Judging pictorial and linguistic aspects of space

SANDRA R. PALEF

*Ontario Institute for Studies in Education, University of Toronto
Toronto, Ontario, Canada M5S 1V6*

A test is made of the notion that Stroop-like interference and facilitation effects arise from two different sources, one pictorial and the other linguistic. It was hypothesized that when irrelevant information is pictorial, it interferes with a pictorial code used in the processing of the relevant information; when it is linguistic, it interferes with a linguistic code. The experiment required subjects to respond to (1) the meaning of a spatial word, (2) its absolute position, or (3) its relative position, while attempting to ignore the two irrelevant dimensions of the display. It was found that word meaning and absolute position information affected the speed of relative position judgments in an additive manner. No other Stroop-like effects were found. The results supported the hypothesis under test. It was concluded that the existence of different kinds of Stroop effect must be accommodated by current models of the phenomenon.

A useful technique for investigating how people mentally describe and judge space is a modification of the Stroop (1935) experiment, in which spatial rather than color information is presented. The typical finding is that judgments of position or direction are interfered with by words whose meanings are incongruent with the meanings of the spatial displays. For example, White (1969) required subjects to respond to the position of a word that was north, east, south, or west within a square. When the meaning of the word was incongruent with the position (e.g., the word "north" at the bottom of the square), reaction time (RT) increased compared to a control condition in which the word was a nonsense syllable. Similarly, Shor (1970) found that when subjects indicated the direction of an arrow pointing up, down, left, or right, RT increased compared to a control condition when words located within the arrows were different from the direction of the arrow. Fox, Shor, and Steinman (1971) showed that interference to naming spatial direction decreased as the semantic aspects of the words ranged from incongruent names to space-related words to common words, rare words, and nonsense words. Finally, Palef and Olson (1975) demonstrated that the direction of interference, that is, whether spatial information interferes with judgments of word meaning or words interfere with judgments of space, depends on the relative processing speeds of the two sources of information. Words interfere with spatial judgments when they are processed faster than space; positions interfere with judgments of word meaning when they are processed faster.

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Since all of these findings about space resemble the Stroop color effect, in which the meaning of a word interferes with the naming of the color of ink in which the word is printed, investigators have argued that they can be explained in the same manner as the Stroop effect (see, e.g., Dyer, 1973). The experiment described here throws doubt on this conclusion, that is, that one explanation can encompass all of the Stroop-like effects, by demonstrating that pictorial and linguistic aspects of space interfere with different parts of spatial judgment tasks.

Explanations of the Stroop effect may be conveniently grouped into two categories according to the stage of processing at which the interference is presumed to occur. The perceptual encoding explanation assumes that words disrupt or delay the encoding of pictorial events (Hock & Egeth, 1970). The response competition model holds that responses to the two dimensions of the stimulus compete for a single channel output mechanism (Morton, 1969). A recent review of the Stroop literature (Dyer, 1973) indicates that the response competition model is the most highly substantiated. All of the evidence in support of the former explanation appears to be handled as well by response competition. Furthermore, the finding that there is interference on color judgments from words that are the same as the response words but semantically unrelated to the encoding of color can only be explained by some form of response competition (Dalrymple-Alford & Azkoul, 1972; Egeth, Blecker, & Kamlet, 1969).

More recently, however, Clark and Brownell (1975) found evidence in favor of the perceptual encoding explanation of interference in a spatial situation. The basic task required subjects to read an instructional word "up" or "down." Then, while timed, they were presented with a display containing an arrow pointing up or down and positioned in the upper or lower half of the rectangle, and responded "true" if the instruction

and direction of the arrow matched and "false" otherwise. Clark and Brownell assume that the timed part of the task consists of three stages, namely, perceptual encoding of the direction of the arrow, comparison in memory of the code for direction with the code for the instruction word along with computation of the code for the motor response, and, finally, initiation of the motor response itself. Given eight conditions in which the instruction word is "up" or "down," the direction of the arrow is up or down, and its position is up or down, the pattern of RTs will vary depending on whether the irrelevant position information interferes at the level of encoding or response. Clark and Brownell also consider that the interference could take place at the level of comparison in memory. It was found that position information affected the direction code, while the other codes were unaffected, suggesting that the interference occurred at the level of encoding only.

The findings of Clark and Brownell (1975) are in striking contrast to those of Seymour (1974), who employed a very similar spatial task. Subjects were presented with the instruction words "above" or "below" in the center of a reference square, and responded "yes" if the position of a word outside the square matched the meaning of the instruction word and "no" otherwise. The meaning of the word outside the square was irrelevant, and was designed to interfere either with the response or encoding aspects of the task. The irrelevant linguistic information was "yes" or "no" and "right" or "wrong" in the former case, and "up" or "down" in the latter. Only the distractor words "up" and "down" showed a Stroop-like effect, and the pattern of RT results suggested that the irrelevant linguistic information affected the code for the instruction word. Seymour explained his data by assuming that distractors that are semantically related to the encoding part of the task cause adjustments in the settings of thresholds for production of "yes" and "no" responses. However, he did not account for the fact that it was the instruction word code that was affected rather than the pictorial code as in Clark and Brownell's experiment. The basic difference between the two experiments is that in the former, the irrelevant interfering information was linguistic, while in the latter it was pictorial.

The difference between the types of interfering material and the corresponding difference between the codes that are interfered with led Clark and Brownell (1975) to conjecture that when the irrelevant information is pictorial, it interferes with a pictorial code; when it is linguistic, it interferes with a linguistic code. This may either be because of greater similarities between codes of the same type than between codes of different types all of which are formatted in the same manner (as Clark might suggest), or because of more fundamental differences between pictorial and linguistic information processing (e.g., Paivio, 1971). Clark and Brownell admit that there is little empirical support

for their conjecture, but suggest that if supported, it would point to the existence of different types of Stroop effect.

The purpose of this investigation is to test the notion that pictorial information interferes with pictorial codes and linguistic information interferes with linguistic codes. The task used is a three-dimensional spatial one, in which subjects are presented with the words "above" or "below" in one of two absolute positions on a screen (above or below) and in one of two positions relative to an asterisk (above or below). Subjects respond to word meaning, absolute position or relative position, attempting to ignore the other two dimensions of the display.

When subjects respond to word meaning, it is assumed that two stages of processing are involved: formation of a linguistic code for the word, and initiation of the motor response. When subjects respond to absolute or relative position, three stages are involved: formation of a pictorial code for the spatial information, translation of the pictorial code to a linguistic code, and initiation of the motor response. The linguistic translation stage is assumed to occur whenever the subject is required to make a verbal response to the dimension in question. Verbal responses include those made orally as well as the pressing of verbally labeled keys (as in the present experiment). However, when the response is not verbal, or when the dimension is irrelevant and does not require a response at all, the translation stage is unnecessary. The evidence for these assumptions comes from experiments that demonstrate a reduction or elimination of interference from words to judgments of color or space when the latter judgments can be performed nonverbally. For example, Pritchatt (1968) showed a reduction of interference from irrelevant words to color judgments when the response keys were labeled with colors rather than color words. Similarly, Dalrymple-Alford and Azkoul (1972) report that subjects sort Stroop color stimuli on the basis of color with less word interference if the sorting bins are identified by color patches rather than color names. With practice, the interference effect is eliminated completely. Morton and Chambers (1973) and Treisman and Fearnley (1969) required subjects to sort cards with two colors according to whether the colors were the same or different, and found little interference when one color was a Stroop stimulus. Finally, Palef and Nickerson (Note 1) showed a reduction in interference when subjects respond to the auditory location of a spatial Stroop stimulus by pressing keys whose spatial arrangement is compatible with the spatial locations of the stimuli compared to when they are labeled with spatial words. All of these studies point to the conclusion that when a nonlinguistic response can be made, the linguistic translation is not performed, and as a consequence, there is little or no interference from irrelevant words.

The notion that pictorial information interferes with

pictorial codes and linguistic information interferes with linguistic codes makes the following predictions about the present experiment: (1) Judgments of word meaning will not be affected by relative or absolute position, since these sources of irrelevant information are coded differently from the relevant information. Word meaning is coded linguistically only; relative and absolute position are coded pictorially, and since they do not require a response, are not translated into a linguistic code. (2) Judgments of absolute position will be affected by both relative position and word meaning at different stages of processing. Absolute position is coded pictorially and then translated into a linguistic code in order for the linguistic response to be made. Relative position is coded pictorially only, while word meaning is coded linguistically. Since the pictorial and linguistic stages of processing absolute position are independent, the effects of the two sources of irrelevant information should be additive. (3) Judgments of relative position should be affected by both absolute position and word meaning, again in an additive fashion. Absolute position will affect the pictorial stage of processing, while word meaning will affect the linguistic stage. However, one of the prerequisites for Stroop-like interference is that the irrelevant information must be processed faster or at least as fast as the relevant information (see Palef & Olson, 1975). One might explain this by assuming that the potentially interfering code must be activated prior to the task-relevant code. Therefore, these predictions will probably not hold when the irrelevant information is processed more slowly than the dimension to be judged. Since it is difficult to know the relative speed of processing the three dimensions of the display prior to the experiment, one can merely make the general statement that given appropriate relative processing speeds, the above predictions will be met.

It is important to note that this experiment is not designed to discriminate between the encoding and response competition explanations of the Stroop effect. Its purpose is simply to test the hypothesis that different interference effects arise depending on the nature of the irrelevant information code. Linguistic and pictorial interference effects may occur at encoding or at response or at both stages, depending on the kind of task in question. The alternative to the hypothesis under test is that the nature of the irrelevant code is unimportant. This view predicts that each dimension will interfere with the others as long as the irrelevant code is activated prior to the relevant one. Furthermore, the effects of the two sources of irrelevant information would be interactive, since, presumably, they would affect common stages of processing.

METHOD

Subjects

Thirty-six students from the University of Toronto served as subjects. Each one participated in one 1-h session for \$2.50.

Apparatus and Procedure

Stimuli were presented on a cathode-ray tube (CRT) screen that was controlled by a PDP-9 computer. The stimuli were the words "above" and "below." Each word occurred directly above or below an asterisk (relative position) and either above or below the midline of the CRT screen (absolute position). Each word subtended approximately 1 deg in height, was separated from the asterisk by approximately 2 deg, and separated from the midline of the display by approximately 6 deg. One group of 12 subjects responded to the meaning of the word while attempting to ignore relative and absolute position, while two other groups responded to absolute and relative position, respectively, attempting to ignore the irrelevant dimensions in each case. In each response condition, each of the irrelevant dimensions could be congruent with the relevant one, incongruent, or neutral. The stimulus neutral with respect to word meaning was a string of xs presented in one of two relative and absolute positions; the stimulus neutral with respect to absolute position was the word "above" or "below" presented above or below an asterisk but in the center of the CRT screen; the stimulus neutral with respect to relative position was the word "above" or "below" presented in a given absolute position without an asterisk. For each response condition then, there were 18 types of trials corresponding to the possible combinations of response to the relevant dimension ("above" or "below"), the nature of the first irrelevant dimension (congruent, incongruent, neutral), and the nature of the second irrelevant dimension (congruent, incongruent, neutral). These trial types occurred equally often and in random order within a response condition.

Each trial consisted of a 200-msec warning signal, a .5-sec delay, the stimulus, which remained on until the subject responded, and an intertrial interval of 5 sec. Reaction time was measured from the onset of the word to the pressing of one of two response keys. The keys were located one beside the other, and were labeled "above" and "below." Subjects used the index finger of their dominant hand for responding. They were instructed to respond as rapidly as possible without making mistakes. Each group of subjects received 450 trials, 25 in each of 18 conditions. Of these, the first 10 were considered practice, and were not included in the experimental analyses.

RESULTS

Mean correct RTs for each response condition as a function of both irrelevant dimensions are presented in Figure 1. Error rates varied around 2%. The curves are

Figure 1. Mean reaction time for each response condition as a function of two irrelevant dimensions (C = congruent, N = neutral, I = incongruent).

collapsed over subjects and over response to the relevant dimension ("above" vs. "below"). From the figure it is clear that control RT (i.e., when both irrelevant dimensions were neutral with respect to position) was fastest for absolute position (414 msec), next fastest for word meaning (504 msec), and slowest for relative position (570 msec). Given that an irrelevant dimension will interfere only when it is processed faster than the relevant dimension, a simple encoding or response competition model would predict effects of absolute position and word meaning on judgments of relative position, and effects of absolute position on judgments of word meaning. Of these, only the effects on relative position would be predicted by the hypothesis under test.¹

Analyses of variance were performed on the data for each response condition separately. For the absolute position response condition, there were no significant effects of word meaning or relative position. For the word meaning response condition, the effect of absolute position was significant [$F(2,22) = 24.87$, $p < .01$], whereas the effect of relative position was not. However, the effect of absolute position was semantically indiscriminate. Both congruent and incongruent absolute position information slowed responses to word meaning compared to the control condition. Neuman-Keuls tests on individual means showed that both the congruent and incongruent conditions were significantly different from the neutral condition at the .05 level, but were not different from each other. For responses to relative position, both word meaning and absolute position had significant effects [$F(2,22) = 18.01$, $p < .01$, and $F(2,22) = 23.94$, $p < .01$, respectively]. The effect of word meaning information on decisions about relative position includes both facilitation and interference. Neuman-Keuls tests ($p < .05$) showed that both congruent and incongruent conditions were significantly different from the neutral condition and from each other. On the other hand, the effect of absolute position included only interference. The incongruent condition was slower than the congruent and neutral conditions ($p < .05$), which were equal. The effects of word meaning and absolute position on relative position judgments were additive; the analysis of variance showed no significant interaction between the two effects [$F(4,44) = .39$, n.s.].

Some differences occurred as a function of whether the relevant information was above or below. In the word meaning response condition, there was a significant main effect of the word "above" vs. the word "below" [$F(1,11) = 7.75$, $p < .05$], with "above" RTs at 509 msec and "below" RTs at 529 msec. This effect did not interact with the effects of absolute position on word meaning. In the relative position response condition, the main effect of above vs. below was not significant, but the interaction of above vs. below and the effect of word meaning was significant [$F(2,22) = 6.83$,

$p < .01$]. The data show that the interfering effect of incongruent word information was smaller when relative position was below than when it was above. Finally, there were no differences between above and below in the absolute position response condition.

DISCUSSION

The experiment provided support for the notion that pictorial information interferes with pictorial codes and linguistic information interferes with linguistic codes at different stages of processing. It was assumed that irrelevant sources of information interfere with or facilitate responses to relevant information only when the irrelevant material is processed faster than the relevant information (Paeff & Olson, 1975). Since the relative processing speeds of the three information sources in this experiment were absolute position fastest, followed by word meaning, and then relative position, a simple encoding or response competition model would predict Stroop-like effects of absolute position on word judgments and of words and absolute positions on relative position judgments. The conjecture under test predicts only the effects on relative position. Furthermore, the conjecture that there are different kinds of Stroop interference predicts that the two effects on relative position will be additive, whereas the alternative view of one type of Stroop effect predicts an interaction. The results supported the hypothesis under test in both respects, suggesting that absolute position affects an initial pictorial stage of processing relative position, and that word meaning affects a second, linguistic stage of processing. Two other findings support this conclusion. The first is the difference in the nature of the effects of absolute position and word meaning on relative position judgments. The former provides an interfering effect only, whereas the latter shows both facilitation and interference effects. It is not clear from the Stroop literature under what conditions facilitation effects arise. The present experiment suggests that the nature of the code that is affected might be an important variable. Another source of evidence in support of the conclusion that absolute position and word meaning affect different stages of processing relative position is that word meaning interacts with the effects of above vs. below relative positions, whereas absolute position does not. This suggests that word meaning affects a stage of processing that above vs. below also affects, but that is unaffected by absolute position.

The above-below effect has been explained by Clark (1969) as a markedness effect. Unmarked or positive words such as above, on top of, before, are assumed to be encoded more easily than their negative counterparts below, underneath, after. This seems to be true for pictures as well as words at least when pictures and words are compared (Clark, Carpenter, & Just, 1973). In the present experiment, there is an above-below effect

when subjects encode word meaning. The effect also occurs in the relative position response condition, but only as an interaction with the irrelevant word information. It is tempting to conclude from these findings that the effect occurs only at a linguistic stage of processing. This possibility warrants further investigation.

The semantically indiscriminate effect of absolute position on responses to word meaning requires an explanation. This is not a Stroop-like effect, since both congruent as well as incongruent information increased RT compared to the neutral condition. Seymour (1974) found similar effects, and suggested that, although the information is not completely analyzed semantically, its presence in the display is registered and delays responding compared to a neutral condition. In order for that explanation to be applicable to the present experiment, one would have to explain why absolute position is completely processed semantically in the relative position response condition, but not completely processed semantically in the word meaning response condition. A better explanation might be that absolute position is always completely processed semantically, but semantically discriminate effects are seen only when there is a pictorial stage of processing that can be affected by the pictorial code for absolute position. The detection of irrelevant position information that is not coded like any of the codes in the relevant task may simply raise the threshold for making a response or cause the subject to perform a check on his response choice, thereby increasing RT. An alternative explanation is that the subject, not knowing where the stimulus will appear, fixates the midline of the display. This strategy produces fast RTs when absolute position is neutral compared to when it is congruent or incongruent with the meaning of the word.

The view of the Stroop task that has been presented here so far is a completely data-driven one; that is, the display is analyzed in a series of independent stages until a response can be made. Indeed, Norman (1976) has suggested that the Stroop phenomenon is an important indicator of data-driven processing. It is important to point out, however, that there is a conceptually driven component to this task. Ideas about spatial position are primed, and this priming may somehow encourage the processing of irrelevant spatial information. Evidence in support of this explanation comes from a color experiment by Warren (1972). He primed words by introducing them auditorily at various periods prior to the Stroop color-word task. Then he used these primed words instead of color words, and required subjects to name the colors of ink in which the words were printed. It was found that the words interfered with color naming even though they were semantically unrelated to color. Even more surprising is the finding that when words belonging to a common semantic category are primed, the category name interferes with color naming. Any word that is primed sufficiently

may cause Stroop-like effects. It may even be true that by means of the recursive processes of perception, irrelevant information is processed to the extent that it is related semantically to the primed, expected kinds of information.

The present experiment points to the conclusion that any general view of the Stroop phenomenon such as the one presented above must account for the finding that Stroop-like effects seem to arise only when the nature of the interfering material corresponds to one of the codes used in the processing of the relevant information. This may be either the initial code for the stimulus or some translation that is necessary for a certain type of response to be made. The findings presented here do not discriminate between interference at encoding or at response; the selective interference and facilitation effects may occur at one or both stages depending, among other things perhaps, on the relevant and irrelevant codes at each stage. Stroop-like effects have at least two sources, pictorial and linguistic. This finding must be accommodated by current models of the Stroop effect.

REFERENCE NOTE

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NOTE

1. Note that the control RTs for absolute and relative position are based on linguistic responses to position, and hence include an estimate of linguistic translation time. Since the translation stage presumably does not occur when position is irrelevant, the RTs for absolute and relative position are inflated estimates of processing time when these dimensions are irrelevant. This does not affect predictions concerning the interfering effects of absolute position, since it is the most quickly processed even when the estimates for position are inflated. However, if relative position is processed faster than 570 msec when it is irrelevant, a simple encoding or response competition model would predict that it might interfere with judgments of absolute position and words, while the conjecture under test would predict possible effects on judgments of absolute position only. These effects were not found, however.

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