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THE IMPACT OF THE STROOP EFFECT ON COGNITIVE ASSESSMENT – A STUDY ON SELECTIVE ATTENTION

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ABSTRACT

This investigation aims to explore attentional capacity in response to the presentation of visual stimuli. Attention, as an essential process, underpins skills such as language and learning, in addition to supporting various other critical cognitive functions and processes. With this ultimate goal in mind, the Stroop Color Word Test (SCWT), a widely used neuropsychological test in experimental, developmental, clinical, psychopathological, and neuropsychological contexts, was employed to assess attention. The SCWT was administered using SuperLab version 6 software, where the entire experiment was developed and created. The results reiterated the robustness of the Stroop Effect, with participants showing increased reaction times and a higher error rate for incongruent stimuli compared to congruent ones. These results were consistent among participants regardless of age, suggesting that cognitive conflict affects individuals of different ages similarly. The data did not indicate a correlation between participants' age and performance measures on the test.

Keywords: Experimental Psychology; Stroop Color Word Test; Selective Attention; SuperLab Software.

INTRODUCTION

According to the State of the Art, there are numerous investigations aimed at studying cognitive processes to understand how humans process information and stimuli from the environment (Cunha et al., 2015; Vedechkina & Borbonovi, 2021). Attention is a complex cognitive process that allows us to focus on one stimulus at the expense of processing other information. It is indispensable for language, learning, and memory processes. Attention can take various forms, including focused, selective, or divided attention (Escobar, 2016).

In terms of definition, selective attention can be described as the ability of an individual to attend to only one source of information while neglecting the others. Selective attention control is crucial in situations involving decision-making and error detection, as well as when the individual needs to perform new tasks (Cunha et al., 2015; Ghimire et al., 2014; Scarpina & Tagine, 2017).

The Stroop Color Word Test (SCWT) is a widely used neuropsychological test in experimental, developmental, clinical, psychopathological, and neuropsychological contexts to assess attention (Scarpina & Tagine, 2017). The Stroop Color Word Test (color-word) is considered a reliable and easily applicable test. It is often used to investigate attentional functioning and the speed of stimulus processing (Cunha et al., 2015; Ghimire et al., 2014). Colour naming appears to require cognitive effort, necessitating a greater amount of attentional resources (Neto & Dias, 2013). In this context, it seemed interesting to explore attentional capacity in response to the presentation of visual stimuli created using SuperLab version 6 software.

State of the Art

According to Scarpina and Tagine (2017), the Stroop Color Word Test is named after psychologist John R. Stroop, who conducted pioneering research in the 1930s on selective attention and stimulus processing speed, as well as exploring the phenomenon of interference.

Psychologist Stroop (1935) observed that the presence of multiple factors involved in processing a specific stimulus can create interference between them, affecting reaction time to a given task. This phenomenon is particularly evident when words denoting colours, such as "blue," "green," or "red," are presented in colours incongruent with the semantic meaning of the words (for example, the word "red" written in blue ink). This incongruence leads to a delay in the processing of reading the word, resulting in slower response times and an increase in the number of errors (Cunha et al., 2015; Ghimire et al., 2014; Scarpina & Tagine, 2017).

Investigating the Interference between Distracting Attributes and Targets

Stroop (1935) conducted two experiments aimed at investigating the interference caused by a distracting attribute on the target attribute, focusing on two dimensions of a single stimulus: the word and the colour. The objective was to demonstrate that naming colours takes longer than reading the printed colour names. In the first experiment, the focus was on measuring how long it took participants to read aloud a list of 100 colour names. However, there was an added challenge: the words did not match the colours in which they were printed. For instance, the word "blue" might be printed in green ink. This incongruence between the word and the colour was intended to investigate how this discrepancy would affect the time needed to process and read each colour name (Cunha et al., 2015; Ghimire et al., 2014; Neto & Dias, 2013; Starreveld & La Heij, 2016).

After the initial phase of the experiment, where the time taken for participants to read colour names in an incongruent setup was measured, a second phase followed for comparative analysis. In this phase, a neutral or control condition was introduced: the colour names were now presented in black ink, without any incongruence between the word and the colour. The aim was to assess whether there would be a significant difference in reading time under neutral conditions compared to the previous incongruent condition.

Upon analysing the results of the two conditions – incongruent and neutral – the researcher observed that the average time required to read the colour names did not significantly vary between them. This led to the conclusion that the colour in which the word was printed, whether congruent or not, did not significantly influence the speed with which individuals could read the colour names. This finding suggests that the challenge imposed by the incongruence did not affect the efficiency of reading the words to the expected extent (Neto & Dias, 2013; Starreveld & La Heij, 2016).

In the second experiment, Stroop (1935) introduced a variation by using the same incongruent stimuli from the first experiment. However, the task for participants changed: they were to name the colour of the ink used to print each word, rather than reading the word itself. For example, if the word "green" was printed in red ink, the correct response would be "red".

RESULTS AND INTERPRETATION

The results showed that participants took significantly longer to name the ink colour compared to a control condition, where the task was to name the colour of non-verbal symbols, such as crosses, presented in the same colours. This time difference highlighted the cognitive interference experienced when the ink colour information conflicts with the semantic information of the word. This observed difference in processing time was termed the Stroop Effect (Neto & Dias, 2013; Starreveld & La Heij, 2016).

The automatization hypothesis explains the results of the Stroop (colour-word) test by suggesting that certain cognitive processes become automatic due to constant practice and frequent execution. In the context of the Stroop test, reading words is an example of such processes. From a very early age, people are exposed to reading, practicing it regularly throughout their lives. This continuous habit makes word reading an automatic act, requiring little conscious effort to perform (Neto & Dias, 2013; Starreveld & La Heij, 2016).

Two Theories Underpinning the Stroop Color Word Test

The primary theories underpinning the phenomenon observed in the Stroop (color-word) test include the processing speed theory and the focused or selective attention theory.

The processing speed theory suggests that the brain can recognize words more quickly and efficiently than colours, which explains the delay in colour identification in situations of incongruence. According to this theory, the automaticity of reading speeds up word recognition, while colour naming, being less practiced, takes longer.

On the other hand, the focused or selective attention theory indicates that identifying a colour demands greater attentional effort than reading a word. Reading is a more automated process, requiring fewer cognitive resources. This theory posits that selective attention is necessary to filter out the conflicting information (the word) and focus on the target attribute (the colour), which requires additional cognitive effort.

Stroop Color Word Test

The literature features numerous investigations (Melone, 2021). Various studies have been conducted to explore significant differences in Stroop (color-word) test performance between men and women. These studies suggest that women complete tasks more quickly, demonstrating a higher speed in processing stimuli. However, contradictory findings exist. According to Datta, Nebhinani, and Dixit (2020), some investigations mention that there are no significant gender differences.

Regarding studies focused on evaluating whether there are statistically significant differences in Stroop (color-word) test performance concerning age, several investigations indicate that older individuals tend to make more errors in task execution compared to younger individuals. Additionally, it is observed that the time required to process stimuli is greater in older participants. This suggests that the ability to handle the interference generated by the Stroop test, which requires recognizing the ink colour in which a word is printed rather than reading the word itself, tends to decrease with advancing age. Thus, both task accuracy and the speed of processing stimuli exhibit notable variations when comparing different age groups (Datta, Nebhinani & Dixit, 2020; Melone, 2021).

Using SuperLab Software to Assess Selective Attention

To ultimately evaluate the selective attention of participants and determine how cognitive interference (Stroop Effect) affects response time and accuracy when naming the ink colour of words that denote either congruent or incongruent colours with the used ink, the researchers decided to use SuperLab version 6.

SuperLab version 5 is a sophisticated software designed for creating and conducting psychological experiments involving the presentation of stimuli and the collection of responses. It provides researchers with the ability to develop complex studies that can include a variety of visual and auditory stimuli, as well as accurately record participants' reactions, such as response times and choices made. This tool is widely used in cognitive, neuropsychological, and psychological research to explore dimensions such as attention, perception, memory, and decision-making.

Ethical Considerations

Before commencing the experiment, it was necessary to obtain informed consent from the participants.

This involved clearly explaining the research objectives and ensuring the confidentiality of their data.

Procedures

To create the experiment and assess selective attention using the Stroop Test in SuperLab version 6, we followed several premises:

1. Participant Preparation: Participants were briefed on the task they would be performing. They were informed that their goal was to name the ink colour of the words presented, ignoring the word itself.
2. Stimulus Presentation: The stimuli included words that denoted colours, printed in either congruent or incongruent ink colours. For example, the word "blue" could be printed in blue (congruent) or red (incongruent) ink.
3. Software Configuration: SuperLab version 6 was configured to present the stimuli in random order to avoid any predictable patterns that could influence the results. The software also recorded the reaction times and accuracy of participants' responses.
4. Control Conditions: A neutral control condition was included where non-verbal symbols (e.g., crosses) were presented in different colours to establish a baseline for naming colours without semantic interference.
5. Data Collection: The software collected precise data on the reaction times and error rates for each type of stimulus (congruent, incongruent, and control).
6. Debriefing: After completing the experiment, participants were debriefed about the purpose of the study and any questions they had were answered.
7. Data Analysis: The collected data was analysed to determine the impact of cognitive interference on response times and accuracy, comparing performance across different conditions (congruent, incongruent, and control).

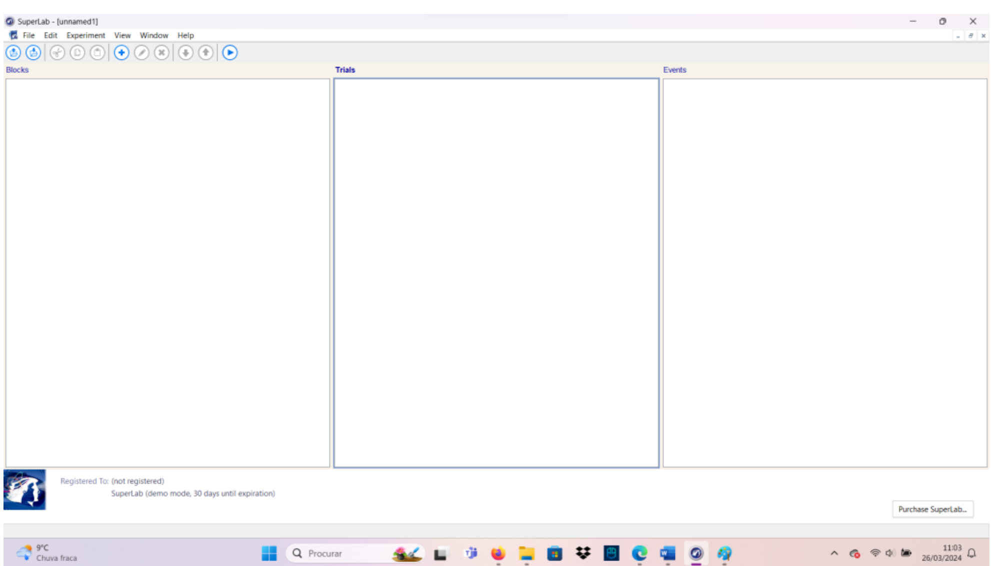

Image 1: Creation of the Experiment

Source: SuperLab 6 Demo

Preparation of Stimuli

The researchers created two groups of stimuli in SuperLab: a list of words denoting colors, printed in both congruent colors (e.g., "red" printed in red) and incongruent colors (e.g., "red" printed in blue).

Image 2: Group of Incongruent Stimuli

Own source

Design

The experiment was configured in SuperLab to present each stimulus randomly to the participants. The presentation time for each stimulus was set to 5 seconds, with a 10-second interval between stimuli. The software was set up to record the response times and the participants' responses.

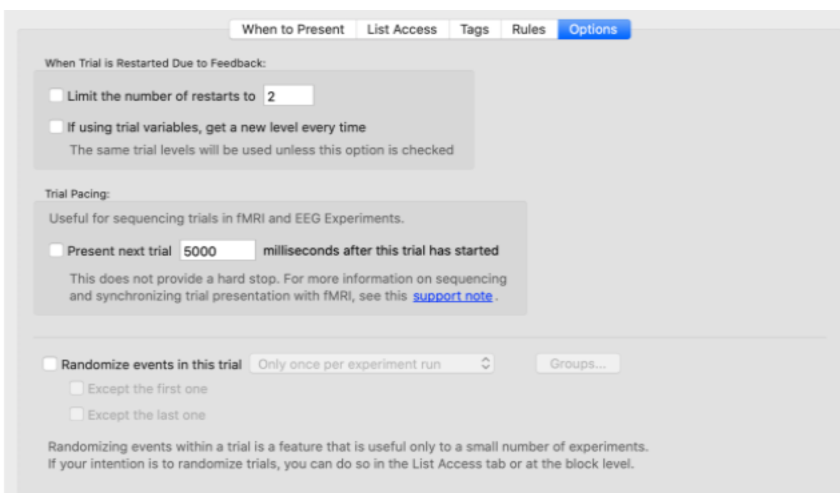

Image 3: Creation of Timing

Source: SuperLab 6 Demo

Additional Setup

This configuration can be particularly useful in ensuring that participants have enough time to fully process each stimulus and then have a period of rest or "cognitive clearing" before the next stimulus.

Instructions to Participants

Participants were instructed to name the ink colour in which the word was presented, ignoring the semantic meaning of the word. They were also informed to respond as quickly and accurately as possible.

Test Execution

Participants performed the test individually. Each stimulus was presented on the screen, and the participant responded verbally. The participant pressed a key corresponding to the colour on the keyboard. The experiment continued until all stimuli were presented.

Data Analysis

After collecting data from all participants, response times and accuracy of responses for each group of stimuli (congruent and incongruent) were analysed. Average response times and error rates between the two types of stimuli were also compared.

Sample Contextualization

This study focused on a convenience sample composed exclusively of university professors from Lisbon, totaling 10 participants. The gender distribution in the sample was 60% female and 40% male, reflecting a female predominance. This selection aimed to explore the peculiarities of cognitive processing and decision-making in a homogeneous group in terms of professional environment, but diverse in gender.

Sample Composition and Selection

Participants were selected based on their availability and interest in participating in the study. All held active positions in university teaching, providing a rich context for exploring the cognitive dynamics associated with attention and information processing tasks.

Demographic Characteristics

The sample consisted of 6 women and 4 men, reflecting the mentioned gender composition. The age range varied from 35 to 57 years, with a mean age of 44.5 years and a standard deviation of 8.25 years, indicating a relatively mature and experienced population. This characteristic is relevant for interpreting the results, considering that professional experience and age can influence cognitive processing and responses to conflicting stimuli.

Results – Analysis and Discussion of Stroop

This chapter presents a detailed analysis of the results obtained in the experiment with the Stroop Color Word Test, which investigates the impact of cognitive conflict on participants' ability to process information effectively. The stimuli were categorized into two main groups: congruent and incongruent, aiming to measure the reaction times (RT) and error rates of participants in each condition.

Reaction Times

The analysis of reaction times revealed significant differences between congruent and incongruent conditions. As expected, the incongruent condition resulted in longer reaction times, suggesting a higher level of difficulty in information processing due to the cognitive conflict present (Table 1).

Participant	Gender	Age	Congruent	Incongruent
Participant 1	Female	35	530	650
Participant 2	Female	37	440	600
Participant 3	Male	41	520	630
Participant 4	Female	42	505	620
Participant 5	Female	51	490	610
Participant 6	Female	54	510	640
Participant 7	Male	35	475	590
Participant 8	Female	52	480	580
Participant 9	Male	41	500	620
Participant 10	Male	57	540	660

Table 1: Reaction Times (in milliseconds) of 10 Participants in Congruent and Incongruent Conditions
Own source

ANALYSIS AND DISCUSSION

Reaction Times

The analysis of reaction times revealed significant differences between congruent and incongruent conditions. The average reaction time for congruent stimuli was 499 milliseconds, whereas for incongruent stimuli, it was 620 milliseconds. These reaction times are significant as they indicate a clear and measurable delay in processing when participants faced the more complex task of identifying the ink colour of incongruent words, such as the word "red" written in blue, compared to identifying the ink colour of congruent words, like the word "red" written in red.

The standard deviation for congruent reaction times was 29.33 milliseconds, and for incongruent reaction times, it was 25.82 milliseconds, suggesting relatively consistent responses among participants, especially under incongruent conditions.

These results support the existing literature on the Stroop Effect and highlight the impact of cognitive conflict on tasks involving attention and inhibitory control. The increased response times for incongruent stimuli reinforce the notion that the brain takes longer to resolve information conflicts, a task requiring greater cognitive effort.

Error Rates

In addition to reaction times, error rates followed a similar pattern, with participants making more errors under incongruent conditions compared to congruent conditions. This increase in error rates supports the theory that cognitive conflict interferes with processing capability, leading to a higher number of incorrect responses.

Reaction Times and Error Rates Versus Participant Age

In attempting a deeper analysis of the obtained results, it was possible to observe that with the provided data, the existence of apparent relationships between participants' ages and their reaction times and error rates could be explored. However, to establish a true statistical correlation, a larger sample would be necessary. Only with a larger sample could appropriate statistical analyses, such as Pearson's correlation or regression models, be conducted.

Thus, analyzing the sample, it can be stated that there was a noticeable trend of increased reaction times and error rates under incongruent conditions compared to congruent conditions, regardless of participants' ages. This trend aligns with the cognitive conflict theory proposed by the Stroop Effect, which posits that processing conflicting information demands more cognitive effort and, consequently, more time and potential for errors (Stroop, 1935).

While the data do not demonstrate a direct relationship between the participants' ages and their task performance (a more robust analysis would be needed for this), the general pattern of the results underscores the universality of the Stroop Effect. The findings are particularly relevant in an academic context, given that all participants are university professors, suggesting that even highly educated and experienced individuals are subject to similar cognitive conflicts when processing incongruent information.

These results emphasize the importance of considering cognitive load when designing tasks that require processing colours and words, as well as the relevance of investigating strategies that might mitigate the effects of cognitive conflict in specific populations, such as academics. However, due to the convenience sample nature and small sample size, caution is recommended in generalizing the results to broader populations. Future research with larger and more diverse samples could provide additional insights and confirm the applicability of the present study's results.

DISCUSSION OF RESULTS

The sample, composed of university professors from Lisbon with an average age of 44.5 years and a female predominance, exhibited relatively homogeneous performance, although the small size and convenience nature of the sample limit the generalization of the results. The Stroop Color Word Test (SCWT) results were generally consistent with the literature (Stroop, 1935; Scarpina & Tagini, 2017; Datta Nebhinani & Dixit, 2020).

Researchers observed that incongruent stimuli resulted in longer reaction times (620 ms) compared to congruent stimuli (499 ms), reflecting greater cognitive load. The standard deviation for reaction times was 29.33 ms for congruent and 25.82 ms for incongruent, indicating consistency in responses, especially under incongruent conditions. These results align with studies by authors such as Cunha et al. (2015), whose study highlights the use of SCWT to investigate attention and stimulus processing speed, noting that colour naming requires more cognitive resources, especially under incongruent conditions, resulting in longer reaction times and higher error rates. Ghimire et al. (2014) observed that the presence of incongruent stimuli significantly increases reaction times due to the need to resolve cognitive interference, corroborating the idea of greater cognitive load. Scarpina & Tagine (2017) reviewed the SCWT and confirmed that the interference between ink colour and word meaning results in longer reaction times and higher error rates, reflecting the complexity of cognitive processing under incongruent conditions. Finally, Neto & Dias (2013) discussed the automatization hypothesis and how reading words, a highly automated process, significantly interferes when there is incongruence between ink colour and written word, resulting in greater cognitive effort and longer reaction times.

On the other hand, error rates were also higher under incongruent conditions, reinforcing the idea that cognitive interference compromises response accuracy. No clear correlation was found between participants' ages and reaction times or error rates, although there was a general trend of increased reaction times and error rates under incongruent conditions, regardless of age. Authors such as Scarpina & Tagine (2017) highlight that cognitive interference generated by incongruent stimuli in the SCWT increases both reaction times and error rates, corroborating findings of greater cognitive difficulty. Ghimire et al. (2014) also analyzed how the presence of incongruent stimuli significantly affects error rates due to the higher cognitive load needed to overcome interference. Cunha et al. (2015) observed that cognitive interference between ink colour and word meaning results in a higher number of errors in participants' responses, indicating additional difficulty in resolving cognitive conflict.

The findings confirm the robustness of the Stroop Effect in evaluating selective attention and inhibitory control, corroborating studies by Cunha et al. (2015), Ghimire et al. (2014), Scarpina & Tagine (2017), and Neto & Dias (2013). Future research is recommended to include larger and more diverse samples, considering variables such as the level of professional experience and individual factors to obtain a more comprehensive understanding of the Stroop Effect's impact on different populations.

CONCLUSION

In conclusion, the experiment conducted with the Stroop Color Word Test on a sample of university professors from Lisbon consistently demonstrated that reaction times were longer and error rates were higher for incongruent stimuli compared to congruent stimuli, corroborating the classical premises of the Stroop Effect. This pattern was observed regardless of the participants' ages, which varied significantly within the sample.

The data analysis did not provide sufficient evidence of a relationship between the participants' age and their performance on the test, indicating that the cognitive conflict inherent to the Stroop Effect may be a relatively stable phenomenon throughout adulthood. However, given the small sample size and the specific context of the participants, these observations should be interpreted with caution.

These results highlight the relevance of the Stroop Effect as a robust tool for understanding cognitive processing and conflict, and also emphasize the importance of considering cognitive design factors in educational settings. Future research could benefit from including a larger and more diverse sample to explore in greater depth the dynamics between age, profession, and cognitive performance.

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