Associative facilitation and interference in the Stroop color-word task*

E. C. DALRYMPLE-ALFORD
Trent University, Peterborough, Ontario, Canada

It is difficult to name the color of a stimulus when the stimulus is a word naming a different color. When the word is congruent with the color in which it is written, color naming is much quicker. Similar results are also obtained when color-related words are used instead of color names. These results are taken as evidence for the operation of associative factors that could facilitate or impair performance in the color-word task.

In the Stroop color-word task, Ss are presented with words written in different colors and are required to name the colors as quickly as possible while ignoring the words themselves. In the standard version of the task the words are color names and are written in noncongruent colors (e.g., the word RED written in blue ink). The interference of the word with color naming is a reliable phenomenon. Not only are response times longer but the errors in naming are more numerous. The fact that word reading is generally faster than color naming in nonconflict situations (see Jensen & Rohwer, 1966), suggests an explanation of what is happening, namely that the stronger habit of reading words is difficult to suppress and must be inhibited before the color naming response can be made. This would account for the greater interference produced by common words than by rare words (Klein, 1964), assuming common words are read (i.e., responded to) faster than rare words. However, other principles must be invoked to account for the greater interference produced by color-related words, such as "lemon" and "fire," which are no more common than "put" and "take" (the words are from the set used by Klein, but see also Scheibe, Shaver, & Carrier, 1967). One possibility is that the color-related words elicit the color names that are associated with these words and these interfere with the correct response. If this is the case, instead of interference we would expect facilitation when the color-related words are written in the colors they are related to (e.g., BLOOD in red). Some indirect support for this view comes from the results of Langer and Rosenberg (1966). They found that naming the colors in which nonsense syllables were written was speedier when the nonsense syllables were written in the colors they tended to evoke. Further support comes from the performance of bilinguals when the interfering word is in one language and their color naming response in another. When the words were translation equivalents of the correct response, response delay was reduced, a result not attributable to direct translation of the word since translation took longer (Dalrymple-Alford, 1968). It was suggested that when the word was the translation equivalent of the color-naming response, even though it produced some delay in responding because it had to be suppressed, there was also facilitation of performance to the extent to which the word "primed" the correct response.

The expectation, then, is that color-related words produce interference with color naming when these words are written in noncongruent colors (e.g., BLOOD in green ink); when written in congruent colors (e.g., BLOOD in red ink), facilitation should occur. However, this facilitation need not result in color naming being quicker than under the control condition (Xs or color patches), for it could be offset by the need to suppress reading the word aloud. If the latter effect may be estimated from performance on items consisting of words unrelated to the colors in which they are written, the prediction derived from the foregoing conjectures would be that congruent combinations of colors and color-related words would result in less interference with color naming than that produced by unrelated words, and that the latter would produce less interference than noncongruent combinations of colors and color-related words.

Included in the experiment reported below, which was designed to test this prediction, were the usual types of Stroop item consisting of noncongruent color-word combinations (e.g., RED in green ink), as well as combinations of congruent colors and color words (e.g., RED written in red). What might our expectations be for these? Dalrymple-Alford and Budayr (1966) felt that a general set to suppress the written word would also lead to temporary suppression of the correct response in the case of congruent combinations. This would result in greater impairment of color naming relative to performance on noncongruent combinations, for in the latter there is no incompatibility between suppressing the word and naming the color in which it is written. On the other hand, we may argue that one has to "find" the appropriate word in order to name the color, and that the written word in the congruent condition would facilitate color naming by making the correct response more readily available. Dalrymple-Alford and Budayr (1966) found, with the serial version of the Stroop test, that performance on lists containing congruent combinations was no worse than performance on lists consisting wholly of noncongruent items. However, their study also showed that the sequential structure of the list could influence performance. The question, then, was whether or not differences would emerge when latencies were obtained for single responses. It turned out that the answer was already available. Sichel and Chandler (1969) report that color naming is quicker for congruent items, a result confirmed by Dyer (1970). Dyer's data also show that the congruent items resulted in faster color naming than did combinations involving "neutral" words, which in turn produced less interference than the noncongruent combinations. These results are consistent with the view presented above. Further support from data on color-related words is reported below.

METHOD

Three categories of words were used: unrelated words (joy, hand, square); color-related words (sky, grass, snow, blood); and color names (blue, green, white, red). In addition there were control "words" consisting of 3, 4, or 5 Xs. While the choice of related and unrelated words was originally based on the writer's intuition, subsequent reference to the association data of Keppel and Strand (1970), Palermo and Jenkins (1964), Scheibe et al (1967), and Underwood and Richardson (1956) confirmed the appropriateness of the selection. Those norms show that the unrelated words almost never elicit a color name as a response, while the color-related words have a high likelihood of eliciting one

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and only one color name (green by "grass," blue by "sky," red by "blood," and white by "snow").

The 14 words (including the Xs) were reproduced by a photocopying process so that each appeared in white against a dark gray rectangle. By coloring the white print each word was made available in red, green, blue, and white. The 56 word-color combinations were then mounted on cards for presentation to the Ss. Two decks of the cards were prepared. The ordering within each deck was random except for the following constraints: (1) runs of more than two cards requiring the same color naming response were not permitted, (2) the mean position of cards belonging to a particular "condition" was approximately the same for all six conditions (identified below and in Table 1).

The cards were presented one at a time in a simple tachistoscope. S initiated exposure of each card which remained in view until she called out the color of the word. The response, picked up by a voice key, stopped the timer that started with the onset of the display. Response latencies were measured to the nearest millisecond. Both decks of cards were presented to each S, half beginning with one deck and half with the other. At the end of each deck, cards to which the S had responded incorrectly were presented again.

The Ss were 12 female U.S. students studying at the American University of Beirut.

RESULTS

Mean latencies (excluding those for incorrect responses) for each half of the experimental session (i.e., each deck) were obtained for each S for the six categories of stimuli or "conditions": control (XXX, XXXX, XXXXX); unrelated (e.g., "joy" in the different colors); related congruent ("sky" in blue, "blood" in red, "grass" in green, "snow" in white); related noncongruent (all cases involving the words "sky," "blood," "grass," "snow," excluding those mentioned in the previous category); color name congruent (e.g., "red," "blue," written in the colors they name); color name noncongruent (e.g., "red," "blue," written in noncongruent colors). Table 1 shows the mean latencies for each of these six cases. The standard deviations also given there are based on pooled within-S variances for each condition. One surprising feature of these results is that despite a number of differences between this experiment and that of Dyer (1970), very similar latencies were obtained. Dyer reports latencies of 658, 722, 662, and 803 msec for the control, unrelated, color-name congruent, and color-name noncongruent conditions, respectively. Corresponding values in this study were 685, 750, 687, and 881 msec.

Table 1
Color Naming Latencies

Condition	Mean	SD
Control	685	39
Unrelated	750	45
Related		
Congruent	708	48
Noncongruent	793	44
Color Name		
Congruent	687	42
Noncongruent	881	54

Analysis of variance carried out on the S means showed a significant difference between latencies for the six categories of stimuli ($F = 26.2$, $df = 5/121$, $p < .001$). Effects relating to the deck variable and to stage of practice (first-deck means vs second-deck means) were not significant ($p > .10$). The Newman-Keuls procedure was then used to make multiple comparisons between the condition means. The control, color-name congruent, and the color-related congruent means were not significantly different from each other ($p > .05$). All other differences were significant at the 5% level or better.

DISCUSSION

The data from this study confirm that color names produce less interference with color naming when they are written in congruent colors. It may be argued, however, that the congruent condition does not lead to quicker color-naming responses, but that on some occasions S may in fact be reading the word, i.e., the shorter mean latency is an artifact of averaging faster reading times with slower color-naming times. There are a number of reasons for rejecting this interpretation. In the first place such averaging should result in a higher variance for the congruent condition. In fact, the variance was the second smallest among the six conditions, the largest being for the noncongruent color-name condition (similar results are reported in Sichel & Chandler, 1969). Secondly, Ss had no means of knowing in advance of each stimulus presentation whether or not the interference word would match the color-naming response. We would thus expect the number of occasions when their response was a reading response to be no different for the congruent condition than for the noncongruent condition. In the latter condition, reading responses may be identified readily, and they turned out to be less than .5% of all responses. With this as our estimate of the proportion of word-reading responses, even if we accept the impossibly low value of 100 msec for reading latencies, we would still arrive at a much lower estimate of the color-naming latency for the congruent condition than that obtained for the unrelated word condition.

The data on color-naming times for congruent and noncongruent color-related words are less open to criticism and show that congruent combinations result in quicker responses than are obtained when unrelated words constitute the interference. These results are clearly in line with what was expected.

It has been suggested to the writer that while these results are consistent with an explanation in terms of associative processes, the differences in latencies may, in fact, be due to another characteristic that distinguishes the stimulus items used in the different conditions. It is possible that the extent to which the printed word interferes with the color-naming response depends on whether or not the initial sound of the interfering word belongs to the set of initial sounds of the required color names, and whether or not in each case it conflicts with the initial sound of the particular response that has to be made. We find that, in the color-name noncongruent condition, the interfering word always has an initial sound that is a member of the set of initial sounds of the words RED, GREEN, BLUE, and WHITE and that it conflicts with the required initial sound in all cases. This condition produces the longest color-naming latencies. For the related noncongruent condition the same conditions hold for 5 of the 12 items, and this condition gives rise to the second longest latencies. These observations suggest that articulatory and not semantic features of the words give rise to the present findings. However, there are some strong indications that this is not the case. "Grass" and "blood" have initial sounds that belong to the set of initial sounds of the color naming responses, while this is not true of the words "sky," "snow," "joy," "hand," and "square." If an explanation in terms of initial sounds accounts completely for the differences here attributed to associative relations, then we would expect color-naming latencies in the related noncongruent condition to be greater for the set of such items as "grass" in red, white, and blue and "blood" in green and white than for the set "sky" in red, white, and green and "snow" in red, green, and blue; the latter should have the same latencies as the items consisting of "joy," "hand," and "square" written in red, blue, green, and white (the "unrelated" condition). However, the mean latencies for these three sets of items were 795, 784, and 750 msec, respectively. Thus, it appears that an explanation solely in terms of initial sounds will not fit the present results. Whether or not initial sounds do have any effect at all in the Stroop task may be decided, on the one hand, by the use of interference words such as "blunt," "greed," "rent," etc., and on the other, by the use of words similarly unrelated to color names but having initial sounds different from those of the color-naming responses.

The picture that emerges from these data is as follows: Ss typically react to a color-word combination with a reading response, and this has to be suppressed in order that the color-naming response be made. Additionally, responding to the written word tends to "prime" associated words. If these include the correct color-naming response, color naming is facilitated because the appropriate verbal response is made more available. If the primed words include a word that, though not the particular response appropriate at the time, is still within the set of responses appropriate to the task (i.e., other color names), a further component of interference will be present beyond that arising out of the tendency to read the presented word aloud.

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