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Color recognition

ROBERT L. SOLSO and BRUCE A. SHORT
University of Idaho, Moscow, Idaho 83843

Reaction times to color/color, color/color-name, color-name/color-name, and color/associate pairs were measured under simultaneous pairing and priming conditions. The results indicated that the briefest reaction time occurred under color-to-color matching, but that the reaction time latencies among conditions were similar when the prime preceded the to-be-matched item by 1,500 msec. The results were interpreted in terms of a modified parallel processing model.

Posner and Snyder (1975) have presented a model of automatic pathway activation in which both the color name and word name (e.g., of a color) are processed in parallel. The model, which was specifically designed to account for output interference noted in the Stroop effect, provides a broad conceptualization of the internal processes used by the human subject in color and color-name matching. The research of Posner and others has led us to conclude that a stimulus may lead to information that may be simultaneously coded in different systems. Color stimuli seem particularly flexible in their codability. On one level, a physical color (e.g., the color red) may lead to an internal color code that is quickly recognized by the human subject. On another level, a physical color may lead to a name representation (e.g., RED). Yet, on a third level, a physical color may lead to a complex conceptual representation in which semantic associates are stimulated in memory (e.g., BLOOD). Each of these levels are thought to require some amount of time, with later levels requiring more time than earlier levels.

A recent experiment by Rosch (1975) on the nature of mental codes of color categories used a priming technique (similar to Posner & Mitchell, 1967) to study color coding. Rosch hypothesized that a prime, such as a color name, can only facilitate a mental code if it contains some information consistent with the code. She reported data that indicated that reaction times were facilitated for "same" responses if primed by physically identical colors.

In the present report, we extend the research by Rosch (1975) by examining the influence of color primes on three classes of color codes. The present research is predicated on the assumption that colors are represented in a person's cognitive structure in (at least) three distinctive codes. One code is physical (e.g., the color red), another is a name (e.g., RED), and a third is conceptual (e.g., BLOOD), in which the associative components of a color are represented. It was hypothesized that color recognition, as measured in a matching task, would be facilitated by presenting the same prime color (or color name) in advance of a test color (or color name) and that the reaction times for color recognition would increase from physical codes to name codes to conceptual codes.

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METHOD

Subjects

Subjects were 10 students in general psychology classes, ranging in age from 18 to 28 years, who reported having normal color vision. Subjects received course credit for their participation in the experiment.

Apparatus

Stimuli were presented by means of a Scientific Prototype three-channel tachistoscope Model N-1000.

Stimuli

In the first condition, six colors were used for experimental trials and two different colors for practice trials. Colors used in the first condition were green, blue, red, yellow, brown, and purple. Expressed in Munsell notation, these colors were 2.5G/8, 5PB4/10, 5R4/14, 5Y8/12, 5YR3/4, and 10P3/10. Practice colors consisted of orange and pink (2.5R7/8 and 10P3/10). Color names were GREEN, BLUE, RED, YELLOW, BROWN, and PURPLE.

In the color/color matching task, color cards 70 x 75 mm (horizontal by vertical) were mounted on a dull, light gray background. The distance between pairs of colors subtended a visual angle of 1 deg. The combined width of the pair subtended a visual angle of 12.5 deg. In name and associate matching tasks, the letters were constructed from 36-point Futura Letraset bold black letters on a white surface 70 x 75 mm mounted on a dull, light gray background. The same visual angle between pairs was used for the name display as the color/color display, and the average total visual angle in these conditions was 8.5 deg.

After completion of the first condition, subjects were given a brief rest period before participating in the second experimental condition.

The second condition called for the matching of colors and associated words. In this condition, four colors were used, BLUE, YELLOW, RED, and GREEN, along with high verbal associates to these colors, as determined by Solso (1971). Those associates were SKY, SUN, BLOOD, and GRASS.

The two displays (right side and left side) were identical in description to those in the first experimental condition, except that half the trials consisted of a pairing of the color and its high associate (e.g., RED-BLOOD) and half consisted of a pairing of the color and word judged to be a nonassociate of the color (e.g., RED-SLEEP). Subjects were given 16 warm-up trials in which nonexperimental colors and their associates or nonassociates were paired. Subjects were instructed to decide if the

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word was an associate of the color and to indicate their decisions by pressing an appropriate key.

Procedure

In the first condition, half of the displays were composed of the following four types: (1) two identical colors, (2) two identical color names, (3) a color (on the left) and a same-color name (on the right), and (4) a color name (on the left) and the same color (on the right); the other half consisted of the same four types of visual displays but with mismatched colors and color names. Three different temporal ("priming") sequences were used. In one type of display, the right and left stimuli were presented simultaneously; in a second type of display, the left-side stimulus appeared 500 msec before the right-side stimulus; in a third display, the left-side stimulus appeared 1,500 msec before the right-side stimulus. Thus, the total design consisted of six colors, four paired conditons (mentioned above), two matching conditions (same or different), and three priming sequences, or a total of 144 stimulus combinations. The order of presentation was random. Each trial consisted of having a subject depress a key with his or her preferred thumb when ready to indicate a sequence. After a delay of 500 msec, the left-side display appeared (except in the simultaneous condition, in which both right and left items appeared). The subject was to decide if the stimulus on the right matched the stimulus on the left and to indicate his or her decision by pressing as fast as possible one of two keys upon which his index fingers were lightly resting. Half the subjects pressed a right-hand key for a match response; the other half pressed a left-hand key for a match response. The left-side display remained visible through the appearance of the right-side display. Reaction time recordings were measured from the moment the right-side display appeared until the subject depressed the key indicating a match or mismatch decision. Before the main experiment, subjects were presented with stimuli representing each of four types of visual display, either the same or different, with two warm-up colors that were dissimilar to the test colors.

Following the first condition, the second (associate) condition was done. In this condition the same temporal relationships were repeated as in the first condition. However, the subjects were asked to decide whether the right-side word was an associate of the color. Half the trials consisted of a match; the other half consisted of a mismatch. Match and mismatch trials were randomly presented. Subjects were given the entire test sequence in 1 day. On the next day, the entire procedure was replicated, except that the sequence of stimuli was rearranged. Only data from Day 2 are reported here. However, the overall results from Day 1 to Day 2 were similar except that the Day 2 reaction times were generally faster than those on Day 1.

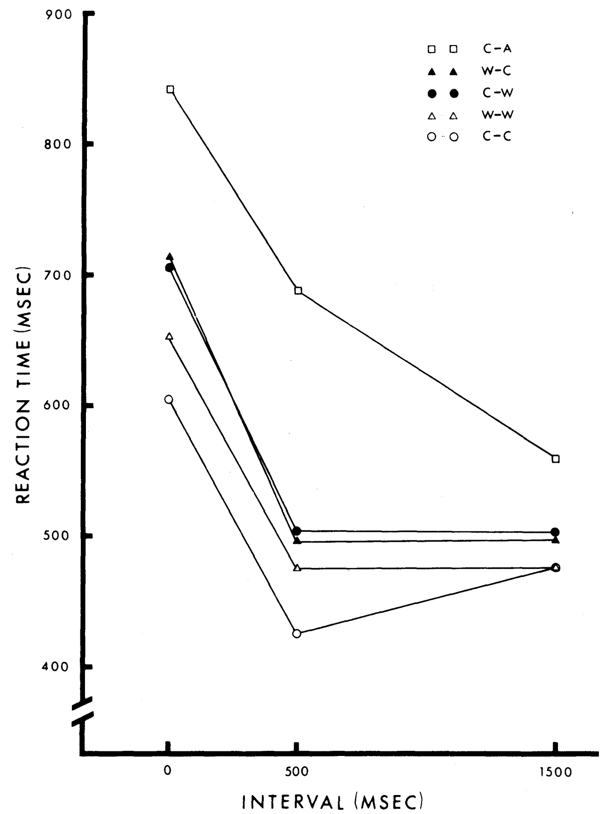

Figure 1. Reaction times of various match conditions as a function of "priming" interval (C-A = color to associate, W-C = word to color, C-W = color to word, W-W = word to word, and C-C = color to color.)

RESULTS

The overall results for the match condition are shown in Figure 1. As shown, the reaction times were longer when the displays were simultaneously presented than when the left-side display preceded the right-side display. An analysis of variance of the three priming factors yielded $F(2,578) = 145.37$ ($p < .0001$); for matching conditions, $F(4,578) = 26.40$ ($p < .0001$); and for the Time by Match interaction, $F(8,578) = 2.28$ ($p < .02$).

Separate analyses of variance were calculated for each time condition [simultaneous condition, $F(4,193) = 11.78$, $p < .0001$; 500-msec condition, $F(4,193) = 15.07$, $p < .0001$; 1,500-msec condition, $F(4,188) = 2.37$, $p > .05$]. In general, three main reaction times curves emerge: one associated with color/color match, a second with color/word match, and a third with color/associate match. An analysis of variance of these three match conditions by the three time conditions yielded significant main effects for match conditions [$F(2,339) = 43.75$, $p < .0001$], time [$F(2,339) = 79.59$, $p < .0001$], and the Match by Time interaction [$F(4,339) = 3.93$, $p < .004$].

The mismatch decisions were generally similar to the match conditions except the reaction times were longer. About 7% of the responses were in error, with no seemingly anomalous distribution of errors.

The reaction times by color and percent of subjects who report the verbal associate to colors (as determined from Solso's, 1971, data) were correlated. The correlation between the reaction time for colors (yellow, blue, red, green) and the percent of subjects responding with the associates used in this study (SUN, 51%; SKY, 62%; BLOOD, 43%; and GRASS, 75%) was −.43 for simultaneously paired displays, −.90 ($p < .05$) for the 500-msec latency between prime and associate, and −.06 for the 1,500-msec latency between prime and associate.

DISCUSSION

One of our results, which indicated that color recognition is facilitated when preceded by a prime, is consistent with the results reported by others (e.g., Posner & Boies, 1971; Rosch, 1975). Also, in all conditions except the color-to-associate condition, minimum reaction time was attained when the latency between the prime and the to-be-matched item was about 500 msec. However, in the color-to-associate condition, reaction time to make a correct match was much briefer when the color prime preceded its associate by 1,500 msec than when the associate was preceded by a prime by 500 msec or was simultaneously paired with the associate. It is noted that reaction time performance improved up to the 1,500-msec latency between prime and associate. The latter finding differs from Posner and Boies' (1971) conclusion that the optimal prime latency is 500 msec. In the case of priming an associate seems to be at least 1,500 msec.

A second result indicated that reaction time for a color/color match was faster than a match between a color and its name or associate. The above finding is consistent with the basic assumption of this research, in which "colors" are represented in a person's cognitive structure in (at least) three different codes: a physical code, a name code, and an associate code. Because reaction times increase from physical matches to name matches to associative matches, it is reasonable to postulate that colors are simultaneously processed in the cognitive structure, but that some processes require less time than other processes. The consequence of parallel but uneven processing of information is that subjects' reaction times seem to reflect a sequential processing of information.

At a basic level, the sensation of a physical color (e.g., red) is initially copied by the sensory system and represented in terms of a physical code. Colors represented by a physical code seem to remain viable for at least 500 msec, but then some deterioration in functional properties is noted. Similar data have been reported by Posner and Boies (1971). It is further postulated that throughout the "physical code" stage, subjects are simultaneously processing color information by means of name codes and associative codes. The second of these codes, the name code, seems to emerge after about 500 msec and remains unaffected through at least 1,500 msec. The associative code requires the greatest amount of time to emerge: from our data, at least 1,500 msec.

When color (names or physical colors) are simultaneously paired with other colors (names or physical colors) and subjects are asked to identify matches between the pairs, four different classes of reaction times seem to emerge. The briefest reaction times were observed when subjects were asked to make a color/color match. These reaction times were followed by color-name/color-name match, which, on the average, required about 50 msec more time. Then followed the color-word/color and color/color-word matches, which required another 50 msec. Finally, there was the color/associate match, which required an additional 150 msec. Because the reaction times in all conditions using some form of a verbal code were greater than those in the color-to-color condition, it is plausible that in the color-to-color match it was not necessary to assess a name code: The subject's comparison between color displays was readily made on the basis of the physical color alone. We therefore conclude that in very short-term memory (0 to 500 msec), color coding takes place.

The emergence of a color code seems to appear prior to a name code or an associative code. However, after about 500 msec, a name code emerges, and after about 1,500 msec, an associative code emerges. The once conspicuous differences among color/color, color/color-name, and color/associate comparisons noted when the displays were simultaneously presented nearly vanish when the separation between the color and its to-be-matched item spans a latency of 1,500 msec. Only a small amount of the reaction time differences between display conditions at 1,500 msec can be attributed to the decay of stimulus availability in the color-to-color match.

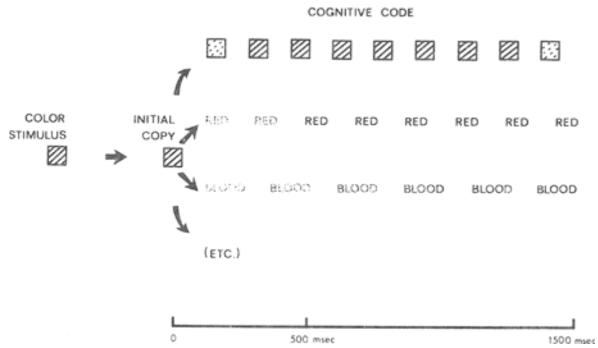

Figure 2.

Finally, in the color-to-associate match condition, it was noted that reaction time was, in general, inversely related to the percent of subjects who had previously reported the associate. It is postulated that when subjects perceive a color, they begin to assess implicit associative responses (IAR) and that, among the IARs assessed, common associates emerge first, with more remote associates later.

The results of this experiment are viewed in terms of a modified parallel processing model of color coding. An outline of that model appears in Figure 2. It is postulated that physical colors (e.g., red) are initially copied by the sensory system and then are variously coded. The first code to reach a level of operable strength (sufficient to base a decision on) is a color code. This code seems to reach full strength sometime before 500 msec, and then it decays slightly. A name code is initiated in parallel, approximately simultaneously; it reaches full strength after about 500 msec and remains vital through 1,500 msec. A series of associative codes are also initiated approximately simultaneously with the other codes. Associative codes, poorly resolved at first, increase in strength at least through 1,500 msec. The present experiment does not rule out the possibility that some associates, especially remote associates, emerge in sequence. For example, it is likely that a subject who views a red display may form an implicit associative response of "blood," which would then lead to another response, for example, "accident." Thus the overall scheme is conceptualized as a parallel model, with possible sequential subroutine processing occurring within the structure.

REFERENCES

Posner, M. J., & Boies, S. Components of attention. *Psychological Review,* 1971, **78**, 391-408.

Posner, M. I., & Mitchell, R. F. Chronometric analysis of classification. *Psychological Review*, 1967, **74**, 392-409.

Posner, M. I., & Snyder, C. R. R. Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium*. Potomac, Md: Erlbaum, 1975.

Rosch, E. The nature of mental codes for color categories. *Journal of Experimental Psychology: Human Perception and Performance*, 1975, **1**, 303-322.

Solso, R. L. Meaningfulness of colors. *Psychonomic Science*, 1971, **23**, 301-303.

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