviewed had the capability of fully accessing effect. They proposed an alternative neuropsychological test in addition to the Stroop Color and Word Test (SCWT) which is able to fully access the performance of all the conditions required for stroop test such as word reading, color naming, named color-word as well as the speed, accuracy and number of errors of the response in order to develop a more proper interpretation of the performance of the SCWT method.

Baghdadi G., Towhidkhah F., Rajabi M. (2021) investigated the human attention control system, its importance in neurocognitive functions such as perception, learning recognition and its dependence on different stimuli characteristics. They expanded on the use of different assessment methods as it relates to attention and distraction in memory, neurocognitive disorders such as Attention Deficit Hyperactivity Disorder (ADHD), Autism, Anxiety, Depression and much more. They also detailed several subjective and objective assessment methods as well as therapeutic methods to regulate and correct these disorders. One of the assessment methods presented was the Stroop tests and how it was used to evaluate the emotional biases of participants. For instance, they explained how participants with the depressive disorder tend to have a more negative attentional bias which led to them taking more time in naming the color of words which they associated with negative emotions in contrast to the speed in which they named those colours whose word had a neutral or positive connotation for them. Based on their reviews of research done several decades ago, they shared how the literature claimed that people with damage to their frontal lobe and selective attention tend to perform more poorly on Stroop-related tasks. They detailed different models of the attention system both conceptual models such as divided attention spotlight model, oscillatory-based model such as the proposed corticothalamic pathway model and also computational models such as the reinforcement-learning models that could lead to further unbiased insights on the different cognitive and executive functions.

STATEMENT OF PROBLEM

The problem at hand is to understand the cognitive processes involved in reading and color perception. Specifically, the Stroop effect seeks to understand why it is more difficult for people to name the color of a word when the word itself is the name of a different color. The Stroop effect is an important phenomenon in cognitive psychology and has been used to study attention, automaticity, and interference.

To address this problem, a study was conducted to examine the reaction time of individuals when opposing stimuluses are presented.

STATEMENT OF OBJECTIVE

The objective of the Stroop effect study is to investigate the cognitive processes involved in reading and color perception. Specifically, the study aims to understand why it is more difficult for people to name the color of a word when the word itself is the name of a different color. The study also aims to explore the role of attention, automaticity, and interference in the Stroop effect. Additionally, the study may seek to identify factors that influence the Stroop effect, such as age, anxiety, or cognitive impairment. Overall, the objective of the Stroop effect study is to gain a deeper understanding of cognitive processes and their impact on perception and behavior.

RESEARCH QUESTION AND HYPOTHESIS STATEMENTS

How does the Stroop effect impact the time it takes to name the color of a word?

This research question aims to investigate the cognitive processes involved in the Stroop effect and their impact on perception and behavior.

In this research paper, we will be using a null hypothesis, H0 because it can be used to determine whether a link exists between two measurable variables. It can tell us if the findings were acquired by chance or by influencing phenomena.

Research question: **Is there any significant difference in reaction time and score between congruent and incongruent conditions?**

Null Hypothesis, H0: there is no significant difference in the reaction time and score between congruent and incongruent condition i.e mean of control group (M1) = mean of experimental group (M2).

Alternative Hypothesis, H1: there is significant difference in the reaction time and score between congruent and incongruent condition i.e mean of control group (M1) ≠ mean of experimental group (M2).

SIGNIFICANCE OF STUDY

The Stroop effect study is significant because it has contributed to our understanding of cognitive processes such as attention, automaticity, and interference. The Stroop effect has been used in a wide range of research studies, including studies on aging, anxiety, and mental illness. The Stroop effect has also been used in educational research to study reading and

comprehension. Additionally, the Stroop effect has practical applications, such as in the development of tests for cognitive impairment and in the design of user interfaces for technology. Overall, the Stroop effect study has had a significant impact on our understanding of cognitive processes and has led to important practical applications.

SCOPE OF AND LIMITATIONS OF STUDY

The scope of study for the Stroop effect includes a wide range of research areas, including cognitive psychology, neuroscience, and education. The Stroop effect has been used in studies on attention, automaticity, and interference, as well as studies on aging, anxiety, and mental illness. The Stroop effect has also been used in educational research to study reading and comprehension. Additionally, the Stroop effect has practical applications, such as in the development of tests for cognitive impairment and in the design of user interfaces for technology. The scope of study for the Stroop effect is broad and has led to important advances in our understanding of cognitive processes.

A limitation of the Stroop effect can be influenced by factors such as language proficiency, familiarity with the task, and cognitive abilities.

Other limitations include the possibility of practice effects, the difficulty of generalizing results to real-life situations, and the potential for experimenter bias.

METHODOLOGY

RESEARCH DESIGN

The experimental design used in this experiment was the post-test only with control group design.

This is a type of experimental design that uses random assignment and an experimental and control group but does not use a pretest.

The post test would help show whether a participant gained the knowledge required to successfully complete the test. And they reveal how much each participant's knowledge grew and how much the participant's improved during the test.

POPULATION

In this research our population was based on covenant university students.

There were 24 participants from Covenant University. Participants were between the ages of 18 and above. No one reported a color deficiency.

SAMPLE AND SAMPLING TECHNIQUE

Sample size: The sample size used were 100 level international relation students and sociology students, 200 level students from the college of engineering, college of computer science and technology, 300 level students from the college of leadership and development studies.

Sampling techniques: convenience sampling and simple random sampling.

Convenience sampling is a non-probability sampling method where units are selected for inclusion in the sample because they are the easiest for the researcher to access. This can be due to geographical proximity, availability at a given time, or willingness to participate in the research.

Simple random sampling is a sampling technique in which each member of a population has an equal chance of being chosen through the use of an unbiased selection method. Each subject in the sample is given a number, and then the sample is chosen by a random method.

I used these sampling techniques due to geographical disadvantages, willingness, and limited time in gathering participants, and to assign my participants to groups, I used a ballot picking method. After they had gotten their numbers, I assigned the even numbers to the control group and the odd numbers to the experimental group.

TREATMENT

Participants were presented with a list of words that are printed in different colors. The participant was asked to name the color of the ink in which the word is printed, rather than reading the word itself. The treatment involves manipulating the congruency of the word and ink color, such that some words are printed in the same color as the ink (congruent condition) and others are printed in a different color than the ink (incongruent condition). The treatment also involved measuring the time it takes for participants to name the color of the ink in each condition. Overall, the treatment of the Stroop experiment is designed to investigate the cognitive processes involved in reading and color perception, and to explore the role of attention, automaticity, and interference in these processes.

STIMULI

There were 2 different stimuli for this study. In one condition the stimulus was a list of congruent colors, meaning that the color the word spelled out matched the actual color of the word. The other condition had incongruent words, meaning that the color the word spelled out did not match the actual color of the word. For example, if the word said orange, but the font color was green then this would be considered incongruent.

The entire font was size 50 and written in Calibri (Body), so it was without any fancy lettering.

EQUIPMENTS

1. List of congruent colors
2. List of incongruent colors
3. Research instructions
4. Stopwatches
5. Debriefing letter for participants

DATA COLLECTION PROCEDURE

The data collection procedure for the Stroop experiment involved presenting participants with a list of words that are printed in different colors and asking them to name the color of the ink in which the word is printed. The data is collected by measuring the time it takes for participants to name the color of the ink in each condition (congruent and incongruent). The experiment was conducted in Covenant university chapel and college of leadership and development studies (CLDS).

Participants were instructed to pick a number from the ballot in order to assign them to their groups. After they had gotten their numbers from the ballot, I assigned the even numbers to the control group and the odd numbers to the experimental group.

Reassurances were given about the confidentiality of their personal data

DATA ANALYSIS

For the data analysis, the descriptive information of the observed data was computed using google sheets and the independent samples t-Test was also used for the statistical data analysis method.

INDEPENDENT SAMPLES T-TEST

The independent sample t-test is a statistical analysis method that is commonly used to evaluate if there is any statistical difference from data collected between two unrelated sample groups of an experiment. The test always requires a null hypothesis which it does not accept because for the idea of independence to hold and the test to be performed on the data, it has to reject the null hypothesis based on comparing the mean value for two sets of data.

The independent t-test requires certain assumptions on the collected data to be fulfilled for the data to be analyzed using the method. It makes an assumption that the mean distribution of the data collected from the two groups are the same i.e. the null hypothesis, H0 states that the mean distribution of the first group is equal to the mean distribution of the second group is checked by the T-test and if it rejects the hypothesis, it implies that both groups are very distinct from each other. The t-test always rejects the null hypothesis, H0.

Other assumptions checked for the test are: the data is collected at random from the population for both groups, both groups must have at least 6 or more participants, the observed responses collected for every participant in each group must not depend on the responses observed by others, the independent variables must consist of two (2) categories, the value of the dependent variable must be a continuous numerical value and it also assumes that both of the groups have the same variance. The test works best for sample size between 20 and 30 data samples, if the sample size for the groups becomes larger than 30 then other statistical tests are more appropriate for conducting the analysis.

HYPOTHESIS STATEMENTS

For the independent samples t-test of this work, the null and alternative hypothesis are as follows:

H0: *mean of control group = mean of experimental group* **OR** mean *of control group – mean of experimental group = 0*

H1 : *mean of control group ≠ mean of experimental group* **OR** *mean of control group – mean of experimental group ≠ 0*

In other words, for the t-test, the null hypothesis, H0 states that the mean reaction times of the control and the experimental groups are equal or can be stated as the difference between the mean reaction times of the control and the experimental groups is equal to zero. On the other hand, the alternative hypothesis, H1 states that the mean reaction times of the control and the experimental groups are not equal or can be stated as the difference between the mean reaction times of the control and the experimental groups is not equal to zero.

COMPUTING THE INDEPENDENT T-TEST SCORES (T-SCORES)

The underlying formula for the computation of the standard t-test statistic is the t-score.

The t-score value is defined as the ratio of the difference between the mean of the two sample sets and the variation that exists within the given sample sets. It is given by the formula:

$$t = \frac{\underline{X1} - \underline{X2}}{S}\sqrt{\frac{n1 \times n2}{n1 + n2}}$$

Where:

- the standard deviation for the independent sample t-test is given by

$$S = \sqrt{\frac{\Sigma\,(X1 - \underline{X1})(X1 - \underline{X1}) + \Sigma\,(X2 - \underline{X2})(X2 - \underline{X2})}{n1 + n2 - 2}}$$

- $\underline{X1}$ represents the mean of the data samples for the first group of X1 observations.
- $\underline{X2}$ represents the mean of the data samples for the first group of X2 observations.
- Σ represents the summation
- $n1$ represents the number of the data samples for the first group of X1 observations.
- $n2$ represents the number of the data samples for the first group of X2 observations

Once the t-score value is obtained, then it is searched for in the T Table (also known as the T Distribution Critical Values Table) where the probabilities for the T distributions can be found for the two samples t-test values.

The null hypothesis, H0 is then rejected if the absolute t-value from t-test analysis is greater than the value in the t-table:

H0 : M1 - M2 = 0
H1 : M1 - M2 > 0

Where:

- H0 is the null hypothesis
- H1 is the alternative hypothesis
- M1 is the mean of the dependent variable for the control group
- M2 is the mean of the dependent variable for the experimental group

RESULTS

Given that the comparison of two independent groups based on the experiment is required as well as computing the difference between both groups, the method chosen for the statistical data analysis was the independent samples t-test. The software tool, SPSS statistics was used to carry out the statistical analysis for the data with the independent sample t-tests being performed. The procedure for the independent sample t-test analysis using SPSS was to:

1. Set and check the null and alternative based on the assumptions requirement of the t-test on the sampled data.
2. Choose which significance level (alpha term) to use. alpha was set to 0.05 for this analysis.
3. Compute the value of t-test statistic which could be calculated using the number of samples, the means and the standard deviation.
4. Then either reject or fail to reject the null hypothesis, H0 based on if the absolute value of the t-statistic is greater than the t-critical value or not.

OBSERVED DATA

In the Table 1 below, the scores for each observation was computed using the custom scoring system I created.

Scoring system

- 1 (very fast) – 10-5 seconds and above
- 2 (fast) – 10 -15 seconds
- 3 (medium) – 15-20 seconds

- 4 (slow) – 20-25 seconds
- 5 (very slow) – 25- 30 seconds and above

To assign the scores, I conducted a mini experiment with my friends to get my scoring system. I added and divided the time it took them to call out the words from the congruent list to get the median reaction time. After getting the median time I subtracted five seconds to get my fast and very fast and I added five seconds to get my slow and very slow.

Table 1: Data Samples And Assigned Scores

	Control group	Congruent Reaction Time (seconds)	Congruent Scores	Experimental group	Incongruent Reaction Time (seconds)	Incongruent Scores
1	Female	21.15	4	Female	26.01	5
2	Female	12.58	2	Female	22.8	4
3	Female	20.81	4	Female	27.6	5
4	Female	12.98	2	Female	26.07	5
5	Female	9.8	1	Female	34.75	5
6	Female	13.05	2	Female	18.5	3
7	Male	10.39	1	Male	33.18	5
8	Male	11.33	2	Male	20.72	4
9	Male	8.5	1	Male	25.46	4
10	Male	10.94	1	Male	13.35	2
11	Male	9.9	1	Male	15.25	3
12	Male	16.49	3	Male	21.43	4

For my sampling I used convenience and simple random sampling. To assign my participants to groups, I used a ballot picking method. After they had gotten their numbers, I assigned the even numbers to the control group and the odd numbers to the experimental group.

DATA ANALYSIS

For the analysis of the data, the scores were analysed to get the descriptive summary such as the range, mean, median, mode and standard deviation for each list. The descriptive statistics for the groups (control and experimental) as well as other statistical analysis methods were carried out for the reaction times where the independent variable was the ink colour used and the dependent variable was the time taken for the student to say the colour ink.

The variables used in Stroop Effect Experiment:

- Independent variable (IV) – Nature of stimuli, i.e. congruent and incongruent
- Dependent variable (DV) – reaction time taken and score based on errors calculated via the scoring system.

DESCRIPTIVE STATISTICS

The control and experimental group had a balanced number of data samples, the mean of reaction time for the experimental group was 13.16 while the mean of reaction time for the control group was 23.76. The standard deviation of the reaction time for the experimental

group was 4.19 while the standard deviation of the reaction time for the control group was 6.48.

Table 2: DESCRIPTIVE STATISTICS - REACTION TIME (seconds)		
	Control Group - Congruent	Experimental Group - Incongruent
Number of Samples, N	12	12
Total Sum	157.92	285.12
Maximum	21.15	34.75
Minimum	8.5	13.35
Range	12.65	21.4
Mean	13.16	23.76
Standard Error Mean	1.210482624	1.8700158
Median	11.955	24.13
Variance	17.58321818	41.96350909
Standard Deviation	4.193234811	6.477924752
Confidence level for mean	2.664254291	4.115877024
Lower bound confidence interval	10.49574571	19.64412298
Upper bound confidence interval	15.82425429	27.87587702

The mean score for the experimental group was 4.08 while the mean score for the control group was 2. The standard deviation of the scores for the experimental group was 1.128 while the standard deviation of the scores for the control group was 0.996.

Table 3: DESCRIPTIVE STATISTICS - SCORES		
	Control Group - Congruent	Experimental Group - Incongruent
Number of Samples, N	12	12
Total Sum	24	49
Maximum	4	5
Minimum	1	2
Range	3	3
Mean	2	4.083333333
Mode	1	5
Median	2	4
Variance	1.272727273	0.9924242424
Standard Deviation	1.12815215	0.9962049199
Standard Error for Mean	0.3256694736	0.2875795893
Confidence level for mean	0.7167936786	0.6329584085
Lower bound confidence interval	1.283206321	3.450374925
Upper bound confidence interval	2.716793679	4.716291742

THE MEAN REACTION TIME STROOP EFFECT VALUE ANALYSIS

For the analysis, the Stroop effect scores for congruency were then computed. The formulation of the Stroop effect is the difference between dependent variables for the incongruent stimuli and congruent stimuli based on participants' response to the color of the color-words. It is given by:

Stroop Effect Values = Dependent Variable Incongruent – Dependent Variable Congruent

Table 4. Reaction Time - Scores : Stroop Effect for Congruency					
	Number of color-word samples, N	Total Reaction Time	Total Score	Mean Reaction Time	Mean Scores
Group : Control - Congruent	12	157.92	24	13.16	2
Group : Experimental -Incongruent	12	285.12	49	23.76	4.083
Total	24	443.04	73	36.92	6.083

The difference between the mean reaction times of the incongruent stimuli and congruent stimuli based on participants' response on the color of the color-words is given by:

Stroop Effect Values = Mean Reaction for Incongruent – Mean Reaction for Congruent

Stroop Effect values (Reaction Time) = MRTI – MRTC

Stroop Effect values (Reaction Time) = 23.76 – 13.16 = 10.60 ≠ 0

Where:

- MRTI represents the mean reaction time for the incongruent observations of the control group.
- MRTC represents the mean reaction time for the congruent observations of the experimental group.

- The stroop effect value for the mean reaction represents the difference between the mean reaction time for the control group and the mean reaction time for the experimental group.

Based on this basic formulation, the stroop effect value for the mean reaction time i.e the mean difference between both groups of stimuli is 10.60 which contradicts the null hypothesisH0 for the analysis.

The difference between the mean reaction times of the incongruent stimuli and congruent stimuli based on participants' response on the color of the color-words is given by:

$$\textit{Stroop Effect Values} = \textit{Mean Scores for Incongruent} - \textit{Mean Scores for Congruent}$$

$$\textit{Stroop Effect values (Scores)} = MSI - MSC$$

$$\textit{Stroop Effect values (Scores)} = 4.08 - 2.00 = 2.08 \neq 0$$

Where:

- MSI represents the mean score for the incongruent observations of the control group.
- MSC represents the mean score for the congruent observations of the experimental group.
- The stroop effect value for the mean score represents the difference between the mean score for the control group and the mean score for the experimental group.

Based on this basic formulation, the stroop effect value for the mean score i.e the mean difference between both groups of stimuli is 2.08 which contradicts the null hypothesis, H0 for the analysis.

INDEPENDENT SAMPLES T-TEST RESULTS

Further analysis was carried out for this work using the independent two-samples t-test. The independent samples t-test was used to understand whether there was a difference in the mean response speed (the dependent variable) in saying the colour of the stimuli shown and the congruency of the coloured-words lists (the independent variables) for both the control (congruent lists) and experimental (incongruent lists) groups.

The result of the analysis based on the independent samples t-tests gives information on the group statistics which basically compares the summary statistics such as the sample size (N), the mean, the standard deviation and the standard error for the mean reaction times for each group.

Table 5: Group Statistics Reaction Time

Group		No of Samples (N)	Mean	Standard Deviation (SD)	Standard Error of Mean
Reaction Time	Control	12	13.16	4.193234811	59.86494456
	Experimental	12	23.76	6.477924752	108.6329104

The mean of reaction time for the experimental group was 13.16 while the mean of reaction time for the control group was 23.76. The standard deviation of the reaction time for the experimental group was 4.19 while the standard deviation of the reaction time for the control group was 6.48.

Table 6: t-Test Group Statistics Scores					
Group		No of Samples (N)	Mean	Standard Deviation (SD)	Standard Error of Mean
Scores	Control	12	2	1.12815215	0.3256694736
	Experimental	12	4.083333333	0.9962049199	0.2875795893

The mean score for the experimental group was 4.08 while the mean score for the control group was 2. The standard deviation of the scores for the experimental group was 1.128 while the standard deviation of the scores for the control group was 0.996.

The t-test for the independent (paired) two samples for means was computed using google sheets tools. The input (independent) variables for the control group and the experimental group were entered to evaluate the mean of the reaction time which is our dependent variable of the first experiment and also to evaluate the mean scores which is our dependent variable of the experiment relating to the scores.

It also gives information on the independent samples test which basically shows the following:

- **t-Test for Equality of Means:** the mean is assumed to be equal to zero based on the null hypothesis, H0: M1 - M2 = 0. The alpha value was set to 0.05, to indicate a 95% confidence interval.
- **Test for Equality of Variances**: The assumption check for the equality of variance does not hold since the difference between the variance of both groups is greater than zero. The null hypothesis is always rejected.

Table 7. Reaction Time t-Test: Paired Two Sample for Means		
Alpha	0.05	
Hypothesized Mean Difference	0	
	Control Group - Congruent Reaction Time (seconds)	Experimental Group - Incongruent Reaction Time (seconds)
Mean	13.16	23.76
Variance	17.58321818	41.96350909
Observations	12	12
Pearson Correlation	0.08630712129	
Observed Mean Difference	-10.6	
Variance of the Differences	54.85792727	
Df	11	
t Stat	-4.957660592	
P (T<=t) two-tail	0.0004303781648	
t Critical two-tail	2.20098516	

Table 8. Scores t-Test: Paired Two Sample for Means		
Alpha	0.05	
Hypothesized Mean Difference	0	
	Control Group - Congruent Scores	Experimental Group - Incongruent Scores
Mean	2	4.083333333
Variance	1.272727273	0.9924242424
Observations	12	12
Pearson Correlation	0.4044463885	
Observed Mean Difference	-2.083333333	
Variance of the Differences	1.356060606	
Df	11	
t Stat	-6.197404395	
P (T<=t) two-tail	0.0000674063458	
t Critical two-tail	2.20098516	

The null hypothesis which assumes an equality of means between the incongruent and congruent stimuli if there is no difference between the mean reaction times is therefore rejected because the absolute t-value i.e the absolute value of t-statistic which gives 4.958 from t-test analysis for the dependent (scores) variable is greater than the value in the t-distribution critical values table i.e the t-critical value of 2.201 in Table 7.

The null hypothesis which assumes an equality of means between the incongruent and congruent stimuli if there is no difference between the mean scores is therefore rejected because the absolute t-value i.e the absolute value of t-statistic which gives 6.197 from t-test

analysis for the dependent (scores) variable is greater than the value in the t-distribution critical values table i.e the t-critical value of 2.201 in Table 8.

Table 9: GROUP STATISTICS

	GROUP	N	Mean	Std. Deviation	Std. Error Mean
SCORE	CONGRUENT LIST	12	2.00	1.128	.326
	INCONGRUENT LIST	12	4.08	.996	.288

Table 10: Independent Samples *t* Test

		Mean Reaction Time	
		Equal variances assumed	Equal Variances not assumed
Levene's Test for Equality of Variances	F	.066	
	Sig.	.799	
t-test for Equality of Means	T	-4.795	-4795
	Df	22	21.668
	Sig. (2-tailed)	.000	.000
	Mean Difference	-2.083	-2.083
	Std. error Difference	.434	.434

	95% confidence Interval of the Difference	Lower	-2.984	-2.985
		Upper	-1.182	-1.182

From the table above; t = -4.795, p = .000

The Decision rule states that;

If p < 0.05, then reject the null hypothesis and accept alternative hypothesis.

If p > 0.05, then accept the null hypothesis and reject alternative hypothesis.

From the results above, the significant value “p”, is .000. Therefore, from the decision rule stated above the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted.

Therefore, there is significant difference in the reaction time and score between

congruent and incongruent condition

DISCUSSION

For this work, the hypothesis was that reaction times as well as scores would be the same for the words which had the color words spelled correctly with the font in a different color than what the word spelled and those words whose colour doesn't align with the word's colour-name reference. The results of the analysis supported the alternative hypothesis instead and rejected the main hypothesis, as all incongruent words condition, which had the color words spelled correctly and the font in a different color than what the word spelled, was the slowest. These results differed significantly and it was found that participants had trouble reading the list of incongruent coloured ink due to a conflict in stimuli.

In addition, it was observed that the best mean difference in reaction times and scores were mostly achieved by the female participants. This is a noticeable difference as was also observed in a study by Silvia von Kluge (1992). The study found that when speed is stressed on a Stroop task, women and men tend to perform at equal speeds, but women are more accurate. Also, we could have checked in more details during our analysis for a difference in reaction times between genders and another way to improve the collection of data and the study which could help us get better results would be to digitize the test and in a nice interactive interface to reduce the stress participant's might face when giving their response as the stress might have an effect on the attention of the participants.

I intend to carry out further studies and analysis on a more advanced Stroop effect, where the conditions are jumbled randomly with the hypothesis that reaction times would be faster the more jumbled the words. I also intend to use more advanced statistical analysis methods for the data analysis and make a comparison with those done in the literature. The advanced stroop would be interesting as a follow up study based on the idea of a continuum of

automaticity, as was found in MacLeod and Dunbar's (1988) research. We do not get a lot of practice reading words that are spelled incorrectly, therefore they do not become automatized. Because the words were so jumbled in the all-random condition, we might not automatically read them, and so the words would not interfere with our ability to report the color of the word. On the other hand, when we see the words orange, purple, and green since we first started reading, we can read them automatically now. Therefore, it might take longer for participants to report the color of the word, because the word itself gets in the way.

Having a larger sample size with more of a variety of ages would have had its own effects on the results. As people get older, their automaticity for cognitive functions fades, thus their reaction times would have been faster. In addition, if the participants were of different educational levels, we would have seen a faster fading of cognitive functions in the older participants of lower education. (Van der Elst, Van Boxtel, Van Breukelen, & Jolles, 2006) Thus, our results cannot be applied to people of all cultures and age ranges, but to this specific population.

The results of this study are important in looking at how children learn, specifically at how they learn to read. When students first begin to learn to read, the task is not automatic. It requires thought and effort. The students cannot focus as much on what is being read, mostly on the process of reading. As students get older, reading becomes easier and more automatic. They can read without paying attention to what is read. Teachers need to be aware of this, and the information about automaticity and strive for a more conscious and attentive way of reading.

This is not to say that automaticity is bad, or that being able to read automatically is wrong, but it is good to be more aware when performing such tasks.

In conclusion, the results of this study suggests that individuals find it hard to respond quickly when there is a conflict in stimuluses in a given situation.

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APPENDIX

EQUIPMENT 1: CONGRUENT WORD COLOURS

COLOURS	1	2	3
Blue	Blue	blue	b l u e
Brown	Brown	brown	b r o w n
Orange	Orange	orange	o r a n g e
Black	Black	black	B l a c k
Pink	Pink	pink	p i n k
Yellow	Yellow	yellow	y e l l o w

CONGRUENT LIST USED

Blue brown

o r a n g e Black

p i n k

yellow

Brown black

brown Yellow

blue

pink

Orange brown

black Pink

yellow

blue

EQUIPMENT 2: INCONGRUENT WORD COLOURS

COLOURS	

Blue	Brown Orange
Brown	Blue Black
Orange	Blue Black
Black	Pink Yellow
Pink	Blue Brown
Yellow	Brown Pink
Purple	Black Orange
Green	Brown Yellow
Red	Yellow Pink

INCONGRUENT LIST USED

Blue Brown

O r a n g e B l a c k

P i n k

Yellow

Brown Black

Brown Yellow

Blue Pink

Orange Brown

Black Pink

Yellow Blue

EQUIPMENT 3: RESEARCH INSTRUCTIONS (THE STROOP EFFECT)

TO GENERAL PARTICIPANTS

Hello guys, my name is Favour and today we will be performing an experiment for my experimental psychology class. I will be attending to each participant individually and each of you will be asked to perform a certain task. After this experiment, you will be given a debriefing letter to explain the purpose and results of this experiment.

TO INDIVIDUAL STUDENTS

Today, I will be showing you lists of words spelling out colors and your job is to state the color of the ink of each word as fast as possible. you can point to each word as you go down the list in order to make it easier for you. the time you take to complete the task will be recorded. If at any point you feel uncomfortable, you can stop the experiment and withdraw if you'd like.

EQUIPMENT 4: DEBRIEFING LETTER FOR PARTICIPANTS

(THE STROOP EFFECT)

Dear Participant,

Thank you for your participation in the Stroop Experiment. This study aims to investigate the cognitive processes involved in reading and color perception, and to explore the role of attention, automaticity, and interference in these processes.

During the study, you were asked to name the color of the ink in which a list of words was printed, while ignoring the word itself. The study involved manipulating the congruency of the word and ink color, such that some words were printed in the same color as the ink (congruent condition) for the control group and others were printed in a different color than the ink (incongruent condition), for the experimental group. We measured the time it took for you to name the color of the ink in each condition.

Overall, the results of the study showed that participants were slower to name the color of the ink in the incongruent condition than in the congruent condition. This suggests that the Stroop effect is a real phenomenon that reflects the interaction between cognitive processes involved in reading and color perception.

We want to thank you again for your participation in the study. If you have any questions or concerns, please do not hesitate to contact us.

Sincerely,

Favour Eze
Telegram: +234 8163547678

T-Table : T Distribution Critical Values Table

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										