The duration of word meaning responses: Stroop interference for different preexposures of the word

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Stroop stimuli, i.e., color names in incongruent colors, were preexposed in black for different intervals prior to coloration. Color-naming times increased slightly, then decreased sharply as preexposure intervals increased. Some delay in color naming still appeared for the longest (500-msec) preexposure. The results indicate stages in word processing and their temporal characteristics. The preexposure interval that precedes the interference drop would be expected to shift with changes in color luminance, hue, and saturation and also with changes in word legibility. Thus it offers potential for assessing the effects of such manipulations on the speed of color and word processing.

In the Stroop color-word test (Stroop, 1935), the time to name a series of colors is determined on a card of color patches where each color patch spells a color name incongruent to the color (e.g., the word *red* printed in green ink). This time is typically found to be from 1½ to 2 times as long as the time to name colors on a control card where the patches are simple rectangles of color. Jensen & Rohwer (1966) have provided an extensive review of the Stroop test.

This difference in naming time between the incongruent color word and control conditions will be referred to in this paper as Stroop interference. Gumenik & Glass (1970) have shown that increasing the legibility of the words increased Stroop interference. This might suggest that *any* acceleration of word processing relative to color processing would increase Stroop interference. Klein (1964), however, had Ss first read the word then name its color; total times for this double-response condition were only slightly greater than times for naming the colors alone on the interference card. In addition, Ss reported that this double-response task was much easier than color naming alone. In light of this latter result, speeding of word processing relative to color processing beyond some point would be expected to reduce the interference of the words to color naming for the incongruent words condition.

The purpose of the present study was to explore the effect on color naming and, more specifically, on Stroop interference of beginning word processing early by preexposing the word in black prior to its coloration. Taken together, the studies of Gumenik & Glass (1970) and Klein (1964) suggest that some optimum preexposure interval would maximize the interference of the word to color naming. And preexposures shorter or longer than this optimum would produce a decrease in interference. If such an increase, then decrease, in Stroop interference with increasing preexposures of the word prior to coloration were found, it would appear to support the traditional response conflict explanationof Stroop interference (Jensen & Rohwer, 1966). It could be that the optimum short preexposure allows a strong reading response to build and compete maximally with the naming response. Longer preexposures would allow this response to be completed ["Getting it out of your system . . . ," one of Klein's (1964) Ss described it] before the color-naming response is made. The characteristics of a buildup and decline in Stroop interference as a function of preexposure interval would thus provide an index of the latency of the buildup of an implicit reading response and also of its duration.

The traditional Stroop paradigm involves total color-naming time for a series of color stimuli. In the present study, individual single verbal reaction times to individual stimuli were obtained. This procedure has been shown to produce reliable differences in response times for incongruent and control stimuli (Dalrymple-Alford & Budayr, 1966). It also permits an assessment of the latency of color-naming responses for congruent combinations of colors and words which can be included in the stimulus sequence (Sichel & Chandler, 1969).

SUBJECTS

Ten males ranging in age from 17 to 22 who had recently completed Army basic training served as Ss in the experiment. Visual acuity (with correction, if necessary) and color vision were normal.

STIMULI

The words *red*, *blue*, *green*, and *yellow* and a control nonword stimulus consisting of a series of five Vs (alternately right-side up and

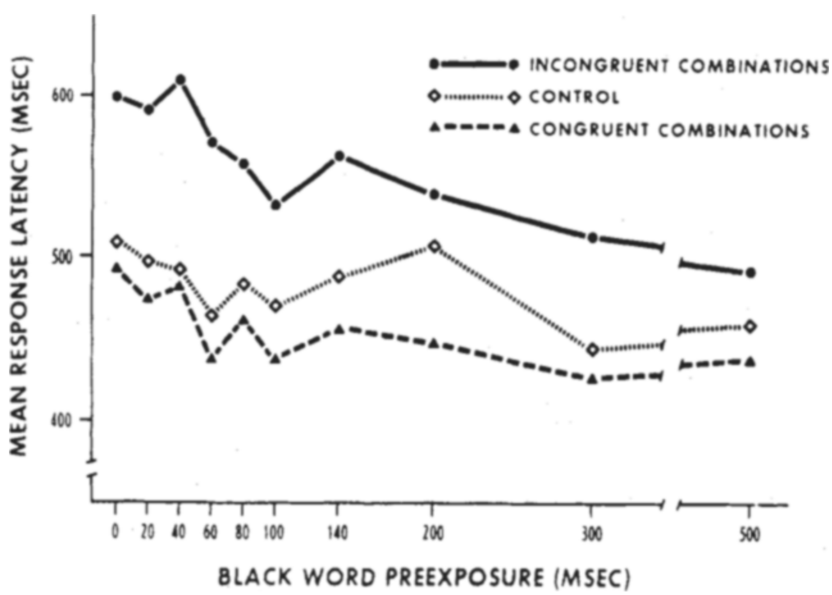

Fig. 1. Average color naming response latency as a function of black word preexposure for congruent, incongruent, and control conditions.

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upside down) were presented in the colors red, blue, green, and yellow. The words and Vs were cut out of white cards and presented in one field of a three-field tachistoscope (Scientific Prototype Model GB). Color filters over a white background were viewed *through* the cutout letters with the illumination for the colors separate from that for the white cards. The illumination for colors was provided by a standard back-illuminator attached to the same field of the tachistoscope. The back-illuminator utilized the timers and circuitry normally used in one of the other fields of the tachistoscope. The words were centered in the exposure field and constructed of block capitals 3/8 in. high. Viewing distance was 50 in. Centered in the blank field was a small fixation cross on a white background. Luminance of the blank field and of the white background of the words was 8 fL. Color luminances were 3 fL for red, 2 fL for blue, 5 fL for green, and 13 fL for yellow. Luminance measurements were made with a Spectra Spot brightness meter. Color luminance and spectral location were selected only to produce an unequivocal naming response, since previous work (Dyer, 1970) had indicated that matching of luminances did not equate choice reaction times.

PROCEDURE

The fixation cross remained in view between stimuli, and, to prevent changes in adaptation, S was instructed to view it constantly. About 1 sec following a verbal ready signal, the word card was exposed and a black word was seen on a white background. After 1 of 10 preexposure intervals, the back illuminator was also turned on and the word was then seen in one of the four colors for a period of 2 sec. A millisecond clock began with illumination of the color and was stopped by S's color-naming response through a voice key. Ten preexposure intervals were used: 0 (simultaneous onset of word and color), 20, 40, 60, 80, 100, 140, 200, 300, and 500 msec. Each S received two practice sessions and 10 experimental sessions, with each session consisting of the 20 possible combinations of the five words and four colors at one of the preexposure intervals. Prior to each experimental session, two additional stimuli were presented to acquaint S with the preexposure interval for that session. The sequence of preexposure intervals for the 10 sessions was random, with the restriction that the 10 sequences of the 10 Ss complete a Latin square. At the ready signal, S was instructed to bring the fixation point into sharp focus, and, when the stimulus appeared, he was instructed *not* to blur it or view it indirectly. When the color appeared, he was to name it as quickly and accurately as possible. Accuracy was further emphasized by giving feedback of the reaction time only on the correct trials. Time for a session averaged about 15 min, which included a break of 2 min after 10 presentations.

RESULTS

Three incongruent stimulus combinations, one congruent combination, and one control stimulus were presented in each color and at each preexposure interval. The mean of color-naming times for the three incongruent combinations and the single response times for the other two conditions were analyzed as one three-level factor in a repeated measures analysis of variance along with color and preexposure interval. The factor of congruent, incongruent, and control conditions produced a highly significant main effect, $F(2,18) = 73.74$, $p < .001$, with the differences occurring at all preexposure intervals. Not only is responding for the incongruent combination delayed (556 msec for incongruent vs 481 msec for control), but a facilitation effect for congruent combinations (455 msec) was obtained which does not appear to have been previously reported. A Newman-Keuls test of ordered means indicated that all pairwise combinations of the comparisons of the three conditions differed significantly from each other ($p < .01$). Colors also produced a significant main effect, $F(3,27) = 11.08$, $p < .001$, with red named fastest (464 msec), followed by blue (497 msec), yellow (502 msec), and green (522 msec).

The main effect of preexposure interval was also significant, $F(9,81) = 3.51$, $p < .001$, as was theinteraction of preexposure interval and condition, $F(18,162) = 2.47$, $p < .005$. Figure 1 shows the average response times plotted as a function of preexposure interval for the three conditions. The interaction illustrates an effect of preexposure interval on Stroop interference, since the decline in color naming is much faster for the incongruent color-name condition than for the control stimuli. To evaluate this interaction better, a second analysis of variance was performed on the variable of Stroop interference. The basic datum for this analysis was the difference between the mean of the three incongruent combinations and the control condition. Color and preexposure interval were the two factors of this analysis. As would be expected, since the baseline now is the control stimulus for the particular color by preexposure interval combination, main effect differences of color disappeared. The main effect of preexposure interval was still strong in this analysis, however, $F(9,81) = 3.42$, $p < .001$, reflecting the large interaction (Condition by Interval) variance of the previous analysis in conjunction with the relatively constant response latencies over preexposures for the control stimulus. Stroop interference means for preexposures increasing from 0 through 500 msec were 90, 94, 118, 108, 75, 61, 78, 31, 68, and 32 msec, respectively. Only four of the individual comparisons between the 10 means were significant at the .05 level or less by the Newman-Keuls test of ordered means. These were the differences between each of the two highest (40- and 60-msec preexposures) and each of the two lowest (200- and 500-msec preexposures) values. The conservative Scheffé test of the difference between mean Stroop interference for the 0- and 20-msec preexposure intervals and the mean of the 40- and 60-msec intervals did not indicate this rise in Stroop interference with increasing preexposure interval to be significant. The general decline in interference with increasing preexposure interval was significant by this test as shown by the significant difference between the mean of observations at the first five preexposure intervals and the mean of the observations at the second five intervals ($p < .05$).

DISCUSSION

For the most part, the predictions stated in the introduction were obtained. Long preexposures of the word in black prior to coloration resulted in a dramatic decrease in interference. This illustrates the important point that the neural and/or muscular activity corresponding to viewing a word changes despite continuous fixation of the word, with a great portion of the change occurring by 200 msec of exposure. Some interference still existed even with the longest 500-msec exposure, and this raises the interesting question of whether or not any interval of preexposure of the word prior to coloration will do away with this interference. It may be that the additional flash when the word is colored serves to reinstate the "meaning." The data from the present study strongly suggest that some preexposures between 40 and 60 msec would lead to greater interference than would no preexposure. Such a finding would be in accord with the Gumenik & Glass (1970) study where greatest interference occurred in the condition with fast word processing. Additional measurements with the present paradigm would eventually make increases in interference of the magnitude found in the present study significant. The time-consuming tachistoscopic procedure is presently being automated, and further research is being planned to determine if this increase is an artifact or if word preexposures actually will increase interference as well as decrease it. The preexposure corresponding to the interference peak, or, if no peak exists, to the beginning of the sharp decline in interference, could be used as a reference point to compare the effect of changes in luminosity, saturation, hue, etc., on color-processing latencies. In addition, word legibility manipulations could also be studied in this manner.

Facilitation of color naming with congruent combinations of words and colors was found in this study, which is contrary to a previous study by Sichel & Chandler (1969), who found that reaction times for congruent combinations were slower than for control stimuli. This effect is small for the zero and short preexposure conditions, increasing to a maximum at 200-msec preexposure. This suggests that facilitation is not simply a converse of interference with incongruent combinations, since the maximum effects occur with preexposure intervals that lead to reduced interference. One aspect of the facilitation is the implication that parallel processing of the word and color occurs, and, therefore, Stroop interference cannot be the result of an inability to process word and color information concurrently.

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