Psychology Lab Report Example

The Stroop Effect: Examining Cognitive Interference in Color-Word Recognition Tasks

---

Student Name: Jennifer Park
Course: Psychology 301: Cognitive Psychology
Instructor: Dr. Amanda Torres
Lab Partners: David Kim, Rachel Chen
Experiment Date: October 12, 2024
Submission Date: October 19, 2024

Abstract

This experiment investigated the Stroop effect, a classic demonstration of cognitive interference where naming ink colors takes longer when word meaning conflicts with ink color. Thirty undergraduate participants (ages 18-22) completed three conditions: congruent (word meaning matches color), incongruent (word meaning conflicts with color), and neutral (colored rectangles). Response times were recorded for 20 trials per condition. Results confirmed the Stroop effect: incongruent trials (M = 1,247ms, SD = 183ms) took significantly longer than congruent trials (M = 892ms, SD = 124ms) and neutral trials (M = 765ms, SD = 98ms). A repeated-measures ANOVA revealed significant differences between conditions, $F(2, 58) = 127.43$, $p < .001$, $^2 = 0.81$. These findings support automatic processing theory, demonstrating that reading is so automatic it interferes with the controlled process of color naming.

Word Count: 136 words

Introduction

Theoretical Background

Human cognition involves both automatic and controlled processes. Automatic processes occur without conscious effort or attention, while controlled processes require deliberate focus and mental resources (Schneider & Shiffrin, 1977). Reading, after years of practice, becomes highly automatic for literate adults. This automaticity can create interference when automatic and controlled processes conflict.

The Stroop effect, first documented by John Ridley Stroop in 1935, demonstrates this interference. When asked to name the ink color of words, participants respond slower when the word's meaning contradicts its color (the word "RED" printed in blue ink) compared to when they match (the word "RED" printed in red ink). This seemingly simple task reveals fundamental principles of attention, processing speed, and cognitive control.

Cognitive Mechanisms

Two theoretical explanations account for the Stroop effect:

1. Speed-of-Processing Theory: Reading words occurs faster than naming colors. When these processes conflict, the faster reading response must be inhibited, causing delay (MacLeod, 1991).

2. Selective Attention Theory: Attention cannot fully ignore irrelevant information (word meaning) when focusing on relevant information (ink color). The irrelevant dimension creates interference requiring cognitive resources to suppress (Dalrymple-Alford & Budayr, 1966).

Both theories predict that incongruent stimuli produce longer response times than congruent or neutral stimuli due to the need to overcome automatic reading responses.

Previous Research

Stroop's original study established this effect using manual color naming, finding approximately 47% slower responses for incongruent stimuli. Modern replications using computerized testing consistently demonstrate the effect with reaction time increases of 30-50% (MacLeod, 1991). The effect persists across languages, ages, and cultures, indicating a universal feature of cognitive processing (Magen & Cohen, 2010).

Recent research extends the Stroop paradigm to study executive function, attention deficits in clinical populations, and bilingual language processing (Scarpina & Tagini, 2017). The task's reliability makes it a standard measure in cognitive assessment.

Present Study

Despite extensive research, the Stroop effect provides valuable learning opportunities for understanding cognitive interference. This study replicates the classic Stroop paradigm with undergraduate participants to:

1. Demonstrate that automatic processes (reading) interfere with controlled processes (color naming)
2. Quantify the magnitude of interference using reaction time measurements
3. Compare performance across congruent, incongruent, and neutral conditions

Hypotheses

Hypothesis 1: Participants will show significantly longer reaction times in the incongruent condition compared to the congruent condition, demonstrating cognitive interference.

Hypothesis 2: Neutral stimuli (colored rectangles without words) will produce the fastest reaction times because they involve no conflicting information.

Hypothesis 3: Error rates will be highest in the incongruent condition due to the difficulty of suppressing automatic reading responses.

Method

Participants

Sample: Thirty undergraduate students (18 females, 12 males) from the university participant pool participated for course credit. Age range: 18-22 years (M = 19.8, SD = 1.4).

Inclusion criteria: - Native English speakers - Normal or corrected-to-normal vision - No self-reported color blindness - No diagnosed attention disorders

Exclusion criteria: - Non-native English speakers (reading automaticity may differ) - Colorblindness (inability to distinguish test colors) - Previous participation in Stroop studies (to avoid practice effects)

All participants provided informed consent. The university's Institutional Review Board approved the protocol (IRB #2024-PSY-089).

Materials

Stimuli: - Four color words: RED, BLUE, GREEN, YELLOW - Four corresponding ink colors: red, blue, green, yellow - Font: Arial, 48-point, bold - Presentation: White background, centered on 15-inch monitor

Equipment: - Desktop computer with 15-inch LCD monitor (60Hz refresh rate) - Standard QWERTY keyboard for responses - PsychoPy software (v2024.1) for stimulus presentation and data collection - Sound-attenuated testing room with controlled lighting

Response Assignment: - R key = Red - B key = Blue - G key = Green - Y key = Yellow

Keys were labeled with colored stickers matching their assigned colors.

Design

Within-subjects design: All participants completed all three conditions in counterbalanced order to control for practice effects.

Independent Variable: Stimulus Condition (3 levels) 1. **Congruent:** Word meaning matches ink color (e.g., "RED" in red ink) 2. **Incongruent:** Word meaning conflicts with ink color (e.g., "RED" in blue ink) 3. **Neutral:** Colored rectangles (control condition, no words)

Dependent Variables: 1. **Reaction Time (RT):** Time from stimulus onset to keypress response (measured in milliseconds) 2. **Error Rate:** Percentage of trials with incorrect responses

Trial Structure: - 20 trials per condition × 3 conditions = 60 total trials - Trial order randomized within each condition block - Each color appeared 5 times per condition (balanced design)

Procedure

Pre-Experiment Phase (5 minutes):

1. Participants read and signed informed consent forms
2. Experimenters explained the task: "Press the key corresponding to the INK COLOR of each stimulus, ignoring the word itself"
3. Participants completed 12 practice trials (4 per condition) with feedback
4. Questions were answered before beginning

Experimental Phase (15 minutes):

1. Participants sat 60cm from the monitor in a sound-attenuated room
2. Each trial followed this sequence:
   - Fixation cross (500ms)
   - Blank screen (250ms)
   - Stimulus (displayed until response)
   - Blank inter-trial interval (1,000ms)
3. Condition order was counterbalanced using a Latin square design:
   - Group 1 (n=10): Congruent → Incongruent → Neutral
   - Group 2 (n=10): Incongruent → Neutral → Congruent
   - Group 3 (n=10): Neutral → Congruent → Incongruent
4. Participants took 30-second breaks between condition blocks
5. Instructions reminded participants to respond "as quickly and accurately as possible"

Post-Experiment Phase (3 minutes):

1. Brief questionnaire assessed:
   - Which condition felt most difficult
   - Whether participants noticed any strategies they used
   - Demographic information (age, native language, vision status)
2. Participants were debriefed about the Stroop effect and thanked

Data Collection:

- Computer recorded reaction time (ms) and accuracy for each trial
- Trials with RT < 200ms or > 3,000ms were flagged as outliers
- Participants' subjective difficulty ratings were recorded

Results

Data Preparation

Data from all 30 participants (1,800 total trials) were analyzed. Outlier removal eliminated 23 trials (1.3%) with RT < 200ms (anticipatory responses) or > 3,000ms (attention lapses). Error trials were analyzed separately for accuracy rates but excluded from RT analysis.

Descriptive Statistics

Mean reaction times and error rates for each condition are presented in Table 1.

Table 1: Reaction Time and Accuracy by Condition

Condition	Mean RT (ms)	SD (ms)	95% CI	Mean Accuracy (%)	SD (%)
Congruent	892	124	[845, 939]	97.8	2.3
Incongruent	1,247	183	[1,179, 1,315]	89.2	5.8
Neutral	765	98	[728, 802]	98.5	1.9

Note: RT = reaction time in milliseconds; SD = standard deviation; CI = confidence interval; n = 30 participants

The incongruent condition produced the longest reaction times (M = 1,247ms), followed by congruent (M = 892ms) and neutral (M = 765ms). The pattern for accuracy showed the reverse: neutral stimuli yielded highest accuracy (98.5%), with incongruent stimuli showing notable decline (89.2%).

Stroop Interference and Facilitation Effects

Interference Effect: Calculated as RT(incongruent) - RT(neutral) - Mean interference = 482ms - Effect size: Cohen's d = 3.12 (very large effect)

Facilitation Effect: Calculated as RT(neutral) - RT(congruent) - Mean facilitation = 127ms - Effect size: Cohen's d = 1.18 (large effect)

The interference effect (482ms) was substantially larger than the facilitation effect (127ms), consistent with previous literature.

Inferential Statistics

Repeated-Measures ANOVA:

A repeated-measures ANOVA was conducted with Condition (congruent, incongruent, neutral) as the within-subjects factor and reaction time as the dependent variable.

Results: - Main effect of Condition: $F(2, 58) = 127.43$, $p < .001$, $^2 = 0.81$ - Mauchly's test indicated sphericity was met: $^2(2) = 3.45$, $p = .178$

The main effect of condition was statistically significant with a very large effect size, indicating that reaction times differed significantly across the three conditions.

Post-Hoc Pairwise Comparisons (Bonferroni corrected):

Comparison	Mean Difference (ms)	SE	t(29)	p	Cohen's d
Incongruent vs. Congruent	355	28.4	12.50	$< .001$	2.28
Incongruent vs. Neutral	482	31.7	15.21	$< .001$	3.12
Congruent vs. Neutral	127	19.8	6.41	$< .001$	1.18

All pairwise comparisons were statistically significant at $p < .001$, confirming that each condition produced significantly different reaction times.

Error Analysis

A repeated-measures ANOVA on error rates also revealed significant differences: $F(2, 58) = 42.18$, $p < .001$, $^2 = 0.59$.

Post-hoc tests showed: - Incongruent condition (M = 10.8% errors) > Congruent condition (M = 2.2% errors), $t(29) = 8.67$, $p < .001$ - Incongruent condition (M = 10.8% errors) > Neutral condition (M = 1.5% errors), $t(29) = 9.34$, $p < .001$ - No significant difference between congruent and neutral conditions, $t(29) = 1.89$, $p = .068$

Higher error rates in the incongruent condition support the cognitive interference hypothesis.

Visual Representation

Figure 1: Mean Reaction Times Across Conditions

```
Reaction Time (ms)
1400 |
```

```
1200 |                     ***
1000 |           ***
 800 |
 600 |
 400 |
 200 |
   0 +----------------------
     Neutral  Congruent  Incongruent

*** p < .001 compared to neutral condition
Error bars represent ±1 standard error
```

Figure 2: Individual Participant Stroop Effects

```
Interference Effect (ms)
700 |    •        •
600 |  •    •  •    •
500 |     •  •  •  •  •
400 |  •  •  •  •  •  •  •
300 |  •  •  •  •  •
200 |
100 |
  0 +--------------------------
    Participant (n=30)

Mean = 482ms (dashed line)
All participants showed positive interference
```

All 30 participants demonstrated the Stroop interference effect (positive values), with individual differences ranging from 278ms to 687ms.

Subjective Reports

Post-experiment questionnaires revealed: - 100% of participants (30/30) rated the incongruent condition as "most difficult" - 73% (22/30) reported "trying to ignore the word meaning" - 27% (8/30) reported "sometimes reading the word accidentally"

These subjective reports align with objective performance data.

Discussion

Summary of Findings

This experiment successfully replicated the classic Stroop effect, confirming three key findings:

1. Significant Cognitive Interference: Participants took 40% longer to name ink colors in the incongruent condition (M = 1,247ms) compared to the congruent condition (M = 892ms). This 355ms difference, confirmed by statistical analysis ($p < .001$, $d = 2.28$), demonstrates robust interference when word meaning conflicts with color naming.

2. Facilitation Effect: Congruent stimuli produced faster responses (892ms) than neutral stimuli (765ms), though the facilitation effect (127ms) was smaller than the interference effect (482ms). This asymmetry suggests interference from conflicting information is more powerful than assistance from matching information.

3. Error Pattern: Error rates increased dramatically in the incongruent condition (10.8%) compared to congruent (2.2%) and neutral (1.5%) conditions, indicating interference affects both speed and accuracy.

All three hypotheses were supported by the data.

Theoretical Interpretation

Automatic Processing Explanation:

The results strongly support automatic processing theory. Reading is so overlearned in literate adults that it occurs automatically and cannot be easily suppressed. When participants attempt to name ink colors, the automatic reading process activates simultaneously, creating competition. In congruent trials, both processes activate the same response, producing facilitation. In incongruent trials, they activate competing responses, requiring cognitive control to inhibit the incorrect (reading) response and execute the correct (color naming) response.

The larger interference effect compared to facilitation effect (482ms vs. 127ms) aligns with Cohen, Dunbar, and McClelland's (1990) connectionist model. Their model proposes that suppressing an automatically activated response requires more cognitive resources than benefiting from response convergence.

Selective Attention Interpretation:

Alternatively, selective attention theory suggests participants cannot fully ignore the word dimension despite instructions to focus only on color. MacLeod's (1991) meta-analysis of 50 years of Stroop research supports this view, showing that even highly motivated participants cannot eliminate interference. Our error data (10.8% errors in incongruent trials) demonstrate that automatic reading occasionally overrides intentional color naming, consistent with attention failure rather than merely slowed processing.

Both theoretical perspectives explain our findings, suggesting they capture complementary aspects of cognitive processing: automaticity describes why interference occurs, while selective attention explains why it cannot be fully prevented.

Comparison to Previous Research

Our findings align closely with established Stroop effect literature:

Magnitude of Effect: Our interference effect (482ms, representing 63% increase over neutral baseline) falls within the typical range reported in meta-analyses (40-70% increase; MacLeod, 1991). The effect size (d = 3.12) exceeds Cohen's criteria for a "large" effect (d > 0.8), confirming robust replication.

Asymmetry Pattern: The larger interference compared to facilitation effect (3.8:1 ratio) replicates the pattern observed by Glaser and Glaser (1982), who found interference effects consistently exceed facilitation effects across multiple stimulus variations.

Individual Differences: While all participants showed the effect, individual interference magnitudes ranged from 278-687ms (2.5-fold variation). This variability matches findings by Kane and Engle (2003), who demonstrated that working memory capacity predicts individual differences in Stroop performance. Participants with higher cognitive control show smaller interference effects.

Practical Implications

Beyond theoretical significance, the Stroop effect has practical applications:

Clinical Assessment: Modified Stroop tasks assess executive function in neurological and psychiatric populations. Patients with ADHD, schizophrenia, and frontal lobe damage show exaggerated interference effects, making the task a diagnostic tool (Scarpina & Tagini, 2017).

Cognitive Training: Stroop-like tasks are used in cognitive training programs to improve attention control and inhibition. Repeated practice can reduce interference, suggesting trainable executive function.

Real-World Interference: The Stroop effect models real-world situations where automatic responses interfere with goal-directed behavior (e.g., breaking habitual behaviors, multitasking while driving). Understanding interference mechanisms informs intervention design.

Limitations

Several limitations warrant consideration:

1. Sample Characteristics: Our sample comprised young undergraduate students, limiting generalizability to other age groups. Children show larger effects due to less automatized reading (Schiller, 1966), while older adults show increased interference due to declining inhibitory control (Verhaeghen & De Meersman, 1998). Future research should examine age-related differences.

2. Practice Effects: Although condition order was counterbalanced, participants may have developed strategies to reduce interference across blocks. A between-subjects design would eliminate practice effects but sacrifice statistical power.

3. Stimulus Characteristics: We used only four colors and four words, limiting stimulus diversity. Rare color-word combinations or additional response options might alter effect magnitude.

4. Individual Differences: We did not measure cognitive control capacity, working memory, or bilingualism, factors known to moderate Stroop effects. Including these measures would clarify sources of individual variation observed in our data (278-687ms range).

5. Ecological Validity: Laboratory color-naming tasks differ from naturalistic interference situations. While theoretically informative, caution is warranted when generalizing to complex real-world cognition.

Methodological Strengths

Despite limitations, several strengths enhance confidence in findings:

- **Within-subjects design** maximized statistical power and controlled individual differences
- **Counterbalanced order** controlled practice and fatigue effects
- **Computerized testing** ensured precise RT measurement (1ms resolution)
- **Adequate sample size** (n=30) provided sufficient power to detect effects
- **Neutral control condition** allowed separation of interference and facilitation components
- **Convergent evidence** from RT and error data strengthens conclusions

Future Directions

This research raises several questions for future investigation:

1. Neuroimaging Studies: Combining the Stroop task with fMRI could identify brain regions (likely anterior cingulate cortex and dorsolateral prefrontal cortex) involved in conflict monitoring and resolution.

2. Developmental Trajectory: Longitudinal studies tracking children as reading becomes automatized would illuminate the acquisition of interference effects.

3. Bilingual Processing: Examining the Stroop effect in bilinguals' first versus second languages could reveal whether automaticity requires native-language fluency or develops with practice in any language.

4. Clinical Applications: Comparing Stroop performance before and after treatment in clinical populations (e.g., ADHD patients receiving medication) could establish sensitivity to intervention effects.

5. Cognitive Enhancement: Investigating whether cognitive training reduces interference effects would have implications for improving executive function in clinical and healthy populations.

Broader Significance

The Stroop effect, though simple in design, reveals fundamental principles of human cognition. It demonstrates that: - Automatic processes operate outside conscious control - Cognitive control is effortful and resource-limited - Attention cannot fully filter irrelevant information - Individual differences in cognitive control are substantial

These principles extend beyond color naming to domains including multitasking, habit change, impulse control, and decision-making under conflict. The Stroop task thus serves as both a specific phenomenon worthy of study and a window into broader cognitive architecture.

Conclusion

This experiment successfully replicated the Stroop effect, demonstrating that automatic processes (word reading) interfere with controlled processes (color naming) when they conflict. Participants showed 40% longer reaction times and 5-fold higher error rates in incongruent compared to congruent conditions. The robust statistical significance ($p < .001$, $^2 = 0.81$) and very large effect sizes ($d = 2.28$ to 3.12) confirm interference is a powerful and reliable phenomenon.

The findings support dual-process theories of cognition, showing that automatic and controlled processes operate simultaneously and compete for behavioral output. When conflict arises, cognitive control mechanisms must inhibit automatic responses, requiring time and effort. The larger interference effect compared to facilitation effect indicates suppressing automatic responses is more demanding than benefiting from response convergence.

Beyond confirming established findings, this experiment provides hands-on demonstration of cognitive principles that might otherwise remain abstract. The Stroop effect remains one of psychology's most robust phenomena, continuing to inform theories of attention, automaticity, and cognitive control more than 85 years after its discovery.

Future research should explore individual differences in susceptibility to interference, neural mechanisms underlying conflict resolution, and applications to clinical populations and cognitive training. Such work will deepen understanding of how humans navigate a world filled with competing demands on limited cognitive resources.

References

Cohen, J. D., Dunbar, K., & McClelland, J. L. (1990). On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review*, 97(3), 332-361. https://doi.org/10.1037/0033-295X.97.3.332

Dalrymple-Alford, E. C., & Budayr, B. (1966). Examination of some aspects of the Stroop color-word test. *Perceptual and Motor Skills*, 23(3), 1211-1214. https://doi.org/10.2466/pms.1966.23.3f.1211

Glaser, M. O., & Glaser, W. R. (1982). Time course analysis of the Stroop phenomenon. *Journal of Experimental Psychology: Human Perception and Performance*, 8(6), 875-894. https://doi.org/10.1037/0096-1523.8.6.875

Kane, M. J., & Engle, R. W. (2003). Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General*, 132(1), 47-70. https://doi.org/10.1037/0096-3445.132.1.47

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, 109(2), 163-203. https://doi.org/10.1037/0033-2909.109.2.163

Magen, H., & Cohen, A. (2010). Modularity beyond perception: Evidence from the PRP paradigm. *Journal of Experimental Psychology: Human Perception and Performance*, 36(2), 395-414. https://doi.org/10.1037/a0015711

Scarpina, F., & Tagini, S. (2017). The Stroop Color and Word Test. *Frontiers in Psychology*, 8, 557. https://doi.org/10.3389/fpsyg.2017.00557

Schiller, P. H. (1966). Developmental study of color-word interference. *Journal of Experimental Psychology*, 72(1), 105-108. https://doi.org/10.1037/h0023358

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review*, 84(1), 1-66. https://doi.org/10.1037/0033-295X.84.1.1

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6), 643-662. https://doi.org/10.1037/h0054651

Verhaeghen, P., & De Meersman, L. (1998). Aging and the Stroop effect: A meta-analysis. *Psychology and Aging*, 13(1), 120-126. https://doi.org/10.1037/0882-7974.13.1.120

Appendix A: Informed Consent Form

[Standard IRB-approved consent form would appear here]

Appendix B: Sample Stimuli

Congruent Trials: - RED (in red ink) - BLUE (in blue ink) - GREEN (in green ink) - YELLOW (in yellow ink)

Incongruent Trials: - RED (in blue ink) - BLUE (in green ink) - GREEN (in yellow ink) - YELLOW (in red ink)

Neutral Trials: - (red rectangle) - (blue rectangle) - (green rectangle) - (yellow rectangle)

Appendix C: Raw Data Summary

Individual Participant Interference Effects (ms): P01: 445 | P02: 512 | P03: 378 | P04: 623 | P05: 489
P06: 567 | P07: 412 | P08: 534 | P09: 398 | P10: 456
P11: 687 | P12: 389 | P13: 498 | P14: 523 | P15: 445
P16: 478 | P17: 556 | P18: 412 | P19: 534 | P20: 487
P21: 398 | P22: 591 | P23: 445 | P24: 512 | P25: 378
P26: 467 | P27: 523 | P28: 434 | P29: 498 | P30: 278

Mean = 482ms | Median = 478ms | Range = 278-687ms