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A Study of the Interference in Selective Attention on the Stroop Test

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A STUDY OF THE INTERFERENCE IN SELECTIVE ATTENTION ON THE STROOP TEST

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

One approach to the problem of selective attention is to examine instances where selective attention malfunctions, for instance, the Stroop Color-Word Test. When Ss are asked to name the color of ink in which a conflicting color-word is printed, it is found that this is significantly more difficult than naming the colors of dots.

The reason for color-word interference is not known. Since the two dimensions of the stimuli, ink color and color name, conflict it can be hypothesized that S has difficulty in selecting the relevant aspect of the stimulus. This hypothesis predicts that a simpler cognitive operation, such as scanning an array of Stroop items and counting the number printed in a certain color, would show color-word interference.

A frequent explanation of color-word interference has been that response competition is elicited because word reading has greater response strength than color naming. This hypothesis predicts that the time taken to count a color plus the time taken to say a color-word would be less than the time taken to name a color in the color-word condition.

The Ss were 20 students from introductory psychology classes. All Ss served under all conditions. Trials under each condition were given in each experimental session, the order of these trials being randomized.

Neither prediction was confirmed. Color-word interference did not occur when items were scanned and counted, indicating that Ss can attend to the relevant stimulus dimension when recognition only is demanded. Inasmuch as the direction of the observed differences in the test of the response competition hypothesis were opposite to that predicted this hypothesis was not confirmed. The over-all results were interpreted in terms of the difference between recognitive and categorizing processes.

A STUDY OF THE INTERFERENCE IN

SELECTIVE ATTENTION ON THE STROOP TEST

INTRODUCTION

Selective attention was attacked early in the history of psychology. In 1862 Donders sought to measure the time required by Ss to attend to a given item that was accompanied by irrelevant items. He presented members of a set of five phonemes to his Ss on successive trials, instructing them to respond to one, but not to the others. Mean response times to the critical phoneme were 46 msec longer than when it was presented alone in a simple-reaction task. Kulpe's (1904) discussion of attention was an important theoretical contribution but, compared to other areas of psychology, little work has been done since. Conceptual and methodological difficulties have contributed to neglect of this area.

Some insight into selective attention may be gained by studying instances in which there is interference in the smooth operation of the process. Irrelevant cues (which vary independently of prescribed cues) might be expected to retard the rate of performance. In general this has been found. For instance, Montague (1965), using a complex auditory-discrimination task, found that irrelevant information had a detrimental effect on learning. He concluded that the locus of interference was in the response competition generated by implicit responses elicited by the nonrelevant dimensions.

Color-word interference (Jaensch, 1929) is an instance where the effect of irrelevant cues is maximized. Stroop (1935b) developed a test to elicit this sort of interference. The test includes three sets of stimuli: (1) the W card, which consists of color-words to be read aloud by Ss; (2) the C card, consisting of color patches which are to be named; (3) the CW card, which consists of color-words printed in conflicting colored inks, and S must name the colors. The last task presents difficulty for Ss. Significantly more time is required on the CW than on the C cards, and many Ss exhibit increased motor activity, nervous laughter and other signs of tension (Jensen and Rohwer, 1966). Clearly, attentional mechanisms are malfunctioning in the performance of the CW task.

A forerunner of Stroop's test was Cattell's (1886) experiment in which he asked Ss to name pictures of objects, letters and colors as well as say words. He found that the time required to see and name colors and pictures was more than one-half second per item, which was about twice as long as for words and letters; however, recognizing a color or picture took less time than a word or letter. Differential practice was the most frequently cited explanation for Cattell's results. Brown (1915) gave Ss extended practice and found no tendency for reading and naming functions to converge. In addition, he deduced that the process of reading words is not involved in the process of naming colors as a subsidiary function. A study by Ligon (1932) also failed to support the differential practice hypothesis. Brown's conclusion that the association process in naming colors is radically different from that of reading printed words seems to be the most likely explanation. Reading a common word involves perceiving the word and making a motor response to it. Naming a color involves perceiving the color, giving it a name, and saying the name. Thus, a categorization is necessary.

Stroop (1935a) participated in the differential practice controversy and subsequently published his experiments on color-word interference. He also conducted a control study in which color-words had to be read in the presence of conflicting colors. There was no measurable interference in this case. Interference on the CW card is a reliable phenomenon, as evidenced by a number of investigations, most notably Jensen's (1965) collection of normative data in which none of the 400 Ss used was able to name colors on card CW as rapidly as on card C, even after ten days of practice.

The C,W, and CW tasks have been used for a variety of purposes, but little effort has been expended in understanding the basis of color-word interference. Wapner and his associates (1963) qualitatively studied the kinds of errors Ss made on the CW card and found seven classes of errors: (1) inappropriate color responses, (2) contaminated responses, (3) inarticulate utterances, (4) insertion of color-words, (5) omissions, (6) inserted linguistic words or phrases, (7) inserted nonlinguistic utterances. From these, Wapner (1964) concluded that the "interference" on the CW card was not unitary. Two underlying processes were suggested: (1) the process of identification of the appropriate aspect of the stimulus item, (2) the process of serial organization of the responses.

Klein (1964) made up six variations of the CW card, each with different kinds of verbal units on it: (1) nonsense syllables, (2) rare words (3) common words (4) color-related words, (5) distant color names, (6) color names of the inks used. A control card consisted of colored asterisks. The amount of interference as compared with the control card was significant even for the nonsense syllables, and increased with each condition in the above order. Klein suggested that words have "attensive" power to provoke motor responses and that this capacity varied with meaningfulness, so that the most meaningful words have the strongest tendency to evoke a motor response and thus create the most interference. Klein also proposed that the increased time taken to make the correct response on the CW card is used by the S to hold back the irrelevant response. Klein conducted an experiment in which Ss were asked to both read the word and name the color of the ink in that order. Other Ss did this in reverse order, the color first and then the word. Ss in the first condition were significantly faster, presumably because they did not have to "hold back" one response while making another.

Schiller (1966), using Ss from grades 1, 2, 3, 5, 8 and college freshman classes, concluded that differential practice in word reading and color naming was not an adequate explanation of color-word interference because interference was minimal in grade 1, but became maximal in grades 2 and 3 and then declined gradually. He suggested, instead, that words contain more information and are therefore more readily perceived than colors. This is not confirmed by Cattell's finding that it takes longer to recognize words than colors.

The essentials of the CW task are: selectively attending to the relevant stimulus dimension, assigning a name to the color, and making a motor response. Interference could occur in any of these three processes. Wapner's suggestion that the process of identification of the appropriate aspect of the stimulus is the source of interference, and Klein's hypothesis that words have "attensive" power to provoke motor responses that interfere with responses to color, deal with two of them. It is also possible that interference occurs in the naming process. Some insight into the relative importance of these factors to color-word interference may be gained by comparing the CW task with a task that has only one aspect in common with it, namely selecting the appropriate aspect of the stimulus. Counting silently the number of items of a certain color demands selective attention, but naming and an overt response are absent. This task consists of scanning, recognizing and counting. Comparing the effects of conflicting words on scanning and naming may indicate if color-word interference occurs in the process of identifying the relevant stimulus dimension. Klein suggested that the motor component of the total response is critical to the occurrence of interference. This is difficult to test directly; however, an attempt was made in this experiment by hypothesizing that naming a color on the CW card would take longer than the time needed to count a color added to the time required to say that color-word (as measured by a word-reading task). This assumes that the cognitive operations of counting an item and giving it a name are equivalent in complexity. Although the accuracy of this assumption is not known, it was believed that this analysis of the data might prove useful.

If there is no measurable interference in scanning items on the CW card, and no evidence that an overt motor response is critical to interference, it can be concluded that the naming process is the source of interference. The purpose of this experiment was to discover the locus of color-word interference by comparing counting and naming.

A second aim was to study the characteristics of the counting process itself. There is little mention in the literature of counting as a method of studying psychological phenomena. Hall and Jastrow (1886) had Ss count the number of clicks presented. They found that errors were greatest when a large number of clicks were presented and the interval between them was shortest. Tinker (1926) repeated Hall and Jastrow's study, using visual stimuli, and concluded that counting is a complex reaction process. He found that a uniform series was easier than an irregular series and that a medium rate was easiest, a slow rate more difficult and a fast rate most difficult. Beckwith and Restle (1966) reported experiments dealing with the effects of number of objects to be counted, arrangement of objects and variations in the shape and color of objects on counting rate. Rapid counting depends upon grouping the material into subgroups, subitizing the number in each group and then adding these numbers to obtain the result.

Previous work has dealt with the problem of counting all items in an array. Another approach is to count only the items having a specified characteristic. This is a combination of scanning and counting. Neisser (1963) found that the relationship between scanning time and number of items is linear, but the relationship between scanning-counting time and number of critical items is unknown. In addition, Neisser's results indicated large differences in scanning as a function of discriminability of the critical item. Using letters of the alphabet he found that more time was required for S to decide that a given item was similar to the others. The effect of discriminability on the time required to decide that a given item is critical is also unknown. If counting time and scanning time are differentially affected by item discriminability, this would support Neisser's assumption that information processing of this kind is hierarchically organized. The literature provided no direct information concerning the effect of number of critical items and item discriminability. However, Neisser's work suggested that the relationship between time and number of critical items would be linear, and the least discriminable items would be counted slowest.

In summary, the aims of this experiment were to compare the effects of conflicting words on counting and naming, and to study the characteristics of a counting task that included critical and non-critical items. Two hypotheses were made:

1. That the presence of conflicting words would interfere with scanning and counting colors;
2. That the time taken to count a color under C condition plus the time taken to say a color-word would be less than the time taken to name a color in the CW condition.

METHOD

Subjects. The Ss were 10 male students and 10 female students from introductory psychology classes. All Ss served under all conditions.

Apparatus. An opaque projector fitted with a shutter controlled by S and connected to a timer was used. Ss exposed the stimuli on a screen (and started the timer), executed the required task and then covered the stimuli (and stopped the timer).

The stimuli were 40 sheets composed of the color-words red, blue and black printed in the three colors such that no word was printed in its own color, and 40 sheets with 4-item groups of the letter X printed in the three colors. The total number of items on each sheet was 243. The number of critical items (ci) varied from 0 to 128 in an approximately logarithmic fashion, except that all points were sampled from ci = 0 to ci = 8. Beyond ci = 8, ci varied ±1 from the logarithmic point chosen. For example, what will be spoken of as ci = 64 when the three colors are combined is an average of times for ci values of 63, 64 and 65. There were also six sheets of 100 items each for naming colors, on which the number of items of each color was equal. A word reading task (SW), consisting of a 50-item array of the color-words blue, black and red, ordered randomly, was also included. Pilot data indicated that reading these three words very rapidly for long periods of time led to difficulties in enunciation that were not present at the slower rates used for naming. Since the aim of the SW task was to obtain an accurate estimate of the time needed to say a color-word, the total number in the array was decreased from 100 to 50 in an attempt to facilitate rapid reading.

Procedure. Prior to testing, Ss were asked to name the colors of the stimuli as a check for color blindness. Three practice trials were given to ensure that Ss understood the procedure.

In the experiment proper, Ss served under five conditions:

1. Saying all colors with color only present--SC
2. Saying all colors with colors and words present--SCW
3. Silently counting critical colors with colors only present--CC
4. Silently counting critical colors with colors and words present--CCW
5. Reading aloud color words--SW

Trials under each of these conditions were given in each experimental session. The order of these trials was randomized.

Under each of the CC and CCW conditions nine trials were given to each S at ci = 0 to ascertain a scanning rate. Three trials were given at or near each logarithmic point. Nine trials were given under the SC and SCW conditions. Ss, tested individually, had answer sheets for recording responses. E recorded times, changed the stimuli and gave instructions during the inter-trial interval.

RESULTS

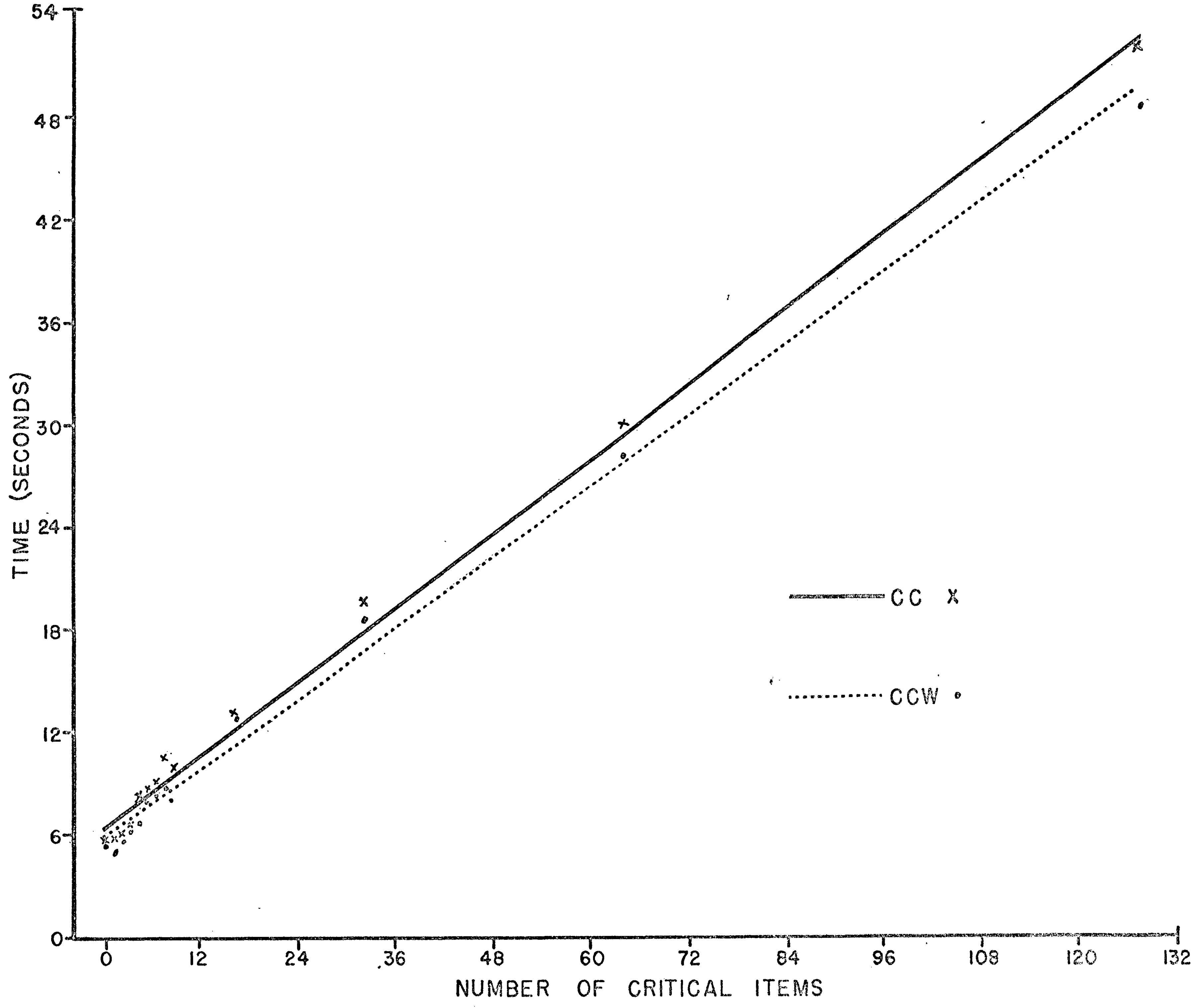
Effect of conflicting words on scanning and counting.

The effect of conflicting words on counting time is presented in Fig. 1. The rates were practically the same at low values of ci. The difference at ci = 128 was not significant ($t = .60$). The direction of this difference is contrary to what would be expected if the presence of words retarded processing rate. Mean counting rates under C (.36 sec/item) and CW (.33 sec/item) conditions were not significantly different ($t = 1.4$) and were not in the predicted direction. The effect of conflicting words on number of errors was in the predicted direction at ci = 128 but was not significant either by the Wilcoxon matched-pairs signed-ranks test ($T = 64$) or by a t-test ($t = 1.8$). Thus, the presence of conflicting words does not affect scanning or counting rates.

Relationship between naming and counting.

The slope of the regression line of time on number of critical items was chosen as the best estimate of counting rate. This was computed from the equation, $Y = a + bX$, where a is the Y - intercept, b is the slope of the line, and X and Y are the coordinates of the data points. Naming time per item was obtained by dividing the total time by number of items (100). The resulting data are presented

Figure 1. Effect of Condition (Groups of X's or Conflicting Words).



TIME (SECONDS)
54
48
42
36
30
24
18
12
6
0
0
12
24
36
48
60
72
84
96
108
120
132
NUMBER OF CRITICAL ITEMS
CC X
CCW •

in Appendix I. An analysis of variance was applied to measure the effects of Task (counting or naming), Condition (C or CW) and Subjects on time per item. The results are shown in Table 1. The main effects of Task and Condition are significant as is their interaction.

The test of Klein's theory suggests that an overt response is not necessary for color-word interference. There was a significant difference ($t = 3.04$, $p < .01$) between naming time per item (.72 sec) and counting plus reading time per item (.79 sec) but it was not in the predicted direction.

Relationship between number of critical items and counting time.

This function can readily be fitted by a straight line, using the previously mentioned linear regression equation. Fig. 2 presents the combined results of CC and CCW conditions for each critical item color. For the range of ci sampled this means that the time taken to count an item does not change from one value of ci to another. The slope of the line provides an estimate of the average time required to count one item. There was considerable variability at small values of ci. This may result partly from longer times to count zero items than to count four or five items. The time taken to conclude that zero items were present was rarely the shortest time for any given S.

As a S in a similar experiment I noticed that when I reached the latter part of an array and had not noticed a critical item, there was a tendency to slow down and examine items more closely. A strong impulse to backtrack was not uncommon, although it was known

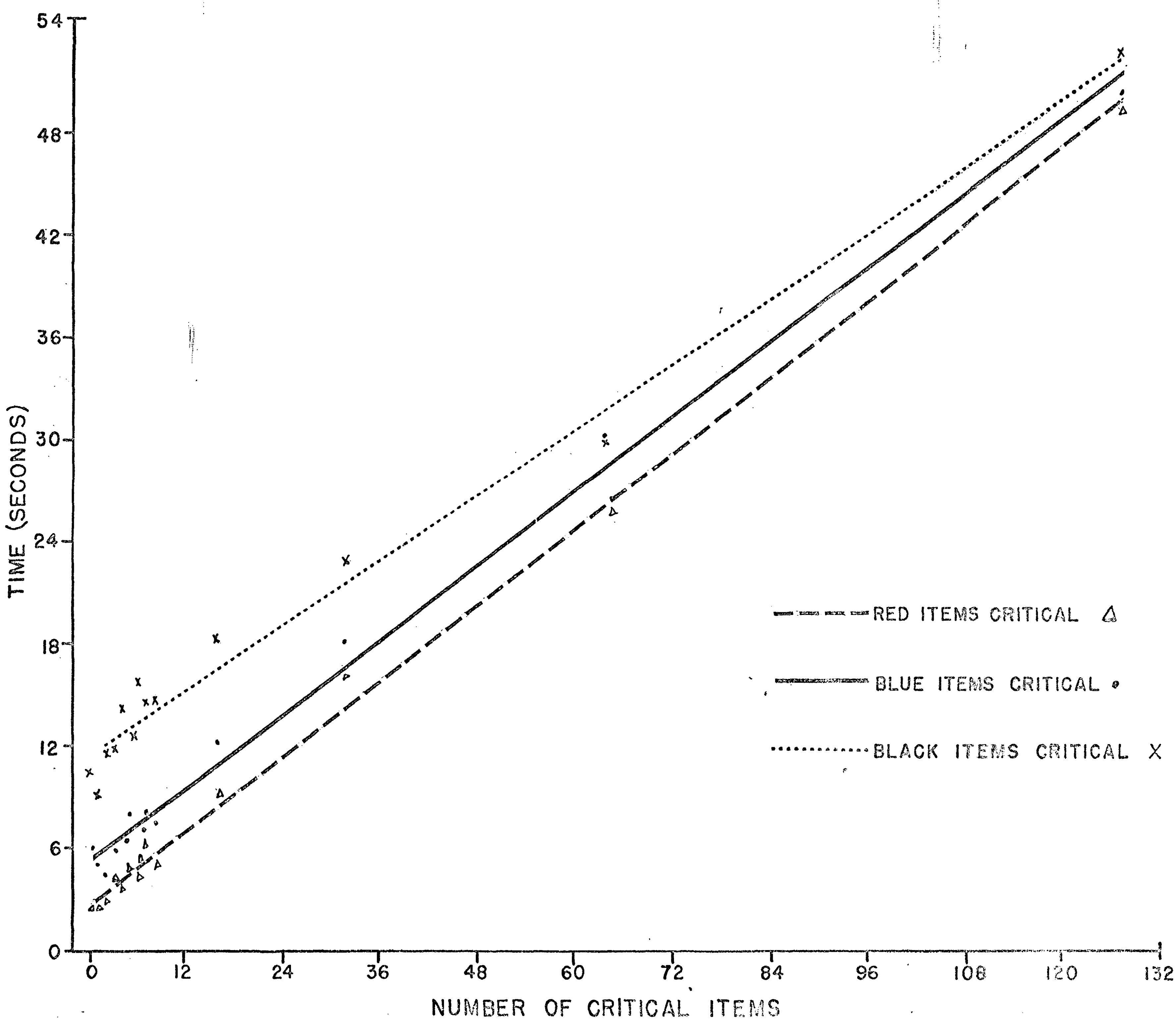
TABLE 1

SUMMARY OF ANALYSIS OF VARIANCE

Source of Variance	SS	df	MS	F
T--task (counting or naming)	1.67	1	1.67	378.6*
C--condition (CC or CCW)	.127	1	.127	30.4*
TC	.193	1	.193	55.8*
S--subjects	.458	19	.0241	
TS	.084	19	.0044	1.26
CS	.079	19	.0042	1.20
TCS	.066	19	.0035	

* significant at .01 level

Figure 2. Effect of color of critical item.


TIME (SECONDS)
54
48
42
36
30
24
18
12
6
0
12
24
36
48
60
72
84
96
108
120
132
NUMBER OF CRITICAL ITEMS
RED ITEMS CRITICAL Δ
BLUE ITEMS CRITICAL •
BLACK ITEMS CRITICAL X

that some arrays might contain no critical items. Ss in the present experiment had no knowledge of the range of ci, so this effect might well have been accentuated.

Color differences in counting.

There were clear-cut differences between colors at ci = 0 (Fig. 2). Time taken to conclude that no red items were present was 2.3 sec., compared with 5.4 sec. for blue and 10.3 sec. for black. The t value of red-blue differences was 6.4 ($p < .001$) for blue-black, 5.9 ($p < .001$). These results are not unexpected because red items were very obvious, whereas blue and black items were difficult to discriminate. However, these differences partially disappear as ci increases. At ci = 128 times for blue (51.0) and black (52.9) as well as for blue and red (49.4) items were not significantly different, but the difference between red and black was significant ($t = 2.4$, $p < .05$). The convergance of the functions at ci = 128 suggests that difficulty of discrimination affects scanning and counting differentially when time is the measure. The number of errors at ci = 0 is virtually the same for each color, but at ci = 128 there are more errors per S for red items (4.2), less for blue (3.2) and least for black (2.7). These differences are not significant, however ($t = 1.07$ for red-black differences).

Other results.

The method of this experiment was somewhat different from previous ones, most notably in the use of apparatus and three colors instead of four or five. The differences noted here may or may not be related to these factors. Contrary to previous work (Jensen and Rohwer, 1966) no significant differences were found in the performances of males and females on color naming. The largest sex difference was found on the SCW task, but it was not significant (t = 1.2). E noted that female Ss tended to be less facile in using the apparatus and, although given practice trials, tended not to be as prepared as males to flip the switch. SC and SCW differences were not as marked as in previous studies (Jensen and Rohwer, 1966). Also, the absolute values of these functions were less in the present experiment. This is probably related to the greater difficulty of tasks using more than three colors.

DISCUSSION

The finding that the presence of conflicting words did not interfere with scanning or counting colors is noteworthy. Earlier it was suggested that attending to the relevant aspect of the stimulus and correctly categorizing the color are two logically important operations in the SCW task. Scanning and counting demand selective attention and recognition, but the color does not have to be given a name. In this respect scanning and counting are covert processes. The source of interference on the SCW task must be peculiar to a process other than identifying the appropriate dimension of the stimulus.

Part of the clear-cut differences between the effects of counting and naming on processing time may be related to the fact that there is no overt muscular response involved in counting as there is in naming. Lund (1927) performed an experiment that combined the tasks used in the present study. In an attempt to find out why color and form naming take longer than word reading, Lund presented his _S_s with the tasks of "color finding" and "form finding". _S_ went through a 100-item array and named and pointed to examples of a required color or form. For instance, if _S_ were instructed to find all the blue items, he would scan the array and each time he encountered a blue item would say, "blue". This task is similar to the one used in the present experiment except that an overt response is used instead of silent enumeration. Lund found that the average total times for color naming (Stroop's C task) and color finding were virtually the same. Naming all items and finding and naming examples of only one kind of item seem to be of the same complexity, as measured by processing time. This suggests that making an overt response does not slow down performance. This is supported by Landauer's (1962) finding that Ss think numbers to themselves at the same rate as they speak them aloud. Thus, the difference between counting and naming seems to be related to differences in cognitive processes.

The hypothesis that less time would be required to count a color plus say that color word than to name a color in the CW task was not confirmed. This suggests that an overt response is not necessary for the occurrence of color-word interference. This, together with the fact that the presence of conflicting words does not affect counting, implies that the cognitive process of applying a name to a color is critical. This conclusion is weakened somewhat by the possibility that the logic underlying the overt response hypothesis is faulty. It was assumed that counting can be thought of as analagous to naming except that it lacks a muscular component. It was also assumed that reading time is an accurate estimate of the time necessary to say words, i.e., that the cognitive operations in reading are so rapid as to be irrelevant for the purposes of this experiment. Further reflection has produced doubt about the accuracy of either of these assumptions.

The finding that color affects scanning time is not in agreement with the results of Smith (1962) who, using red, blue, green, orange and black, reported that the color of the target did not affect search time. The indication from Fig. 2 that discriminability affects scanning and counting differentially supports Neisser's (1963) assumption that the process of recognition is hierarchically organized. In the case of his stimuli, letters of the alphabet, this is readily conceptualized. When S is searching for a "T", for instance, he makes certain low-level (i.e. fast) decisions concerning roundness versus angularity. When the latter condition is met, other criteria, eg. a horizontal line at the top joined by a vertical line, are applied. This leads to what can be called "recognition". This reasoning is more difficult to apply to a color stimulus. Nevertheless, the fact that difficulty of discrimination affects scanning rate but does not appear to affect counting rate suggests that the underlying process consists of at least two stages.

It may be argued that the reason that the recognition stage is longer is because of the time required to attach the appropriate numeral to the critical item, that is, count. There is little doubt but that this takes time. To the writer it seemed to take both time and effort, particularly at higher numbers. However, an experiment by Neisser showed that conditions requiring complete recognition (but no response except to move to the next item) took longer than when full recognition was not demanded. Probably counting time per item in the present study is a combination of recognition time and enumeration time. Another possible explanation of the color differences is that when red items are critical S is able to subitize, that is, he can take in all items at a glance and does not need to count. Since there is little observable difference between the shapes of the color curves, this does not seem to be a tenable explanation.

Linearity implies that it takes approximately the same length of time to add an item at any point. Since the largest ci was only 128 out of an array of 243, it cannot be concluded that a linear relationship obtains when nearly all items in the array are critical. As Beckwith and Restle's (1966) results indicate, Ss will readily take advantage of an opportunity to use a short cut. Four Ss used such a technique on some trials of ci = 128. These results were not used in the analysis, although they are interesting in themselves.

Neisser (1963) points out that the slope of the line in a scanning task provides the most pertinent information, time per item. At first glance, this does not seem to apply to data that includes both scanning and counting. However, if it is assumed that scanning and counting are hierarchical processes such that all items are subjected to a preliminary analysis and those meeting certain criteria are subjected to another set of operations, the slope of the line is an estimate of counting time per critical item. The present data offer no clear empirical test of this conclusion because the variability at low values of ci make the assigning of a true scanning rate difficult. Nevertheless, it might be noted that mean counting time per item at ci = 128 computed from an estimation of scanning time is very close to time per item taken from regression data. For example; time per item for red items - .37, slope =

.370; time per item for blue items = .37, slope = .367; time per item for black items = .35, slope = .321.

The conclusion that assigning a name is critical to color-word interference is supported by Stroop's (1935b) finding that saying words was not affected by the presence of conflicting colors. The operation of categorization, that is, choosing the appropriate name for the color stimulus is the most salient difference between these conditions, which suggests that it is the source of interference. A logical extension of the present study would be to use Lund's (1927) method of "color-finding" with Stroop items. If conflicting words do not affect this task the importance of the cognitive process of categorizing a color by giving it a name would be firmly established.

APPENDIX

COUNTING TIMES AND SW DATA

APPENDIX

COUNTING TIMES AND SW DATA

Subject

Task	Con.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	M
T1	C	.40	.72	.46	.37	.40	.41	.31	.22	.28	.29	.43	.30	.35	.31	.37	.29	.27	.30	.38	.30	.36
Counting	CW	.38	.29	.41	.37	.39	.33	.28	.29	.29	.35	.45	.31	.35	.29	.26	.31	.41	.28	.38	.23	.33
T2	C	.62	.78	.69	.62	.51	.54	.43	.50	.58	.58	.61	.48	.54	.43	.38	.45	.58	.52	.59	.49	.55
Naming	CW	.88	.91	.84	.83	.80	.70	.54	.63	.69	.82	.73	.70	.75	.60	.53	.59	.86	.67	.72	.67	.72
	SW	.54	.50	.46	.38	.46	.42	.38	.37	.55	.44	.44	.42	.41	.37	.33	.40	.45	.45	.45	.39	.43
T1 + SW		.94	1.22	.92	.75	.86	.83	.69	.59	.83	.73	.87	.72	.76	.68	.70	.69	.72	.75	.83	.69	.79

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