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Interactions Between Color and Word Processing in a Flanker Task

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To examine interactions between color and word attributes, participants responded, either manually or vocally, to a central target (color patch or word) flanked by a Stroop stimulus. Color and word attributes of the flanker affected both vocal and manual responding to color patches. Color and word flankers also affected manual responding to word targets, but only word flanker affected vocal responding to word targets. These results are not consistent with models (e.g., translational models) of Stroop tasks, which posit that interactions between colors and words occur only when vocal responding is required.

The Stroop phenomenon (MacLeod, 1991; Stroop, 1935) is cited as strong evidence that word reading cannot be suppressed even when irrelevant to the task at hand. However, several authors (Cohen, 1994; Treisman & Fearnley, 1969; Virzi & Egeth, 1985) presented evidence that led them to attribute the apparent special status of word processing to particular features of the Stroop paradigm. They suggested that stimulus attributes (i.e., color and words) are processed by parallel-processing systems, each using its own internal codes, so that there is no cross-talk between the systems unless a translation, from one system to the other, is required. When participants are required to report the color vocally, a translation from the color system to the linguistic system is necessary, and the linguistic system is primed. In contrast, when participants are required to respond to color manually, no such translation from the color system to the linguistic system is necessary (Virzi & Egeth, 1985), and the linguistic system is not primed. The idea of parallel-processing systems that are noninteracting (Cohen, 1994; Treisman & Fearnley, 1969; Virzi & Egeth, 1985) predicts no effect of an irrelevant word on color response when no translation is needed (manual responding), because the linguistic system is not required to operate on the stimulus. In contrast, if word processing is automatic, interference of the irrelevant word on color response may occur, even when no obvious need for translation exists.

Treisman and Fearnley (1969) suggested that an important characteristic of the Stroop task is a mismatch between attributes, that is, participants are asked to produce a word to match a color (in the reverse Stroop, to match a word). They conducted an experiment in which the relevant and the irrelevant stimulus attributes (i.e., color and word) were spatially separated, and they used card sorting, in which no color or word response was used. Each card presented two items (e.g., the word GREEN in red and the word GREEN in black), and participants were asked to sort the cards into "same" or "different" piles by matching within attributes (word to word or color to color) and between attributes (word to color or color to word). Treisman (1969; Treisman & Fearnley, 1969) suggested that when one matches within an attribute, the other attribute could be switched off so that it does not interfere with processing the relevant attribute. In contrast, when matching across attributes is required, each attribute must be identified first so that it is impossible to switch off either of the processing systems. Thus, when matching within attributes, no interference between irrelevant and relevant attributes is expected, whereas when matching across attributes, interference is expected. Treisman and Fearnley found faster matching within attributes with interference across attributes (matching word to word with interference from color, or color to color with interference from word) and slower matching across attributes with

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interference within one attribute (matching color to word with interference from word, or word to color with interference from color). A third condition, which required matching across attributes but with no interference, produced intermediate response times. Unfortunately, as Treisman and Fearnley mentioned, one condition was missing: matching within an attribute with no competition from another. If it is possible to switch off the irrelevant attribute while matching within an attribute, this condition should produce sorting times comparable to the condition of matching within attributes with competition across attributes.

Treisman and Fearnley (1969) argued that words have no special status. When word processing was not required (i.e., matching color to color), sorting was faster than when word processing was required (i.e., matching color to word). They suggested that different attributes are analyzed by independent processing modules and that the apparent automaticity of word processing could be traced to specific features of the Stroop task, such as the need for translation or the need to produce a word to match a color.

Virzi and Egeth (1985) have presented a similar view. There are several processing systems, and each comprises specific analyzers, a decision stage, and a response stage. The analyzers of a given system feed directly into the decision stage and into a translation mechanism. The translation mechanism feeds into the decision stages of several systems. Thus, a given attribute is analyzed within its natural system (e.g., color by the color system). However, if it has to be translated to a different system (e.g., color translated to the word system), it would be influenced by the information already within that system (e.g., words processed by the word system). However, if no translation is necessary, that is,

> when a subject responds to a word by saying it, or to pitch by humming, [then] processing is contained within the linguistic and tonal systems, respectively. Interference from a conflicting irrelevant cue has no chance to occur because the irrelevant cue is processed by a different system and does not compete with the representation of the word at any point. (Virzi & Egeth, 1985, p. 306).

Thus, the idea of independent noninteracting cognitive systems is at the heart of Virzi and Egeth's translational model. According to this model, only when a translation is necessary (e.g., matching across attributes or producing a word in response to a color) is there interference between attributes. This same idea was also incorporated in a model suggested recently by Cohen (1994).

Sugg and McDonald (1994) reported a study designed to investigate translational models. They presented an achromatic word inside a colored rectangle and asked participants to respond manually either to the color or to the word. On each trial the response keys were labeled with either achromatic words or color patches. Participants responded by pressing virtual keys on a touch-sensitive screen located less than 1 cm beneath the stimuli. The study incorporated translated or untranslated (i.e., direct correspondence between stimulus and response) conditions. Under translation conditions, the irrelevant dimension, which was the dimension corresponding to the required response, affected performance. For example, when participants responded to the word by producing a color response (pressing a colored button), the irrelevant color affected performance. In contrast, under untranslated conditions, the effect of the irrelevant dimension was, in most cases, not significant. For example, when participants responded to the word by producing a word response, the effect of the irrelevant color was not significant under most conditions.

In recent years Kornblum and his colleagues (Kornblum, 1992; Kornblum, 1994; Kornblum, Hasbroucq, & Osman, 1990; Kornblum & Lee, 1995) have suggested a model for stimulus–response (S-R) and stimulus–stimulus (S-S) compatibility effects. Interestingly, this model, which was designed to explain, among other things, the Stroop and Stroop-like effects, incorporates a mandatory stimulus-comparison stage. This stage compares irrelevant and relevant attributes before response mechanisms are engaged.

One way to look at interactions within and between attributes, in the same trial, is to present the relevant and irrelevant attributes in separate locations (B. A. Eriksen & Eriksen, 1974; C. W. Eriksen & Eriksen, 1979; C. W. Eriksen & Schultz, 1979; Miller, 1991). For example, have participants focus on a color patch in the center of the screen and ignore a flanking word. To examine not only the effect of the word on the color but also the effect of color on color (interaction within an attribute), one can present the word in color.

Several studies (Brown, Roos-Gilbert, & Carr, 1995; Gatti & Egeth, 1978; Hagenaar & van der Heijden, 1986; La Heij, Helaha, & van den Hof, 1993, Experiment 3; Merikle & Gorewich, 1979) used color patches as targets and color words as flankers and found that naming the target color was slower when the flanker was incongruent than when it was congruent or neutral. Kahneman and Henik (1981) presented two words on either side of the fixation point and found effects both of attended (target) and unattended words, although the latter effect was much smaller (see Kahneman & Henik, 1981, Experiment 2). Cohen (1994) exposed participants to a red or a green vertical bar flanked by the words *red* or *green* in blue and found a flanker congruency effect (see Cohen, 1994, Experiment 2). So that the paradigm was similar to the Stroop paradigm, these studies used vocal responses to prime the linguistic system. To study interactions between attributes without inherently activating one system or the other, one must use a response mode that has no direct correspondence to the studied attributes (e.g., unlabeled manual responses).

In the current study we examined the effects of flankers with both word and color attributes on responding to colors (Experiments 1, 2A, and 2B) and to words (Experiments 3, 4A, and 4B). We manipulated the need for translation by requiring either manual or verbal responses. In the current experiments, we presented participants with a central target flanked on the right or the left by an irrelevant stimulus, and they made, in separate experiments either vocal or manual responses. In separate experiments, the target could be a red or green color patch or one of the words RED or GREEN in white. The peripheral flanker was either a word or a series of Xs in red, green, or blue. Thus, the flanker had color and word attributes, which were manipulated orthogonally. Each of the flanker attributes consisted of three levels that were congruent, neutral, and incongruent with the target. This arrangement let us look not only at effects between words and colors but also at effects within these dimensions and at possible interactions between them.

The main features and predictions of the experiments are summarized in Table 1. If words and colors are separate, noninteracting systems (Cohen, 1994; Treisman & Fearnley, 1969; Virzi & Egeth, 1985), congruity effects (the difference between incongruent and congruent conditions) should occur within systems; between systems, congruity effects should occur only when translation from one system to the other is required. When manual responses were required, the keys were not labeled (either by a word or by a color patch), and for a given participant, the S-R mapping was consistent throughout the experiment. Vocal responding is compatible or has a "natural" connection to words. In contrast, manual responses have no natural connection either to words or to colors. Thus, although vocal responding may prime the word system, manual responding primes neither the word nor the color systems. Hence, when participants respond manually (i.e., there is no demand for translation between systems), we expected the following: (a) For color targets (Experiments 2A & 2B), there should be an effect of color congruity (within-system interaction) and no effect of word congruity (between-systems interaction), and (b) for word targets (Experiments 4A & 4B), there should be an effect of word congruity (within-system interaction) and no effect of color congruity (between-systems interaction). When participants respond vocally to a target color patch (Experiment 1), so that between-systems translation (color to word) is necessary, there should be an effect both of color (within-system interaction) and word congruity (between-systems interaction). Note that between-systems interaction is produced because the task (vocal responding) requires translation from color to word. When participants respond vocally to a target word in white (Experiment 3), so that no translation is necessary, there should be an effect of word congruity (within-system interaction) and no effect of color congruity (between-systems interaction). However, if the word- and color-processing systems do interact, we expected congruity effects between attributes—not only within attributes—even for manual responding.

Experiment 1

As in the conventional Stroop situation, in this experiment we used vocal responses to confirm that the flanker paradigm produces a pattern of results that is similar to those produced in a Stroop experiment, namely, a large effect of word flanker on responses to a target color patch. In addition, the present design allowed us to look at effects within an attribute (i.e., between target color and flanker color) and at possible interactions between the color and word attributes of the flanker affecting target processing.

Method

Participants. Ten undergraduates participated in the experiment for course credit. For all participants, English was the first language; all had normal or corrected-to-normal vision.

Stimuli. Each stimulus was composed of a red or green square, in the center of the screen, and a flanker to the left or the right of the square. The flanker was the word RED, the word GREEN, or a series of Xs, colored in red, green, or blue. Thus, for each of the two flanker dimensions, the flanker could be congruent (e.g., central square red and flanker word RED or flanker color red), neutral (e.g., central square red and flanker comprising Xs or flanker color blue), or incongruent (e.g., central square red and flanker word GREEN or flanker color green). The two flanker dimensions were manipulated orthogonally so that there were nine flanker conditions (3 word levels × 3 color levels), and each occurred with equal probability. The Xs were used for neutral word flankers because this type of neutral flanker is commonly used in Stroop experiments.

Each participant was shown one experimental block of trials, half with a red central square and half with a green central square. On half of the trials the flanker appeared on the right of the central square, and on the other half, on the left of the central square. Each of the nine flanker conditions was repeated 60 times. Thus, an experimental block contained 540 trials (2 central square colors × 2 sides of the flanker × 9 flanker conditions × 15 repetitions). The practice block contained 36 trials (4 trials from each of the nine flanker conditions). All error trials were repeated and were randomly replaced within the block.

Participants faced a computer screen at a viewing distance of about 57 cm. The central target square was 1° on a side (1 cm at a viewing distance of 57 cm). The closest edge of the word (i.e., the end of the word of the left flanker and the beginning of the word of the right flanker) was 0.5° away from the edge of the target color patch. The words RED and XXX were 1.6° in length, and the word GREEN was 2.7° in length. All the words were 0.7° high.

Table 1
Description of the Four Experiments and Predictions Given Noninteracting Color and Word Systems

Experiment	Target	Distractor	Response	Prediction	Results
1	Color patch	Word	Vocal	+	+
		Color		+	+
2A, 2B	Color patch	Word	Manual	−	+
		Color		+	+
3	Word	Word	Vocal	+	+
		Color		−	−
4A, 4B	Word	Word	Manual	+	4A−, 4B+
		Color		−	+

Note. + = congruity effect; − = no congruity effect.

Apparatus. Stimuli were presented on a 14 in. (35.56 cm) VGA NEC color monitor. Stimuli presentation and data collection were controlled by an IBM 286 compatible computer. Vocal response latencies were recorded in milliseconds via a voice-operated relay, interfaced to the computer.

Design. There were two independent variables that were manipulated orthogonally within subjects. One variable, *word,* depicted the relation between the color of the target square and the meaning of the flanker word: congruent (e.g., red central square and the word RED as a flanker), neutral (e.g., red central square and XXX as a flanker), or incongruent (e.g., red central square and the word GREEN as a flanker). A second variable, *color,* depicted the relation between the color of the target square and the color of the flanker: congruent (e.g., red central square and red flanker), neutral (e.g., red central square and blue flanker), or incongruent (e.g., red central square and green flanker).

Procedure. Participants were asked to respond vocally, as fast as possible, to the target, that is, to say "red" or "green" as fast as possible and to ignore the flanker. On each trial, a fixation—a filled gray circle—was displayed for 500 ms before the stimuli were presented. The central square and the flanker appeared simultaneously and were eliminated by the participant's vocal response. The interstimulus interval was 1,500 ms. The experimenter keyed in the participants' responses. Participants took part individually in sessions that lasted about 30 min.

Results

For every participant in every condition, percent errors and mean reaction time (RT) in milliseconds were computed for the correct responses. Error rates were low; mean percent error was 4.02%. Mean RTs for the various conditions are presented in Table 2.

Mean RTs were subjected to a two-way mixed model analysis of variance (ANOVA). The two main effects were significant: for color, $F(2, 18) = 5.11$, $MSE = 225.03$, $p < .025$, for word, $F(2, 18) = 51.09$, $MSE = 616.46$, $p < .001$. The interaction between these variables was not significant, $F(4, 36) = 1.65$. Mean RTs of the three word conditions were 507, 501, and 560, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 9) = 75.20$, $MSE = 563.86$, $p < .001$, and the neutral condition, $F(1, 9) = 52.92$, $MSE = 975.56$, $p < .001$. Mean RTs of the three color conditions were 519, 519, and 530 for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 9) = 6.20$, $MSE = 285.49$, $p < .05$, and the neutral condition, $F(1, 9) = 8.35$, $MSE = 200.48$, $p < .025$. As shown in Table 2, color congruency produced an effect under both congruent and incongruent word conditions, but under the neutral word condition (a flanker comprising a series of Xs), the color effect was only 1 ms. In spite of the fact that the two-way interaction was not significant, we looked at the neutral word condition more closely. In particular, we counted the number of participants who produced a congruity effect (i.e., for whom the incongruent condition was slower than the congruent condition) and found that 8 out of 10 participants produced a congruity effect.

Table 2
Mean Reaction Times (RTs; in Milliseconds) and Percent Errors for the Nine Flanker Conditions in Experiment 1: Vocal Responses

Color congruency	Word congruency: Congruent RT	Congruent % error	Neutral RT	Neutral % error	Incongruent RT	Incongruent % error
Congruent	499	2.11	501	2.00	558	4.23
Neutral	504	3.02	501	2.68	553	3.41
Incongruent	517	2.11	502	2.59	570	3.02

Discussion

This experiment produced an effect both of word and color on vocal responses to the central color patches. The word effect is analogous to the Stroop effect (MacLeod, 1991), and like the Stroop effect, it is mainly interference based. The flanker word effect replicates findings reported previously (Gatti & Egeth, 1978; Hagenaar & van der Heijden, 1986; Merikle & Gorewich, 1979). These results are also consistent with those reported by Sugg and McDonald (1994) for the translated word-response (i.e., responding to the color by pressing a button labeled with *word*). The color effect was also significant. The color effect is expected because target and distractor are in the same system (Treisman, 1969). The word effect, which reflects interaction (or cross-talk) between systems, is expected because the task requires translation of target color into a vocal response (Treisman & Fearnley, 1969; Virzi & Egeth, 1985). That is, the need to respond vocally primes the word system so that words, even if irrelevant, have an effect on responses to color.

The word and color attributes of the flanker did not produce a significant interaction. This suggests that neither of them modulates the other's effect on color naming. It seems that the unattended flankers may be disassembled into their attributes and may affect attended attributes separately. This pattern is in accord with models of separable attributes in vision (Treisman & Gelade, 1980; Treisman & Schmidt, 1982).

Experiment 2A

This experiment was identical to Experiment 1 except that a manual keypress rather than a vocal response was made to the target color patch. Manual responding is neutral with respect either to color or word (see Kornblum, 1992, for a taxonomy of tasks that makes the same point with respect to manual responding; Kornblum et al., 1990). If there is no interaction between color and word, we would expect a color effect, because the color attribute of the flanker and the target use the same analyzer, but we would not expect a word effect, because the word attribute of the flanker and the target (color) use different analyzers. Moreover, we expected no interaction between the two dimensions of the flanker to affect responding to the target color.

Method

Ten undergraduates who had not participated in any of the other experiments in this study took part in the experiment for course credit. For all participants, English was the first language; all had normal or corrected-to-normal vision. Responses were made on two adjacent buttons on a Gravis joystick placed on the table between the individual and the video screen. All other features of the experiment were the same as those of Experiment 1.

Results

For every participant in every condition, percent errors and mean RT in milliseconds were computed for the correct responses. Error rates were low; mean percent error was 2.83%. Mean RTs for the various conditions are presented in the upper portion of Table 3.

The mean RTs were subjected to a two-way mixed model ANOVA. The two main effects were significant: for color, $F(2, 18) = 15.87$, $MSE = 334.44$, $p < .001$; for word, $F(2, 18) = 15.34$, $MSE = 478.35$, $p < .001$. The interaction between these variables was not significant ($F < 1$). Mean RTs of the three word conditions were 483, 479, and 508, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 9) = 17.70$, $MSE = 519.89$, $p < .005$, and the neutral condition, $F(1, 9) = 27.45$, $MSE = 457.51$, $p < .001$. Mean RTs of the three color conditions were 478, 488, and 504, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 9) = 19.26$, $MSE = 285.49$, $p < .005$, and the neutral condition, $F(1, 9) = 20.85$, $MSE = 191.89$, $p < .005$. There was also a significant facilitory effect: The neutral condition was significantly slower than the congruent condition, $F(1, 9) = 5.59$, $MSE = 270.05$, $p < .05$.

Table 3
Mean Reaction Times (RTs; in Milliseconds) and Percent Errors for the Nine Flanker Conditions in Experiments 2A and 2B: Manual Responses

	Word congruency					
	Congruent		Neutral		Incongruent	
Color congruency	RT	% error	RT	% error	RT	% error
Experiment 2A						
Congruent	469	2.21	463	1.30	500	2.31
Neutral	483	2.31	480	2.11	500	2.21
Incongruent	496	1.89	493	2.41	523	2.94
Experiment 2B						
Congruent	456	1.96	472	1.16	480	3.53
Neutral	462	1.97	474	2.63	471	3.10
Incongruent	470	2.52	486	2.08	486	3.34

Discussion

The results of Experiment 2A suggest that in addition to interactions within a processing system (color), there is evidence for interaction between word and color systems. Even though the word was not primed by task requirements, it influenced processing of target color, and its influence seemed to be interference based. Thus, the strong version of the translation hypothesis (Virzi & Egeth, 1985), which suggested no interaction between processing systems unless called for by task characteristics, may be rejected.

One of the conditions in a recent study by Kornblum (1994) demonstrated the effect of word on color under manual responding (the condition was termed *simple S-S overlap trials, type 4*). The word was presented in the center of the screen, and the color was presented in the upper or lower half of the word background. Participants were asked to respond to the color and ignore the word. Kornblum (1994) reported that word congruity was large (48 ms) and significant when the word led the color by 200 ms, and it was small (5 ms) and insignificant when the word and the color appeared simultaneously. Our experiment departs from Kornblum's (1994) experiment in several respects, which may have contributed to the fact that Kornblum found the word effect under lag 200 and not under lag 0.

Experiment 2B

In Experiments 1 and 2A we used Xs for the neutral condition of the word attribute and the color blue for the neutral condition of the color attribute. In most Stroop experiments, Xs or other nonword stimuli are used for the neutral condition. However, note that the color blue has the same "color" status as the two colors used for the congruent and the incongruent color conditions, but it is not in the response set. In contrast, the Xs have a different status than the two words used for the congruent and incongruent word conditions. To determine whether flanker word interference involved response stage or an earlier stage of processing, we had to use a neutral word that would be conflicting but that would not be in the response set. Because MacLeod (1991) suggested that Stroop interference involves more than response competition, we expected to find a similar pattern here; namely, a neutral word (e.g., the word BLUE) would slow down responding relative to a congruent word.

Method

The experiment was conducted in Israel, and stimuli were presented in Hebrew. Eighteen undergraduates who had not participated in any of the other experiments in this study took part in the experiment for course credit. For all participants Hebrew was the first language, and they had normal or corrected-to-normal vision. We used the Hebrew translations of RED and GREEN for the congruent and the incongruent conditions and the Hebrew translation of BLUE for the neutral condition. The words RED, GREEN, and BLUE are all four-letter words in Hebrew. All other features of the experiment were the same as those of Experiment 2A.

Results

For every participant in every condition, percent errors and mean RT in milliseconds were computed for the correct responses. Error rates were low; mean percent error was 2.48%. Mean RTs for the various conditions are presented in the lower portion of Table 3.

The mean RTs were subjected to a two-way mixed model ANOVA. The two main effects were significant: for color, $F(2, 34) = 4.42$, $MSE = 569.78$, $p < .025$; for word, $F(2, 34) = 5.62$, $MSE = 762.42$, $p < .01$. The interaction between these variables was not significant ($F < 1$). Mean RTs of the three word conditions were 463, 478, and 479, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 17) = 8.44$, $MSE = 828.36$, $p < .01$, and was not different from the neutral condition ($F < 1$). The neutral condition was also significantly slower than the congruent condition, $F(1, 17) = 8.66$, $MSE = 670.92$, $p < .01$. Mean RTs of the three color conditions were 470, 469, and 481, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 17) = 7.38$, $MSE = 480.13$, $p < .025$, and the neutral condition, $F(1, 17) = 8.20$, $MSE = 486.82$, $p < .025$. There was no facilitory effect ($F < 1$).

Discussion

The results of Experiment 2B, which was conducted in Hebrew, were similar to those of Experiment 2A, which was conducted in English. That is, there were two significant main effects of the word and the color variables and no significant interaction between them. The neutral condition for the word attribute, which was of major interest in Experiment 2B, produced interference that was comparable to that produced by the incongruent word. This result suggests that the interference need not involve a response stage because interference can be produced by a stimulus that is not in the response set.

The pattern of results of this experiment suggests an additional point: The irrelevant word and irrelevant color seem to have different effects.[1] The word effect is independent of response set: The word BLUE, which is not in the response set, has the same effect as the incongruent word, which is in the response set. In contrast, the color effect depends on response set: There is a difference between the color blue, which is not in the response set, and the incongruent color, which is in the response set. This suggests that different mechanisms are responsible for the word and the color effects. There are two aspects to this proposal: It implies that words have some special status because they exert their effects regardless of being part of the response set, and it undermines translational models. According to translational models, the major reason for the Stroop effect is the need to translate across systems, and different attributes are supposed to exert their effects in the same way. In

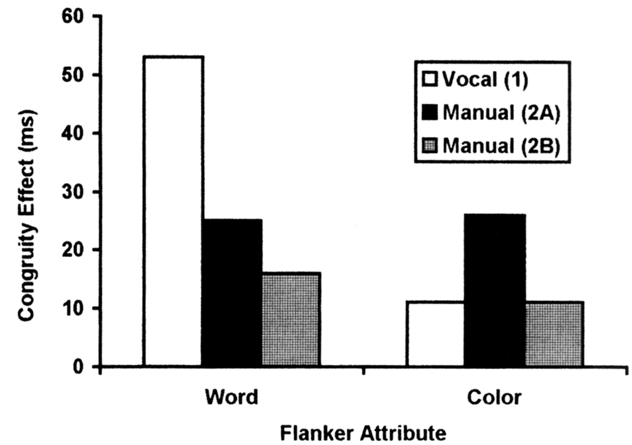

Figure 1. Congruity effect (incongruent minus congruent; in milliseconds) as a function of experiment (i.e., manual or vocal response mode) and flanker attribute for Experiments 1, 2A, and 2B.

contrast, the present results suggest that different mechanisms might be responsible for effects of color and word.

Discussion of Experiments 1, 2A, and 2B

Even though word affects color processing when no translation (from color to word) is required, the interaction between processing systems may be modulated by task requirements. That is, processing systems are not opaque to one another, but their interactions depend, in part, on task requirements. This suggestion is consistent with a word effect (on color), which is larger for vocal responses than for manual ones. In Figure 1 congruity effects (incongruent minus congruent) are presented for flanker word and flanker color as a function of response mode. Word has a larger congruity effect for vocal responses (Experiment 1) than for manual responses (Experiments 2A and 2B). The size of the color effect does not change consistently as a function of response mode. We conducted a three-way ANOVA (color, word, experiment) on the data from all three experiments. This analysis had flanker word and color as within-subjects variables and experiment or response mode (vocal or manual) as a between-subjects variable. In particular, we were looking for interactions between response mode and flanker characteristics (word or color congruity). As expected, the three-way ANOVA produced significant main effects of color and word: for color, $F(2, 70) = 18.55$, $MSE = 420.61$, $p < .001$; for word, $F(2, 70) = 50.40$, $MSE = 651.84$, $p < .001$. The triple interaction was not significant, but the two-way interaction between experiment and flanker word was significant: $F(4, 70) = 13.05$, $MSE = 651.84$, $p < .001$. Additional analysis revealed that the flanker word-congruity effect for vocal responses (Experiment 1) was significantly larger than the congruity effect for the manual responses (Experiments 2A & 2B): $F(1, 35) =$

[1] This idea was suggested by an anonymous reviewer.

16.99, $MSE = 681.02$, $p < .001$. The present pattern of results suggest that task requirements modulate the effect of word on color but that they do not prevent, or are not the sole determinant of, interactions between word and color.

It is noteworthy that there was no interaction between the two flanker attributes either in the analysis of the results of each of the three experiments or in the joint analysis of Experiments 1, 2A, and 2B ($F < 1$). The latter analysis is more powerful than the separate analyses for the three experiments. This result is consistent with independence between systems, at least at some processing stage.

In Experiment 1, the interference of the flanker word on color naming could have been due to competition with a vocal response because the flanker word activated a linguistic code that could interfere with a response based on a linguistic code. It is possible that the need to respond vocally primed the linguistic system and encouraged flanker word processing, even though it was not required by the task. The finding of interference of color words on manual responses in Experiments 2A and 2B makes this explanation less likely. Nevertheless, some verbal mediation between the color target and the manual response may have been used (i.e., participants had to verbally translate: "this color *red* means press this key"). A critical test would be to show that color flanker, which need not be named, interferes with responding to word targets. Relevant data are presented in Experiments 3, 4A, and 4B.

Experiment 3

This experiment was similar to Experiment 1 except that the central color patch was replaced with the word RED or GREEN in white. In this experiment, responses were made vocally, so that it was expected that the word flanker would affect responding to the target word. The question of interest was whether flanker color might have an effect on word naming. Because vocal responding primes the word (and not the color system), no color effect was expected here if the systems are separate and noninteracting. If the two systems interact and word processing is not immune to interference, we expected an effect of color congruity in addition to the word-congruity effect.

Method

Ten undergraduates who had not participated in any of the other experiments in this study took part in the experiment for course credit. For all participants, English was the first language; all had normal or corrected-to-normal vision. The central target was the word RED or GREEN in white. The word RED was 1.6° in length, and the word GREEN was 2.7° in length. The innermost edge of the flanker was 2° from the center of the screen and therefore from the center of the target word. The closest edge of the flanker was 1.2° away from the closest edge of the target word RED and 0.65° away from the closest edge of the target word GREEN. Responses to the central word were vocal. All other features of the experiment were the same as those of Experiment 1.

Results

For every participant in every condition, percent errors and mean RT in milliseconds were computed for the correct responses. Error rates were low; mean percent error was 1.17%. Mean RTs for the various conditions are presented in Table 4.

The mean RTs were subjected to a two-way mixed model ANOVA. The main effect of color was not significant, but the effect of word was: $F(2, 18) = 4.79$, $MSE = 245.73$, $p < .025$. The interaction between these variables was not significant ($F < 1$). Mean RTs of the three word conditions were 463, 463, and 474, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 9) = 4.96$, $MSE = 343.85$, $p < .06$, and the neutral condition, $F(1, 9) = 5.99$, $MSE = 304.76$, $p < .05$.

Discussion

Flanker word had an effect on target reading, whereas flanker color had no effect on target reading. The latter is analogous to the reverse Stroop situation in which participants are asked to read a word and ignore an irrelevant color. As in the present case, the reverse Stroop effect is usually very small and unreliable (MacLeod, 1991; Stroop, 1935). It seems unlikely that this pattern of results is specific to the linguistic or the word-processing system. In a Stroop-like situation, MacLeod and Dunbar (1988) showed that it was possible to create a reverse Stroop effect with practice. Moreover, similar results to the current findings have been reported in the spatial domain. Virzi and Egeth (1985) carried out experiments in which participants were presented with the words LEFT or RIGHT to the left or the right of fixation and were asked to respond vocally or manually to meaning or position (Experiment 2). They assumed the existence of linguistic and spatial cognitive codes that are "particularly suited" (Virzi & Egeth, 1985, p. 309) to vocal and manual responses, respectively. They found that when participants used the response mode that suited the cognitive system that processed the target attribute (no translation necessary), there was no interference of the irrelevant attribute. That is, when participants responded vocally to the meaning of the word, there was no effect of the spatial position of the word, and when they responded manually to

Table 4
Mean Reaction Times (RTs; in Milliseconds) and Percent Errors for the Nine Flanker Conditions in Experiment 3: Vocal Responses

Color congruency	Word congruency: Congruent RT	% error	Neutral RT	% error	Incongruent RT	% error
Congruent	465	0.63	465	0.91	476	1.18
Neutral	459	0.91	462	0.48	470	1.43
Incongruent	465	0.91	461	0.32	475	2.31

the spatial position of the word, there was no effect of the meaning of the word.

Similar results have been reported by Sugg and McDonald (1994) when they asked participants to respond to the word by pressing a button labeled with a word (i.e., the untranslated word-response task). However, in their Experiment 1, the color had a significant effect on the word when the color was presented 100 ms after the onset of the word. Similar effects were found when the word was presented 300 or 200 ms before the onset of the color in the untranslated color-response task. These effects may be related to the particular mode of responding used in these experiments. Participants were asked to respond manually by pressing virtual keys on a touch-sensitive screen. The onset of labels coincided with the stimulus and were changed from one trial to another. The results of Experiment 3, in conjunction with results found in other studies, allowed us to constrain the potential interactions between cognitive systems. When one uses the response mode that is intimately related to a particular cognitive system, irrelevant attributes that are processed by another cognitive system have little or no influence. Under these circumstances, the relevant attribute seems protected from interference.

Experiment 4A

This experiment was identical to Experiment 3 except that manual responses were made to the target words. If the particular combination of word target and vocal responding eliminated the effect of flanker color in Experiment 3, a change to manual responding may reinstate the flanker color effect in a way analogous to the flanker word effect in Experiments 2A and 2B.

Method

Ten undergraduates who had not participated in any of the other experiments in this study took part in the experiment for course credit. For all participants, English was the first language; all had normal or corrected-to-normal vision. Responses to the central word were manual, and all other features of the experiment were the same as those of Experiment 3.

Results

For every participant in every condition, percent errors and mean RT in milliseconds were computed for the correct responses. Error rates were low; mean percent error was 1.13%. Mean RTs for the various conditions are presented in the upper portion of Table 5.

The mean RTs were subjected to a two-way mixed model ANOVA. The two main effects were significant: for color, $F(2, 18) = 5.65$, $MSE = 94.26$, $p < .025$; for word, $F(2, 18) = 5.67$, $MSE = 260.52$, $p < .025$. The interaction between these variables was not significant, $F(4, 36) = 1.36$. Mean RTs of the three word conditions were 418, 408, and 422, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the difference between the incongruent and the neutral conditions was significant, $F(1, 9) = 28.05$, $MSE = 98.41$, $p < .001$; the difference between the neutral and congruent conditions was marginally significant, $F(1, 9) = 4.11$, $MSE = 357.89$, $p < .08$; and the difference between the congruent and the incongruent conditions was not significant. Mean RTs of the three color conditions were 413, 414, and 421, for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 9) = 8.56$, $MSE = 102.96$, $p < .025$, and the neutral condition, $F(1, 9) = 6.95$, $MSE = 101.79$, $p < .05$.

Table 5
Mean Reaction Times (RTs; in Milliseconds) and Percent Errors for the Nine Flanker Conditions in Experiments 4A and 4B: Manual Responses

Color congruency	Word congruency: Congruent RT	Congruent % error	Neutral RT	Neutral % error	Incongruent RT	Incongruent % error
Experiment 4A						
Congruent	413	0.77	408	1.04	419	0.77
Neutral	416	1.04	401	1.04	425	1.04
Incongruent	425	1.04	416	1.04	421	1.30
Experiment 4B						
Congruent	509	2.36	503	3.74	524	1.84
Neutral	494	1.84	496	2.34	518	2.13
Incongruent	512	1.71	517	1.17	556	2.74

Discussion

Similar to the results of Experiments 2A and 2B, the present results suggest that in addition to interactions within the word system, there is evidence for interaction between color and word systems. Even though the color was not primed by task requirements, it influenced processing of the target word. Note, however, that the effect of color suggests that word processing has no special status: Words were influenced by flanker colors in this case, and colors were influenced by flanker words in Experiments 2A and 2B. We have more to say about this later.

Note, once again, that the interaction between flanker color and flanker word was not significant, either in the separate analyses of Experiments 3 and 4 or in the joint analysis of these two experiments.

Experiment 4B

In Experiment 4A, the word-congruent condition (418 ms) was not significantly different from the word-incongruent condition (422 ms), and both were slower than the neutral condition (408 ms). This pattern of results is somewhat odd. Note, however, that there is general agreement in the literature that there should be an influence within a system, and accordingly a word effect is expected. The more important result in Experiment 4A was the influence between systems: the effect of color on word. In light of the color effect in Experiment 4A and the word effect found in a joint analysis of Experiments 3 and 4A, the pattern of results for the word variable in Experiment 4A seems to be a coincidence. This suggestion notwithstanding, we replicated Experiment 4A in Hebrew. One may suggest that the pattern of results in Experiment 4A was due to cognitive load, created by the need to maintain the arbitrary S-R mappings.[2] This load might have made it harder for the participants to screen out the irrelevant information. To test this suggestion, we split the experiment into two blocks to examine whether practice would reduce the effect. Practice should help participants remember the S-R mapping so that if the arbitrary mapping created a load (which, in turn, influenced the results), we should expect an interaction between block and flanker effect.

Method

Twelve undergraduates who had not participated in any of the other experiments in this study took part in the experiment for course credit. For all participants, Hebrew was the first language; all had normal or corrected-to-normal vision. The experiment was conducted in Israel and stimuli were presented in Hebrew. In Hebrew, both the words RED and GREEN are four-letter words. The experiment consisted of two blocks of 270 trials each. Each one of the nine conditions appeared 30 times in each block. A programming mistake confounded flanker side with target color. For a green target, the flanker appeared on the right on 8 out of 15 of the trials, and on the left, on 7 out of 15 of the trials. For a red target, the flanker appeared on the right on 7 out of 15 of the trials, and on the left, on 8 out of 15 of the trials. The differences in probabilities were very small so that we do not think this confounded the results in any way. All other features of the experiment were the same as those of Experiment 4A.

Results

For every participant in every condition, percent errors and mean RT in milliseconds were computed for the correct responses. Error rates were low; mean percent error was 2.27%. Mean RTs for the various conditions are presented in the lower portion of Table 5.

The mean RTs were subjected to a three-way mixed model ANOVA (block, color, and word variables). The three main effects were significant: for block, $F(1, 11) = 48.12$, $MSE = 2{,}875.10$, $p < .0001$; for color, $F(2, 22) = 6.39$, $MSE = 2{,}851.53$, $p < .01$; for word, $F(2, 22) = 7.44$, $MSE = 1{,}638.95$, $p < .01$. No interaction was significant. Participants were faster in the second (489 ms) than in the first (540 ms) block. Mean RTs of the three word conditions were 505, 505, and 533 for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the difference between the incongruent and the congruent conditions was significant: $F(1, 11) = 7.61$, $MSE = 3{,}623.81$, $p < .025$. The same was true for the difference between the incongruent and the neutral conditions: $F(1, 11) = 6.16$, $MSE = 4{,}388.79$, $p < .05$. The difference between the congruent and the neutral conditions was not significant. Mean RTs of the three color conditions were 512, 503, and 528 for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 11) = 7.12$, $MSE = 1{,}320.45$, $p < .025$, and the neutral condition, $F(1, 11) = 10.34$, $MSE = 2{,}307.45$, $p < .01$. The difference between the congruent and the neutral conditions was not significant.

Discussion

The effects of the current experiment were similar to those reported for Experiment 4A. Moreover, the effect of the flanker word was as expected: The incongruent word slowed down responses in comparison with congruent or neutral flanker word conditions. In addition, incongruent flanker color delayed responding to a color name. It is interesting that in spite of the fact that practice speeded up responding, it did not modulate the effects of flankers (i.e., no interaction with block was significant).

Discussion of Experiments 3, 4A, and 4B

To look directly at the effects of response mode, we carried out an ANOVA that included results of Experiments 3, 4A, and 4B. This analysis had word and color as within-subjects variables and experiment (3, 4A, 4B) or response mode (vocal or manual) as a between-subjects variable. As before (the joint analysis of Experiments 1, 2A, and 2B), we were looking for interactions between response mode and flanker characteristics (word or color congruity). There were significant main effects of color and word: for color, $F(2, 58) = 9.58$, $MSE = 369.16$, $p < .001$; for word, $F(2, 58) = 11.55$, $MSE = 697.72$, $p < .001$. Only the two-way interaction between experiment and flanker color was significant, $F(4, 58) = 3.74$, $MSE = 369.16$, $p < .001$, and this was clearly due to the fact that the flanker color effect was not significant for vocal responses (see Experiment 3) but was significant for manual responses (see Experiments 4A and 4B). The relevant results are depicted in Figure 2. In Experiment 3, the difference between the congruent and incongruent word conditions was only marginally significant (the probability value equaled .053), and in Experiment 4A, only the difference between the neutral and the incongruent word conditions was significant. Across Experiments 3, 4A, and 4B, mean RTs of the three word conditions were 462, 459, and 476 for the congruent, neutral, and incongruent condition, respectively. Additional analyses revealed that the incongruent condition was significantly slower than the congruent condition, $F(1, 29) = 10.44$, $MSE = 894.93$, $p < .005$, and the neutral condition, $F(1, 29) = 14.95$, $MSE = 957.48$, $p < .001$.

General Discussion

The results of the six experiments can be summarized as follows (see the rightmost column in Table 1:

1. When vocal responses are required, both flanker attributes (color and word) affect responding to color targets (Experiment 1), but only word flankers affect responding to

[2] This possibility was suggested by Richard Ivry.

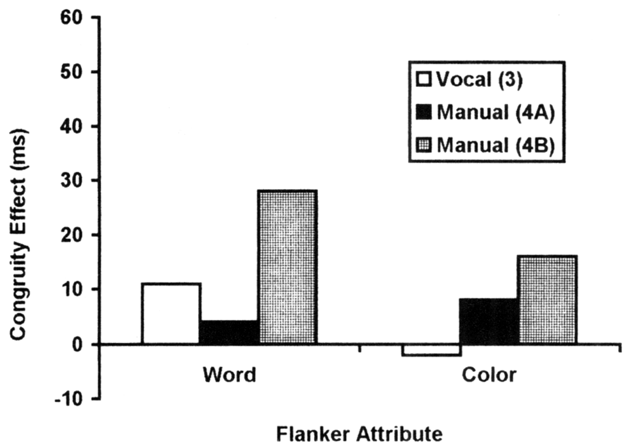

Figure 2. Congruity effect (incongruent minus congruent; in milliseconds) as a function of experiment (i.e., manual or vocal response mode) and flanker attribute for Experiments 3, 4A, and 4B.

word targets (Experiment 3). When manual responses are required, both flanker attributes affect responding to color targets (Experiments 2A, 2B) and to word targets (Experiment 4B).

2. When targets are color patches, word flankers have a larger effect on vocal than on manual responses (the comparison of Experiments 1, 2A, and 2B). When targets are words, color flankers have a significant effect on manual responses but not on vocal responses (the comparison of Experiments 3, 4A, and 4B).

3. The color and word dimensions of the flanker have additive effects on responding to the target (replicated in all six experiments).

We now consider these results in relation to (a) interactions between cognitive systems and (b) the status of word processing.

Interactions Between Systems

Under manual responding, an irrelevant word influenced responding to color targets, and irrelevant color influenced responding to word targets. These results contradict suggestions (Cohen, 1994; Treisman & Fearnley, 1969; Virzi & Egeth, 1985) that interactions between cognitive systems appear only when a task requires translation or encourages cross-talk between attributes or cognitive systems. It seems that we can reject the strong version of the translational models (i.e., no interaction between cognitive systems unless translation is required). In addition, the word affected color even when it was not part of the response set, whereas color affected color only when it was part of the response set (i.e., Experiment 2B). Although translational models suggest that the same mechanism underlies the effects of the two attributes, the present results suggest that different mechanisms might be responsible for the effects of color and word.

The evidence for cross-talk between cognitive systems fits in with the idea of early stages of *stimulus identification* and *stimulus comparison* suggested by Kornblum and his colleagues (Kornblum, 1992; Kornblum, 1994; Kornblum et al., 1990; Kornblum & Lee, 1995). According to this model, these stages identify both relevant and irrelevant attributes and compare them. These processes are carried out before any of the response mechanisms (e.g., *response identification*) are engaged. In addition, it is clear that task requirements do modulate effects of the irrelevant attributes. When one uses the response mode that is intimately related to the target's cognitive system, irrelevant attributes that are processed by another cognitive system show no significant effects (see Virzi & Egeth, 1985, and our Experiment 3). Thus, processing of the target attribute may be protected against interference when the response mode most appropriate for it is used. Another aspect of this is that task requirement may encourage processing of a given attribute or the use of a given cognitive system so that, even when irrelevant, it interferes with processing of the target attribute. This is what happens when the word is irrelevant and responding is vocal (i.e., the translation condition).

Now consider the possibility of verbal mediation. Assume that participants used verbal labels to remember the key assignments. Such a strategy might have been induced by the verbal instructions that we used (i.e., "press this key for red and that key for green"). Certain results allow us to reject this explanation. The verbal mediation strategy predicts no effect of flanker color on responses to word targets. This is because priming the verbal system would suppress processing of flanker color and also enhance processing of the word target. These two aspects should make the word target less prone to color interference. However, as shown in Experiments 4A and 4B, there is a significant effect of flanker color on target word when manual responding is required.

Apart from the interference between the flanker and the target, there is another source of data on interaction (or on lack of interaction) between stimulus attributes. That is, the relationship between the two attributes of the flanker may be examined. Regardless of task requirements, the flanker word and color attributes had separate, noninteractive effects on target processing. This pattern was replicated in all experiments of the current study. These results suggest that the two attributes can be processed independently, as if the unattended flankers may be disassembled into their attributes when first encountered (Treisman & Gelade, 1980; Treisman & Schmidt, 1982). Nevertheless, they may influence processing of the same attribute (i.e., color–color or word–word interactions) or of other attributes (i.e., color–word interactions). This might suggest some changes in Kornblum's model, in which, consistency effects between relevant and irrelevant attributes emanate at the stimulus comparison stage, which compares the relevant and the irrelevant attributes. If this stage was responsible for both the word and the color effects of the flanker, an interaction between them would be expected (Kornblum, 1994). One possible change in the model might be to have a more elaborate stimulus identification stage, something similar to the model's response identification stage, so that it works differently for different attributes. For example, it could be made responsible for detecting inconsistencies between the irrelevant and relevant stimuli when they share an attribute.

Some time ago, Posner and Henik (1983) looked at similar issues with respect to processing spatial and language attributes. In a Stroop-like situation, participants were presented with the words "left" or "right" spoken to the left or right ear or shown on the left or the right side of a screen. Participants were asked to respond manually to the visual word, auditory word, visual position, or auditory position and to ignore the irrelevant attributes. The results indicated that responses based on language processing (reading or speech perception) produced stronger effects on one another, regardless of input modality. Similarly, spatial information (ear of entry or screen side) affected one another more than either affected the language input of the same modality. These results suggest that higher levels of processing tend to be organized according to cognitive systems like language or spatial information, (Posner & Henik, 1983) so that certain interactions among attributes may be found when higher levels of analysis are probed.

Is Word Processing Special?

Words do not seem to be special insofar as attributes (other than words) can be made as automatic as words, if practiced for a long time (MacLeod & Dunbar, 1988). Moreover, several authors (Logan, 1980; Logan, 1985; Tzelgov, Henik, & Berger, 1992; Tzelgov, Henik, & Leiser, 1990) have suggested that an absolute distinction between automatic and nonautomatic processes is inappropriate. Stroop (1935) argued that words are more automatic than colors. In contrast, Treisman and Fearnley (1969) have suggested that word processing is not special and that claims for its special status ignore the fact that the Stroop task encourages word processing, but there is no equivalent task that primes color processing. Treisman and Fearnley suggested that if a task is not biased toward either the word or the color systems, there should be no asymmetry between word and color interference.

Experiments 2A and 4A were similar in design and used manual responding. Thus, they allowed us to compare color and word interference directly. We compared the word-congruity conditions (congruent, neutral, and incongruent) across the color conditions in Experiment 2A with the color-congruity conditions (congruent, neutral, and incongruent) across the word conditions in Experiment 4A. This comparison is analogous to the comparison made by Treisman and Fearnley (1969), who suggested that when participants were asked to match colors to words the effect of the interfering word was comparable to the effect of the interfering color.[3] In addition, the various models mentioned thus far (Cohen, 1994; Kornblum, 1994; Virzi & Egeth, 1985) do not allow for asymmetry in the interference of one attribute with the other. We carried out a two-way ANOVA in which experiment (2A or 4A) or the type of interference (word interfering with responses to colors or color interfering with responses to words) was a between-subjects variable and congruity (congruent, neutral, incongruent) was a within-subjects variable. This analysis gave rise to a significant two-way interaction between congruity and experiment: $F(2, 36) = 7.02$, $MSE = 95.44$, $p < .005$. The congruity effect was larger for the word flanker (25 ms) than for the color flanker (8 ms). This suggests that when manual responses to targets are required, the effects of words on colors are larger than the effects of colors on words. Unfortunately, a comparison of the flanker word congruity in Experiment 2B and the flanker color congruity in Experiment 4B did not replicate this pattern: The effects were the same (16 ms). Sugg and McDonald (1994) found larger inhibition in the translated word-response task (e.g., 102 ms in Experiment 1) than in the translated color-response task (e.g., 37 ms in Experiment 1). These results, like some of ours (see Experiments 2A and 4A), suggest that interference of color on word processing exists but could be smaller than interference of word on color processing.

The results of Virzi and Egeth (1985) pertain to this issue. In their first experiment, they used a card-sorting task that was supposed to prime one or the other system (color or word). For half of the participants, the bins were labeled with color words in black ink; for the other half, the bins were labeled with rectangular patches of color inks. When the bins were labeled with words, sorting the incongruent cards by color and ignoring the meaning increased sorting time (75.1 s vs. 65.3 s for sorting color Xs). When the bins were labeled with color patches, sorting the incongruent cards by meaning was similarly increased relative to sorting color words in black (69.4 s and 62.6 s, respectively). The effect of the interfering word was larger (9.8 s) than the effect of the interfering color (6.8 s). However, there is no way to tell whether this difference was significant, because Virzi and Egeth analyzed the two relevant conditions (bins labeled with color patches vs. bins labeled with color words) in separate ANOVAs. Thus, there seemed to be some asymmetry between interfering effects of colors and words: Words had larger interfering effects on color and were less interfered with by color.

There is an additional point to be made. The results of Experiment 2B showed that a word may have an effect (on a color) even when it is not a member of the response set. Moreover, the effect of such a word is similar to the effect of an incongruent word that is a member of the response set. In contrast, the color effect depends on its membership in the response set. Such a pattern of results implies a special status for words in that they exert their effect regardless of being part of the response set.

With respect to the comparison between color and word attributes, word processing may have some advantage and, in this sense, is special or more automatic. However, the fact that higher levels of our cognitive system may be organized according to systems like language or spatial information

[3] In Treisman and Fearnly's (1969) study, two groups of participants presented different results. In one group there was no difference between these conditions, and in the other group, card sorting was slower when the irrelevant attribute was a word than when it was a color. Treisman and Fearnly dismissed the latter difference as being due to a methodological aspect (a difference between the neutral conditions for the color and word attributes).

(Posner & Henik, 1983) may advise some caution with respect to such a conclusion. Such an asymmetry may be a function of the level of analysis that is probed, by the particular study, with respect to the various attributes at hand.

References

Brown, T. L., Roos-Gilbert, L., & Carr, T. H. (1995). Automaticity and word perception: Evidence from Stroop and Stroop dilution effects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 1395–1411.

Cohen, A. (1994, November). *The Stroop effect: Much less robust than it seems.* Paper presented at the 35th Annual Meeting of the Psychonomic Society, St. Louis, MO.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16,* 143–149.

Eriksen, C. W., & Eriksen, B. A. (1979). Target redundancy in visual search: Do repetitions of the target within the display impair processing? *Perception & Psychophysics, 26,* 195–205.

Eriksen, C. W., & Schultz, D. W. (1979). Information processing in visual search: A continuous flow conception and experimental results. *Perception & Psychophysics, 25,* 249–263.

Gatti, S. V., & Egeth, H. E. (1978). Failure of spatial selectivity in vision. *Bulletin of the Psychonomic Society, 11,* 181–184.

Hagenaar, R., & van der Heijden, A. H. C. (1986). Target-noise separation in visual selective attention. *Acta Psychologica, 62,* 161–176.

Kahneman, D., & Henik, A. (1981). Perceptual organization and attention. In M. Kubovy & J. R. Pomerantz (Eds.), *Perceptual organization* (pp. 181–211). Hillsdale, NJ: Erlbaum.

Kornblum, S. (1992). Dimensional overlap and dimensional relevance in stimulus–response compatibility. In G. E. Stelmach & J. Requin (Eds.), *Tutorials in motor behavior II* (pp. 743–777). Amsterdam: Elsevier.

Kornblum, S. (1994). The way irrelevant dimensions are processed depends on what they overlap with: The case of Stroop- and Simon-like stimuli. *Psychological Research/Psychologische Forschung, 56,* 130–135.

Kornblum, S., Hasbroucq, T., & Osman, A. (1990). Dimensional overlap: Cognitive basis for stimulus–response compatibility: A model and taxonomy. *Psychological Review, 97,* 253–270.

Kornblum, S., & Lee, J.-W. (1995). Stimulus–response compatibility with relevant and irrelevant stimulus dimensions that do and do not overlap with the response. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 855–875.

La Heij, W., Helaha, D., & van den Hof, E. (1993). Why does blue hamper the naming of red? *Acta Psychologica, 83,* 159–177.

Logan, G. D. (1980). Attention and automaticity in Stroop and priming tasks: Theory and data. *Cognitive Psychology, 12,* 523–553.

Logan, G. D. (1985). Skill and automaticity: Relations, implications, and future directions. *Canadian Journal of Psychology, 39,* 367–386.

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163–203.

MacLeod, C. M., & Dunbar, K. (1988). Training and Stroop-like interference: Evidence for a continuum of automaticity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 126–135.

Merikle, P. M., & Gorewich, N. J. (1979). Spatial selectivity in vision: Field size depends upon noise size. *Bulletin of the Psychonomic Society, 14,* 343–346.

Miller, J. (1991). The flanker compatibility effect as a function of visual angle, attentional focus, visual transients, and perceptual load: A search for boundary conditions. *Perception & Psychophysics, 49,* 270–288.

Posner, M. I., & Henik, A. (1983). Isolating representational systems. In J. Beck & A. Rosenfeld (Eds.), *Human and machine vision* (pp. 395–412). New York: Academic Press.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18,* 643–662.

Sugg, M. J., & McDonald, J. E. (1994). Time course of inhibition in color-response and word-response versions of the Stroop task. *Journal of Experimental Psychology: Human Perception and Performance, 20,* 647–675.

Treisman, A. M. (1969). Strategies and models of selective attention. *Psychological Review, 76,* 282–299.

Treisman, A., & Fearnley, S. (1969). The Stroop test: Selective attention to colours and words. *Nature, 222,* 437–439.

Treisman, A., & Gelade, G. (1980). A feature integration theory of attention. *Cognitive Psychology, 12,* 97–136.

Treisman, A., & Schmidt, N. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology, 14,* 107–141.

Tzelgov, J., Henik, A., & Berger, J. (1992). Controlling Stroop effects by manipulating expectations for color words. *Memory & Cognition, 20,* 727–735.

Tzelgov, J., Henik, A., & Leiser, D. (1990). Controlling Stroop interference: Evidence from a bilingual task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 760–771.

Virzi, R. A., & Egeth, H. E. (1985). Toward a translational model of Stroop interference. *Memory & Cognition, 13,* 304–319.

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