EFFECTS OF PRACTICE ON STROOP CONGRUITY

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Abstract

Automaticity, both reading and response, response competition, translation models, and the imbalance/uncertainty model of the Stroop effect were investigated. Two participants received four weeks of key press practice using standard Stroop stimuli. Tests of RT to standard Stroop, Single colored letter, and Stroop dilution stimuli were conducted before and after each week of practice using both key press and vocal responding. After the final practice they also were tested on reverse Stroop stimuli. The results support response competition and partially support response automaticity, Sugg and McDonald's (1994) translation model, and the imbalance/uncertainty model and fail to support the mental set hypothesis of Besner, Stolz, and Boutilier (1997).

The Stroop effect is the interference of words with indicating the color in which the words are presented. Theories of the Stroop effect include automaticity theory, both reading and response automaticity, response competition, translation theory, imbalance/uncertainty, and mental set.

Automaticity The most common theory of the Stroop effect, automaticity (Stirling, 1977), is based on the idea that through long practice reading becomes an automatic process and does not need controlled attention to occur. Automatic reading uses some attentional resources, and thus reduces the resources available to process and name stimulus color.

Stirling (1977) also introduced the concept of response automaticity. He showed that changing the responses from color words to letters that were not part of the color words increased RT and reduced Stroop interference. With letter response practice, RT and Stroop interference with letter responses became more like those with color word responses.

Response Competition Eriksen and Eriksen's (1974) theory of response competition posits the notion that when a stimulus primes both a correct and an incorrect response, the responses compete for the single response channel and the incorrect response must be suppressed before the correct response can be made. With Stroop stimuli, the color word as well as the color itself primes a response. Thus for incongruent stimuli a correct (color) as well as an incorrect (word) response is primed and the word response must be suppressed. Nealis (1974) claims that both congruent and incongruent stimuli produce response competition.

Translation Models According to translation models (Glaser & Glaser, 1989; Sugg & McDonald, 1994; Virzi & Egeth,1985) color and words are processed via separate modules: semantic memory which includes concept nodes that are linked by semantic relationships processes color and a lexicon with word nodes that are linked by non-semantic relationships

processes words. Interference is produced if more than one potential response node is activated by a stimulus. There are two-way links between the modules. An assumption is made that perception of and responses to colors and pictures have privileged direct access through semantic memory and that words, whether spoken or written, have privileged direct access through the lexicon. Interference is obtained only if the irrelevant stimulus aspect has privileged access to the module necessary for response selection.

If an incongruent Stroop stimulus requiring vocal response occurs (e.g. RED in blue) the word RED is processed by the lexicon, and the color blue is processed by semantic memory. The vocal response must be made through the lexicon, thus the semantic memory node must be translated into a word node in the lexicon before one can say "blue," which translation requires extra processing. Similarly, if the response requires pressing a button labeled with the word, there will be interference because the color must be translated into a word node in the lexicon before one can press the "blue" button, which translation again requires extra processing. If, however, the response is pressing a button painted with the color, then the button press response can be made by a semantic memory response without translation. On the other hand, according to Sugg and McDonald (1994) if each key is always the same color, with practice responses to them will become converted to covert word responses and translation, with its attendant interference, will occur.

Imbalance/Uncertainty A newer model, described by Sabri, Melara, and Algom (2001) places Stroop processing into a Garnerian (Garner, 1983) context. The main focus of the model is the difference between asymmetric (the difference between attending to color and attending to words) and global (the average of attending to color and attending to words) selective attention failure in Stroop processing. The model posits independent sources for these two effects: dimensional imbalance between colors and words leading to asymmetric selection failure and stimulus/decisional uncertainty leading to global selection failure. Dimensional imbalance has at least two determinants. One is the psychophysical context, which determines the relative discriminability of the word and color dimensions. The other is the production context, which includes response mode and its compatibility with the stimulus. Key press responses are, initially, imperfectly compatible with colors, but practice should improve compatibility.

It is worthwhile noting that these three models posit similar reasons, stated in different contexts, for reduced Stroop congruity with key press responding, either because the link between words and speaking, but not key press is highly automatic, is based on privileged processing pathways, or leads to selective attentional imbalance. Further, all three yield the same expectation of the effect of key press practice, faster RT and greater congruity effects.

Mental Set Besner, Stolz, and Boutilier (1997) found that coloring only one letter in a Stroop task with colored key responding caused reduced Stroop interference, the single colored letter effect. They (Besner & Stolz, 1999) have argued that the typical mode of processing a stimulus which includes a word is through automatic reading. Circumstances, however, such as having a single letter colored can cause a change in mental set, which allows processing of stimulus color with greatly reduced automatic reading. Reducing the automaticity of reading should speed up processing of incongruent stimuli by reducing the interference of the incongruent color word. It should slow congruent RT only to the extent that there is facilitation. Yet, the opposite actually occurs. Incongruent RT is unaffected by single colored letter, whereas both congruent and neutral RT are slowed (Monahan, 2001), indicating that congruent RT loss is not due to loss of facilitation. The mental set approach does not include differential predictions based on response mode or practice, but does predict reduced Stroop interference with single colored letter stimuli. Published reports confirming the single letter effect have used key press

responding only. Other models do not predict reduced Stroop interference with single colored letter stimuli.

The current experiment was designed to test the effect of the development of key press response automaticity on congruity effects in a variety of Stroop tasks. Participants practiced key press responding to congruent and incongruent standard Stroop stimuli three times a week for four weeks. Before and after each week of practice, participants were tested on standard Stroop stimuli, single colored letter stimuli, and Stroop dilution stimuli using both key press and vocal responding. After the last regular test, participants were also tested on reverse Stroop stimuli. According to the automaticity hypothesis, translation models, and the imbalance/uncertainty hypothesis, key press practice should decrease key press RT but increase key press congruity effects. According to the response competition idea, key press or any other practice with incongruent stimuli should reduce the time necessary to suppress incorrect responses, thus reducing congruity effects. According to the mental set idea, coloring a single letter should reduce congruity.

Method

Materials and Apparatus

RGB values for the colors were red (42, 0, 0), yellow (63, 63, 21), green (0, 42, 0), and blue (0, 0, 42). Sequences were presented to participants on PC's with 17 in VGA displays. Four keys were painted to match the colors presented (red - a, yellow - s, green -l, and blue -;). The words used were RED, YELLOW, GREEN, and BLUE.

Participants and Procedure

There were two volunteer participants who completed the study. They were tested on the standard and single colored letter Stroop task with both voice and key press responding before beginning practice sessions. Practice sessions used standard Stroop stimuli only. At the end of each week of three practice sessions they were tested again. This process was repeated for four weeks. Thus there were five testing sessions and 12 practice sessions. Participants were instructed to respond as quickly as possible without making errors. RT and accuracy were measured.

Practice Practice sessions consisted of three blocks of trials. Within each block there were two sections of 48 data collection trials: one for congruent stimuli and one for incongruent stimuli. No feedback was given on data collection trials. Preceding each section were practice trials, which were repeated if they were responded to incorrectly. Correct practice responses were followed by notification of RT. Before each of the two sections there were 12 practice trials in the first block and four practice trials in the second and third blocks. Congruent and incongruent sections were presented randomly within blocks.

Testing The five test sessions consisted of two blocks of trials, one with key press and one with vocal responding. Each block had six separate sections of 48 data collection trials: standard congruent, standard incongruent, single colored letter congruent, single colored letter incongruent, Stroop dilution congruent (color bar randomly above or below a color word in white), and Stroop dilution incongruent stimuli. The first four sections were presented in random order followed by the last two sections presented in random order. Each section was preceded by

12 practice trials, which, if responded to incorrectly, were repeated. Incorrect practice responses also triggered a tone. On the fifth testing period, a reverse Stroop test (the participant indicates the word, not the color) was administered at the end in a separate block of trials: 12 practice and 48 data collection trials for congruent and for incongruent stimuli, with order of sections determined randomly.

Participants were debriefed and paid for their service.

Results

The four weeks of practice showed faster responses in practice to congruent (\underline{M} week 1 = 497 ms; \underline{M} week 4 = 463 ms) and incongruent (\underline{M} week 1 = 594 ms; \underline{M} week 4 = 485 ms) standard Stroop stimuli, as well as reduced congruity effects (\underline{M} week 1 = 90 ms; \underline{M} week 4 = 34 ms). These speed gains and congruity effect reductions seen in practice were also seen in some, but not all, test session results.

Test session results for all key press conditions showed considerable increase in response speed of at least 100 ms for congruent and incongruent standard Stroop stimuli, single colored letter stimuli, and Stroop dilution stimuli. Only standard Stroop stimuli showed a significant reduction in congruity effects. Single colored letter stimuli had increased congruity effects, and dilution stimuli had no change. At the end there appeared to be little difference in Stroop congruity among the three stimulus types. Mean key press and vocal RT and congruity effects by stimulus type and congruency are shown in Table 1.

	Congruent			 Incongruent				Congruity Effects		
Test	St^1	Sing ²	Dil ³	 St^1	Sing ²	Dil ³		St^1	Sing ²	Dil ³
		-		Key F	ress Re	esponse			-	
Test 1	569	664	593	659	674	635		90	11	42
Test 5	451	501	486	485	552	520		34	51	34
Reduction	118	163	107	174	122	115		56	-41	8
				Vocal Response						
Test 1	437	451	488	647	631	606		211	180	118
Test 5	457	470	467	559	581	591		102	111	124
Reduction	-20	-19	21	88	50	15		108	69	-6
1			2	 			3~			<u> </u>

¹standard Stroop stimuli ²single colored letter stimuli ³Stroop dilution stimuli

Table 1. Key Press and Vocal RT (in ms) by Test and Stimulus Set to Congruent and Incongruent Stimuli, and the Resulting Congruity Effects.

Test session results for vocal response conditions were quite different from key press results. All three types of congruent stimuli showed little, if any, improvement in response speed. Vocal responses to standard Stroop and single colored letter incongruent stimuli showed about half the RT reduction that key press responses did. Responses to Stroop dilution incongruent stimuli showed a negligible RT reduction. Congruity effects were much greater with vocal responding than with key press responding. Congruity effects were greatly reduced for

standard stimuli, reduced for single colored letter stimuli, and not reduced for Stroop dilution

stimuli. Again, at the end, there appeared to be little difference in Stroop congruity effects for the three stimulus types.

The effect of practice on Stroop asymmetry was tested in the last session using a reverse Stroop test. Key press responding yielded a reverse Stroop congruity effect more than five times greater than the standard congruity effect. Vocal responding yielded a reverse congruity effect less than half the size of the standard congruity effect. Key press and vocal reverse Stroop results are shown in Table 3.

Response			
Mode	Congruent	Incongruent	Congruity Effect
Key Press	499	692	194
Vocal	445	486	41

Table 3. Reverse Stroop RT (in ms) by Response Mode to Congruent and Incongruent Stimuli, and the Resulting Congruity Effects.

Discussion

Automaticity, translation models, and imbalance uncertainty theory are not well supported by these results. Although, as predicted, practice reduced key press RT, it did not increase congruity effects except to single colored letter stimuli.

The mental set hypothesis is not supported by these results. Key press practice increased congruity effects for single colored letter stimuli. The current results, also, show that practice with vocal responding to single colored letter stimuli leads to the same level of congruity as with standard stimuli.

The unbalanced/uncertainty and automaticity theories were also not supported by the current results. According to the theory, there is an asymmetry in color-word processing such that words interfere with color naming, but not vice-versa. Because practice leads to a leveling of that dimensional difference in interference, these theories need modification to accommodate the current, as well as the original Stroop (1935) results.

Only the response competition hypotheses escaped unscathed by the current results: incongruent stimulus processing was always slower than congruent. But even that outcome might have been different had there been a reverse Stroop condition at the first test.

Practice with standard Stroop stimuli using key press responding appears to have two different effects on Stroop processing. First, it reduces key press RT. This result is seen in key press responding to congruent and incongruent stimuli of all three types. Second, practice makes participants better able to deal with incongruent stimuli. This result is seen most clearly in the reduction in RT to standard and single colored letter incongruent but not congruent stimuli with vocal responding. This reduced incongruent RT leads to reduced congruity effects. The results can be interpreted to show that the heart of the Stroop effect, incongruent processing, is somewhat independent of response mode. This latter point is also shown by Sharma and McKenna (1998), who found no difference in incongruent RT with vocal and key press responding. The same was true for the current results before, but not after, practice. Thus, there must be some response specific effect and some incongruent specific effect on Stroop processing resulting from the practice experienced in the current experiment.

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