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Comparison of Inhibition in Two Timed Reaction Tasks:

The Color and Emotion Stroop Tasks

D. LISA COTHRAN and

University of Tennessee at Chattanooga

RANDY LARSEN

Washington University

Abstract

The authors examined the cross-task consistency of the ability to inhibit the processing of irrelevant information. They compared interference scores on 2 widely used inhibition tasks and found that color word Stroop interference scores correlated with emotion word Stroop interference scores. An examination of physiological reactivity showed that, in general, the color Stroop was more arousing than was the emotion Stroop, most likely due to increased response conflict.

Keywords

color Stroop; emotion; inhibitory processing

THE STROOP TASK (Stroop, 1935) is a widely used test of inhibitory processing. Other inhibition tasks have been modeled on it, among them the emotion Stroop task. Eide, Kemp, Silberstein, Nathan, and Stough (2002) speculated that inhibitory processing in the emotion Stroop task may be functionally equivalent to inhibitory processing in the color Stroop task (see also Kindt, Bierman, & Brosschot, 1996). However, they did not administer the color Stroop task, so this speculation was not tested. A comparison of reactions in both tasks would, in theory, allow a test of the cross-task consistency of inhibitory processing. Although previous research has demonstrated the test-retest reliability of Stroop tasks (Siegrist, 1995, 1997; Strauss, Allen, Jorgensen & Cramer, 2005), none to date have examined the cross-task consistency and compared physiological reactivity across tasks. In the present study, we compared inhibitory processing and physiological responsiveness across these two tasks.

Color Stroop and Emotion Stroop Effects

The Stroop task presents color words in a congruent (e.g., the word *blue* written in blue ink) or incongruent (e.g., the word *blue* written in yellow ink) format. When instructed to ignore the word and indicate the color, people are slower to color name incongruent stimuli in comparison with congruent stimuli. This effect is termed *interference* or the *color Stroop effect*.

Address correspondence to D. Lisa Cothran, University of Tennessee at Chattanooga, Psychology Department, 2803, 615 McCallie Ave., Chattanooga, TN 37403-2598, USA; lisa-cothran@utc.edu (e-mail)..

D. Lisa Cothran is an assistant professor in the Department of Psychology at the University of Tennessee, Chattanooga. Her research interests include personality, emotion, prejudice, and discrimination. **Randy Larsen** is William R. Stuckenberg Professor of Human Values and Moral Development at Washington University in St. Louis. His research interests focus on emotion, including mood variability, jealousy, attraction, depression, and strategies for the self-management of self-esteem and emotion.

The emotion Stroop task is ostensibly similar (MacLeod, 1991). Here, people are presented with emotion words in varying colors. Instructions, as in the original Stroop task, are to ignore the word and to name the color of the ink. Among persons with various disorders (e.g., anxiety disorders, depressive disorders, eating disorders), interference is found when disorder-relevant words are used (Daghighi, 1995; A. M. Mathews & Sebastian, 1993; Parker, Taylor, & Bagby, 1993). Specifically, persons are slower to color name words relevant to their disorder (e.g., anxiety patients would be slower to color name words such as *panic* in comparison with color naming control words such as *sidewalk*). In disordered and nondisordered populations, performance on the emotion color word task is generally slower when naming the color of negative words (e.g., *death*) compared with positive or nonemotion words (Gilboa-Schechtman, Revelle, & Gotlib, 2000; Williams, Mathews & MacLeod, 1996).

This slowed reaction to color name emotionally relevant or negative words is also frequently referred to as *interference* and is frequently termed the *emotion Stroop effect*. The self-relevance or the negativity of words is said to interfere with processing the color of the ink. Algom, Chajut, and Lev (2004) suggested that the slowing is not necessarily due to inhibition and that resources can be allocated such that threat-irrelevant stimuli receive fewer resources. This depletion then corresponds with slowed responses to the intended target. Noting the underlying theoretical differences in these two tasks, Algom et al. stressed the logic of referring to this effect as an *emotion* or *automatic vigilance effect* (Pratto & John, 1991) in lieu of an emotion Stroop effect. Pratto and John suggested that when negative emotive information is present, it leads to slow processing, an effect that they have called *automatic vigilance*. Thus, in the emotion Stroop task, the presence of the negative information on the negative word trials, compared with the neutral word trials, is said to cause significantly slower reaction times (RTs; i.e., an *emotion effect*).

Explanations for Inhibitory Processing in the Two Stroop Tasks

Stroop (1935) explained the Stroop effect as a function of learning: "The difference in speed in reading names of colors and in naming colors may be satisfactorily accounted for by the difference in training in the two activities" (p. 660). Therefore, the faster activity, reading, is difficult to inhibit while simultaneously attempting the slower task, color naming. Other theorists have proposed alternate, albeit not conflicting, explanations for the Stroop effect (Cohen, Dunbar & McClelland, 1990; Morton & Chambers, 1973; Zhang & Kornblum, 1998). Cohen et al. suggested that processing information related to the response (i.e., identifying the color) is disrupted by processing other information in the stimulus (i.e., the lexical meaning of a word). Zhang and Kornblum suggested that the relations between the two stimuli (S-S; the color of the ink and the word) and between the to-be-ignored stimulus and the response (S-R; the word and the color of the ink) interact and contribute to the Stroop effect.

Theorists have offered explanations of the inhibition, or, rather, the emotion effects noted in the emotion Stroop task. Williams et al. (1996) suggested that the model of Cohen et al. explains these effects (see also G. Mathews & Harley, 1996) in that input units associated with self-relevant words may be more practiced and may be associated with more intermediary units than non-self-relevant words. These more practiced words produce more interference when participants are processing the colors of words. Another explanation is that the resting level of activation for emotional words may be higher than for nonemotion words, resulting in a decreased ability to inhibit the processing of emotional meaning (Williams et al.). In a conceptual and empirical analysis of the two tasks, Algom et al. (2004) suggested that the emotion effect is driven by negativity. Thus, in comparison with the processing of neutral words, the processing of negative words is slowed due to automatic vigilance.

Each of the aforementioned explanations describes the concept of inhibiting the processing of one stimulus feature (the irrelevant semantic content) while processing another feature (the relevant color). The ability to inhibit the processing of irrelevant information is frequently considered to have trait-like consistency, as a feature of executive control. Selective attention and attention shifting are widely agreed-on facets of executive control (for a review see Logan, 2004). Thus, although neither the theories nor the typical pattern of results of the two tasks are isomorphic, if inhibitory processing is a reliable individual difference, researchers should find cross-task consistency (Siegrist, 1997). Siegrist (1997) conducted principal components analyses on performance on several Stroop tasks (color word, taboo word, and self-relevant word) and determined that more than 80% of the total variance in responses was explained by one factor. In the present study, we examined correlations between the timed reaction interference effects in the color and emotion Stroop tasks.

Physiological Reactivity

We also examined physiological reactivity to these two inhibition tasks. Although higher heart rate responses are sometimes but not always associated with increased difficulty, increased heart rate reactivity has been associated with inhibitory processing (Cacioppo & Tassinary, 1990; Stein & Boutcher, 1993; Waked & Jutai, 1990). Stein and Boutcher gave participants a color Stroop task and reported significantly different heart rate (HR), systolic blood pressure (SBP) reactivity, and diastolic blood pressure (DBP) reactivity (i.e., differences between baseline and experimental condition physiological readings). Waked and Jutai compared SBP and DBP reactivity across blocked presentations within the color Stroop task. Block 1 consisted of congruent Stroop trials; Block 2 consisted of incongruent Stroop trials. SBP and DBP reactivity (i.e., differences between baseline and experimental condition readings) were greater for the incongruent than for the congruent task. Johnsen et al. (2003) assessed HR reactivity to a mixed-trial, emotion and color Stroop task. Stimuli consisted of color-incongruent and color-congruent threatening and neutral words presented in different colors of ink on a black background. Johnsen et al. found a significant increase in HR between baseline and Stroop phase (5.4 bpm). However, had Johnsen et al. blocked the presentation of their stimuli, they also could have compared physiological reactivity across the color and emotion Stroop tasks. Larsen, Cothran, and Zelenski (2001) assessed HR and blood pressure responses to a mixed-trial emotion Stroop and found that reactivity was smaller than the published figures for the color Stroop task. They suggested that the color Stroop task may be more difficult, may differentially involve inhibitory processing, or both.

We know of four studies in which researchers have examined the reliability of the emotion Stroop task (Eide et al., 2002; Kindt et al., 1996; Siegrist, 1997; Strauss et al., 2005). Eide et al. examined the test-retest reliability of the emotion Stroop task and speculated that inhibitory processing in the emotion Stroop may be functionally equivalent to inhibitory processing in the original Stroop (see also Kindt et al.). However, they did not administer the standard Stroop task, so they could not test this speculation. Some researchers argue that the emotion Stroop task does not involve as much inhibitory effort as the original color Stroop task (Algom, Chajut, & Lev, 2004; DeHouwer, 2003) and therefore may be less arousing. Strauss et al. demonstrated that RT interference in the color word Stroop task is greater than that in the emotion word Stroop task. It also is important to note that an examination of the relations among the irrelevant and relevant stimuli and the responses of the two tasks reveals considerably more overlap in the color word Stroop design. Because increased overlap among the two stimuli and the response is associated with greater interference effects (Kornblum, Hasbroucq, & Osman, 1990), it is plausible that the two differentially involve inhibitory processing.

Although several researchers have measured physiological reactivity to the Stroop task, they have done so on clinical populations (e.g., individuals with hypertension [Waked & Jutai,

1990], smokers [Hasenfratz & Baettig, 1992]) and have not compared reactivity across Stroop tasks. In the present study, we compared timed reactions and physiological reactivity across two timed reaction tasks in a within-sample design.

Predictions

First, we predicted traditional Stroop effects for both tasks, respectively. Second, we predicted that interference scores (i.e., experimental condition RTs minus control condition RTs) would correlate across tasks. Third, regarding physiological reactivity, we predicted that reactivity in the experimental conditions would be greater than that experienced in the congruent and control conditions. We also predicted that the color Stroop task would be more arousing than would the emotion Stroop task.

Method

Participants

Participants were 32 undergraduate students (9 men, 23 women) whose mean age was 19.5 years ($SD = 1.2$ years). All participants received course credit for their participation.

Materials

For both of the RT tasks, participants received instructions, practice stimuli, and experimental stimuli via an iMac computer. We used Superlab Pro 1.75 software for stimulus presentation. Across both tasks, participants were instructed to ignore the word and indicate the color of the ink as quickly as possible by pressing one of four serially positioned keys on a standard keyboard. Stimuli within each block were separated by a 350-ms “+” in the center of a blank screen. Stimulus trials within each block did not advance unless and until participants indicated their response by pressing an answer key on the keyboard. To minimize fatigue of participants, we held the lengths of the combined tasks’ seven blocks constant at 60 trials each.

Color word Stroop task—The Stroop task used the following colors presented on a black background: red, yellow, blue, and green. Presentation of stimuli within each block was randomized and repeated 15 times per color for a total of 60 trials per block. Blocks were separated by rest periods that lasted approximately 2.5 min. There were three experimental blocks. Block 1 presented color patches; instructions were to indicate the color of the patch. Block 2 presented incongruent word and color pairs; instructions were to ignore the word and indicate the color of the ink. Block 3 presented color words in congruent ink colors; instructions were the same as for Block 2.

Emotion Stroop task—This task used the same four colors on a white background. Participants again were instructed to ignore the word and indicate the color of the ink as quickly as possible. Block 1 presented 20 negatively valenced words (e.g., *weak*, *worried*); Block 2 presented 20 nonemotive words (e.g., *take*, *bramble*). Block 3 presented 20 positively valenced words (e.g., *optimistic*, *love*); Block 4 presented 20 nonemotive words (e.g., *typewriter*, *ring*). Blocks were separated by rest periods that lasted approximately 2.5 min. The nonemotive words were matched for length and frequency of use to those in the corresponding experimental blocks. All words were obtained from Richards, French, Johnson, Naperstek, and Williams (1992). See Richards et al. for a complete list of words and the corresponding normative data and word characteristics. It is important to note that each word was presented in three of the four colors of ink, and that across all blocks, all of the colors and the valences were presented an equal number of times. (Within each block, presentation of each word was randomized and repeated three times.)

Physiological measures—We used the HEM 707 model of the Omron Regency Automatic Inflate Blood Pressure Monitor to measure participants' HR, SBP, and DBP during the Stroop tasks. This device uses standard pressure measurements to calculate and display HR, SBP, and DBP.

Procedure

We randomly assigned participants to one of two experimental presentation conditions to control for Stroop task presentation order. The presentation of Stroop tasks was counterbalanced, the presentation of blocks within each Stroop task was fixed, and the presentation of stimuli within each block was random. After participants sat down, a blood pressure cuff was attached to their nondominant arm, they completed an unrelated filler task, and baseline physiological readings were recorded. Then the first RT task was completed. Physiological readings were recorded 1.5 min into each block. After completing the first RT task, participants completed an unrelated filler task and then the second RT task. Physiological readings were again recorded 1.5 min into each block. Last, participants completed an unrelated filler task and were given a brief period to relax before the final baseline physiological readings were taken.

Results

RT and Error Percentages

See Table 1 for all means and standard deviations. In the emotion Stroop task, RTs were longer in the negative word condition than in the neutral word condition, $t(30) = 3.5, p < .001$; thus, the emotion effect was found. Although positive word interference is not a focus of the emotion Stroop literature, we examined it in the present study. There was no significant difference between RTs in the positive and neutral word conditions, $t(30) = -.18, p > .05$. Because there was no effect for the positive word condition, we largely limited our analyses to the negative word condition. In the color Stroop task, the Stroop effect was found: RTs were longer in the incongruent ink condition than in the congruent condition, $t(30) = 9.4, p < .001$. RTs were also longer in the incongruent ink condition compared with those in the color patch condition, $t(30) = 4.4, p < .001$. A facilitation effect also was found, with RTs to the color patch trials being significantly longer than congruent ink trials, $t(30) = 7.4, p < .001$.

We calculated error percentages by determining the number of valid trials in each condition and calculating the percentage of those trials on which an incorrect response was given. In the emotion Stroop task, analyses of errors revealed higher percentages of error in the neutral word condition than in the negative word condition, $t(30) = -3.60, p < .001$. A comparison of the negative and neutral word conditions revealed slower RTs and fewer errors in the negative word condition, indicating a speed-accuracy trade-off or perhaps a vigilance effect (i.e., slower and more accurate responses in the presence of negative stimuli). In the color Stroop task, there was no significant difference between the percentages of error in the incongruent and congruent conditions, $t(30) = -0.63, p > .05$. Yet, there was a significantly higher percentage of errors in the incongruent condition compared with the color patch condition, $t(30) = 1.93, p < .05$. A comparison of the incongruent and congruent conditions revealed slower RTs and more errors in the incongruent condition, indicating a classic effect for difficulty (i.e., participants were slower to respond and made more errors in the more difficult condition).

Correlations Among RT Interference and Error Percentages

Greater interference from negative words in the emotion task (mean negative RTs minus mean neutral RTs) correlated with greater interference for incongruent stimuli in the Stroop task (mean incongruent RTs minus mean congruent RTs), $r = .42, p < .001$, and with incongruent-color block interference in the Stroop task, $r = .45, p < .01$. Emotion Stroop error interference

scores (percentage of errors in the negative word condition minus those in the neutral word condition) correlated with color Stroop error interference scores (percentage of error in the incongruent condition minus that in the color patch condition), $r = -.52, p < .001$. This last correlation was opposite to our prediction. However, an examination of mean RTs on the emotion Stroop task (see Table 1) shows that slowing in the experimental (negative) condition was accompanied by a decrease in errors. However, for the color Stroop task, a similar slowing in the experimental (incongruent) condition was not accompanied by a decrease in errors. This may have contributed to the negative correlation between error interference scores across the emotion and color Stroop tasks.

Physiological Reactivity

We subtracted an average of the pre- and postbaseline readings from the readings in the respective blocks of each task. The scores in each block thus represent reactivity (i.e., change from baseline). Table 2 shows means and standard deviations, and Tables 3, 4, and 5 show the critical comparisons. In the emotion Stroop task, participants were more responsive to the neutral word conditions than to the negative word conditions in both DBP, $t(29) = -2.49, p < .01$, and HR, $t(29) = -2.54, p < .01$. This difference was not in the direction expected by a straight arousal prediction. However, the smaller increase in HR during the presentation of negative words, compared with the larger increase in HR during the presentation of neutral words, may indicate a type of intake effect (the slowing of HR when taking in information) in the negative word condition (see Papillo & Shapiro, 1990, for a review). Also in the emotion Stroop task, the difference between the larger increase in DBP during the presentation of positive words and the smaller increase in DBP during the presentation of neutral words was significant, $t(29) = 1.71, p < .05$. This difference was in the direction predicted by an arousal hypothesis.

In the color Stroop task, there was a significant difference between DBP reactivity to the incongruent and color patch conditions, $t(29) = 1.89, p < .05$, indicating greater reactivity in the incongruent condition. That this is consistent with an arousal prediction. There also was a marginally significant difference between SBP reactivity in the incongruent and congruent conditions, $t(29) = 1.38, p < .10$, with greater reactivity in the incongruent condition. This finding is also consistent with an arousal prediction.

A comparison of reactivity between tasks indicated that participants experienced more physiological reactivity in the color Stroop task than in the emotion Stroop task. The difference in DBP reactivity when comparing the incongruent and negative conditions was significant, $t(29) = 2.88, p < .01$, as was the difference in HR reactivity, $t(29) = 1.94, p < .05$.

Discussion

Regarding our first prediction, we found traditional effects for each of the Stroop tasks. A larger goal of this study was to compare inhibitory processing across tasks to determine whether it is consistent. Our second prediction was supported: RT interference scores correlated across tasks. Thus, our findings provide support for the consistency of inhibitory processing between these two tasks.

It is important to note that the blocks of stimuli within each Stroop task were blocked in their presentation: within each Stroop task, the different stimuli were not intermingled within the same presentation blocks. Had this been the case, we perhaps would have found larger interference effects between the experimental and control stimuli. However, it would have been impossible to test predictions related to physiological reactivity. It is also important to reiterate that, although the presentation of both Stroop tasks was counterbalanced and the blocks within each Stroop task were presented in a fixed order, the stimuli within each block were presented in random order. We found significant interference effects in both the color and emotion Stroop

tasks. Comparisons between them revealed a significant cross-task reliability of participants' ability to inhibit information. This ability did not seem to be specific to either emotive or nonemotive information because interference scores did correlate.

Our third prediction was partially supported. In the emotion Stroop task, cardiovascular reactivity was greater in the neutral word (control) condition than in the negative word (experimental) condition. This difference in HR activity suggests an intake effect, such that reactivity in the less cognitively demanding condition was greater than was reactivity in the condition in which participants needed to attend to threatening information. In the color Stroop task, cardiovascular reactivity was greater in the incongruent condition than in the congruent condition. This difference indicates that the more cognitively demanding condition was also more physiologically demanding. A separate, yet related prediction was also supported: our comparison of reactivity across tasks in the experimental versus control conditions suggests that there was more DBP and HR reactivity in the color Stroop task than in the emotion Stroop task. This finding is consistent with other research suggesting that the color Stroop task is more demanding than is the emotion Stroop task (DeHouwer, 2003; Larsen et al., 2001; Straus et al., 2005). This difference in reactivity may reflect the difference in cognitive load. Although each task is considered an inhibition task, the color version is more demanding, perhaps because it involves greater response conflict, thus eliciting greater cardiovascular reactivity.

The present study extends the literature by examining the cross-task consistency of the ability to inhibit the processing of irrelevant information. Eide et al. (2002) examined the test-retest reliability of the emotion Stroop task and speculated that inhibitory processing in the emotion Stroop may be functionally equivalent to inhibitory processing in the original Stroop (see also Kindt et al., 1996). However, Eide et al. did not test this speculation. The results of the present study suggest that although the tasks are related, inhibition in both tasks is not functionally equivalent. Our findings demonstrate that the emotion Stroop task does not involve as much inhibitory effort as does the original color Stroop task (Algom, Chajut, & Lev, 2004; DeHouwer, 2003) and, as per the comparison of physiological reactivity, may be less arousing. Thus, the hypothesis that the two Stroop tasks differentially involve inhibitory processing is supported.

Future Directions

One major goal of the present research was to examine the cross-task consistency of inhibitory processing (IP) of semantic information. However, the correlations relating IP in both tasks were moderate, $r_s = .45$ and $.42$. It is possible that, as relevant research implies, r_s in the present study were not higher because of the lack of theoretical overlap between these two tasks. The emotion effect is driven by automatic vigilance, whereas the color Stroop effect is driven by inhibition. It is possible that similarly designed tests of IP may yield higher correlations for RT interference and yield similar patterns of physiological reactivity. For example, IP and physiological reactivity in the Affective Simon Task (DeHouwer & Eelen, 1998) could be compared with IP and physiological reactivity in the color Stroop Task.

Another goal of the current research was to compare reactivity to the Stroop tasks. We noted that participants were significantly less aroused during the emotion Stroop task than during the color Stroop task. We found an intake effect in the emotion Stroop task and an apparent difficulty effect in the color Stroop task. Future researchers should explore the relations among reactivity in these tasks and others (e.g., the Affective Simon Task, a redesigned emotion Stroop task). We speculate that reactivity will be greatest in those tasks that are more cognitively demanding.

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TABLE 1
Means (ms) and Standard Deviations of Reaction Time (RT) and Error Rates

Experimental block	RT	SD	% error rates	SD
Color Stroop				
Incongruent	750	83	5.7	5.7
Congruent	637	67	6.0	5.6
Color block	696	79	4.5	4.5
Emotion Stroop				
Negative	681	69	3.3	3.4
Negative match	655	76	4.9	4.7
Positive	659	81	5.3	4.4
Positive match	660	75	6.1	4.3

Note. $N = 31$.

TABLE 2

Mean Physiological Reactivity

Experimental block	Diastolic blood pressure		Systolic blood pressure		Heart rate	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Color Stroop						
Incongruent	3.0	3.9	2.1	5.4	1.9	5.8
Congruent	2.8	3.4	0.66	4.3	0.85	5.3
Color block	1.8	4.4	1.0	4.5	1.6	4.9
Emotion Stroop						
Negative	1.2	4.0	-0.33	4.3	1.0	4.2
Negative Match	2.5	4.4	0.40	3.7	2.9	4.2
Positive	2.6	5.2	0.20	4.8	3.1	5.1
Positive Match	0.80	5.0	0.77	5.0	3.6	5.4

Note. *N* = 30.

TABLE 3
Comparisons of Mean Diastolic Blood Pressure Reactivity

Comparison	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Color Stroop				
Incongruent-congruent	0.23	3.7	0.34	.37
Incongruent-block	1.2	3.6	1.90	.03
Emotion Stroop				
Negative-neutral	-1.3	2.8	-2.50	.01
Postive-neutral	1.8	5.8	1.70	.05
Negative-positive	-1.4	4.1	-1.80	.04

Note. *N* = 30.

TABLE 4
Comparisons of Mean Systolic Blood Pressure Reactivity

Comparison	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Color Stroop				
Incongruent-congruent	1.5	6.0	1.4	.09
Incongruent-block	1.1	4.6	1.3	.10
Emotion Stroop				
Negative-neutral	-0.73	4.8	-0.84	.20
Positive-neutral	-0.57	3.5	-0.90	.19
Negative-positive	-0.53	5.2	-0.56	.29

Note. *N* = 30.

TABLE 5
Comparisons of Mean Heart Rate Reactivity

Comparison	<i>M</i>	<i>SD</i>	<i>t</i>	<i>p</i>
Color Stroop				
Incongruent-congruent	1.0	5.2	1.10	.15
Incongruent-block	0.27	3.8	0.39	.35
Emotion Stroop				
Negative-neutral	-1.8	3.9	-2.50	.01
Positive-neutral	-0.47	3.9	-0.66	.26
Negative-positive	-2.0	4.4	-2.50	.008

Note. *N* = 30.