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Stroop interference in naming and verifying spatial locations*

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Two experiments are reported that were designed to assess effects of semantic similarity on naming and verification of spatial locations. In Experiment I, the words *above, below, left,* and *right* occurred as distractors when Ss named the location of the word relative to a dot, or the location of a dot relative to the word. In Experiment II, the same dot-word displays were used, but Ss reported whether or not the word correctly specified its own location relative to the dot or the location of the dot relative to itself. The naming task showed some within-dimension facilitation and interference effects, most notably when Ss named the location occupied by the distractor word. The verification tasks showed quite substantial retardation of "no" responses when the word and location represented different values on either the horizontal or the vertical dimension.

The Stroop effect is a well-known phenomenon in which a vocal naming response to a display is inhibited by the presence of an irrelevant verbal stimulus. The response of naming the color of the ink of a word is delayed when the word itself names a color. Klein (1964) reported an important experiment which demonstrated that the degree of interference depended on the extent to which the distractor words were semantically related to the domain of color words. Interference varied according to a "semantic gradient," extending from names of other colors in the stimulus set, through other color names and color-related words, to noncolor words and nonsense words. Fox, Shor, and Steinman (1971) have subsequently confirmed that this semantic gradient effect also occurs for spatial terms (see also Morton, 1969).

The importance of these findings is that they suggest that Stroop interference is dependent on the similarity of abstract or semantic representations of the verbal and pictorial components of the display. Following Paivio (1971), Bower (1972), and others, one may propose that verbal and pictorial aspects of a stimulus are processed in functionally independent channels but that both aspects may be assigned an interpretation at the level of an abstract memory system. Clark has recently argued that comparisons between sentences and pictures depend on the representation of both in a common abstract format (Chase & Clark, 1971; Clark & Chase, 1972). This abstract format may consist of propositions defining spatial characteristics of objects and scenes. The basic contention of the present paper is that Stroop-like effects will arise whenever the semantic representations of the pictorial and verbal aspects of a display share common components.

Experiment I tests this proposal in a task involving the naming of spatial locations, using the locatives *above, below, left,* and *right* as distractors. On each trial, Ss saw a dot and one or another of these four words printed, *ABOVE, BELOW, LEFT,* or *RIGHT*, of it. Under one condition, the task was to name the location of the word relative to the dot; under the other, it was to name the location of the dot relative to the word.

Predictions concerning the occurrence of Stroop interference in these tasks depend on two considerations. A first assumption is that a distractor word will interfere with selection or production of a naming response only if the word is interpreted (i.e., assigned a semantic interpretation). This may be more likely to occur when the word is treated as an object whose location may be varied than when it is merely a reference point. This would follow if the task of naming the location occupied by the word involves focus of attention on the word and if the occurrence of such an act of "focal attention" is a prerequisite for establishment of the representation of meaning which may underlie the Stroop effect.

The second point concerns the nature of the semantic representations of the spatial prepositions, *above, below, left,* and *right*, and the corresponding locations. Table 1 presents a simple system for definition of these terms that has been derived from the work of Leech (1969) and Clark (1971). These terms define place by specifying the location of one object relative to another, using the general formula, (x) – SID (y), which may be paraphrased as "(x) is to the .... side of (y)" (Leech, 1969). The SID relation includes a specification of proximity and of the spatial dimensions of verticality or horizontality. In the analyses of both Leech and Clark, the vertical dimension is assumed to be primary, so that *above* and *below* share the feature (+VERT), with *above* regarded as the positive pole of this dimension and *below* as a negative pole. The terms *left* and *right* share

Table 1
Possible Semantic Representation of Locatives Above, Below, Left, and Right and the Corresponding Locations

Above	(+VERT (+POLAR))
Below	(+VERT (–POLAR))
Left	(–VERT (← LEFT))
Right	(–VERT (→ RIGHT))

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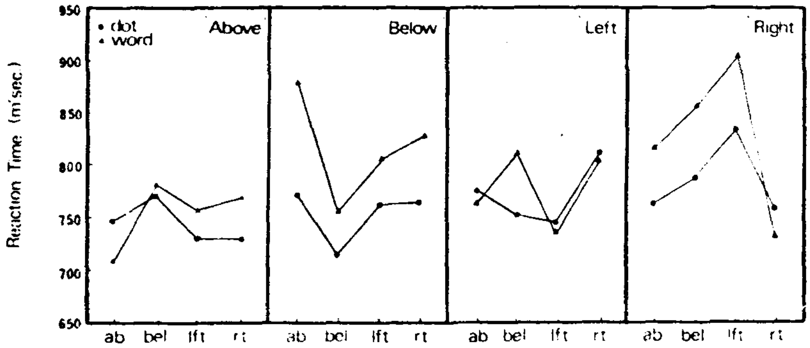

Fig. 1. Summary of naming latencies (milliseconds) for dot location and word location classified by the response made and the distractor word present on the display (Experiment I).

the feature for horizontality (–VERT), although, apart from ad hoc considerations such as handedness, reading direction, and equation of *right* with "correct," there is no obvious basis for defining one or the other end of this dimension as positive (Clark, 1971).

If the spatial locations, *ABOVE, BELOW, LEFT*, and *RIGHT*, are given abstract representation in the same system that defines the meanings of the spatial terms, it follows that delays in response will occur whenever the semantic representations of the distractor word and the location to be named share (+VERT) or (–VERT) features. Thus, the delay of response in naming the location of a word as *ABOVE* a dot should be greater when the word is *below* than when it is *left* or *right*, and so on for the remaining examples.

EXPERIMENT I

Method

Subjects

Sixteen volunteers from final-year classes at Dundee senior secondary schools and classes at the University of Dundee served as Ss in this study.

Apparatus

The displays were rear-projected by means of a modified Gaf slide projector, which included a leaf shutter that could be deflected by pulsing a galvanometer. A series of timing circuits was used to present a warning tone for 500 msec, followed by a 1-sec delay, at the end of which the display was presented and a Venner stopclock was started. The display terminated after 1 sec, and the clock was stopped when the S's vocal response closed the relay of a voice key.

Displays

The words *above, below, left,* or *right* were printed on cards, using lowercase Letraset (Univers 55), *ABOVE, BELOW, LEFT,* or *RIGHT* of a reference dot. These displays were photographed and mounted as slides for projection by the apparatus. The display appeared as a white image on a dark ground and subtended a visual angle of approximately 2 deg when horizontally aligned.

Procedure

Independent groups of eight Ss were assigned to the word naming and dot naming conditions. All Ss were given preliminary practice in the use of the voice key and were instructed to use the reports "above," "below," "left," or "right" to name the location of the word relative to the dot (Group 1) or the location of the dot relative to the word (Group 2). Ninety-six observations were taken on each S. The 16 slides were presented in random orders that were independently determined for each S, with the constraint that each slide should occur twice within each of three sequences of 32 observations. Error responses were discarded and replaced by including the relevant slide later in the random series. Ss were tested individually in a quiet, darkened room during a single test session of 30-45 min.

Results

Figure 1 presents a summary of the naming latency data for this experiment, classified by the response made ("above," "below," "left," or "right"), the word printed on the display (*above, below, left,* or *right*) and the experimental instruction ("Name location of word" vs "Name location of dot"). An analysis of variance of the means for naming the location of the word showed a significant response effect ($p < .01$), no effect for distractors, and a highly significant Response by Distractors interaction, $F(9,63) = 11.37$, $p < .001$. For naming the location of the dot, the response and distractor main effects were not significant, but the interaction between them was significant, $F(9,63) = 3.94$, $p < .001$. The response effect in word naming appeared primarily to reflect a tendency for the responses "above" and "left" to be slightly faster than "below" or "right." The significant Response by Words interaction suggests that differences among distractors depend on the response to be made, and that differences among responses depend on the distractor that is present.

The main prediction of this study is that a locative naming response will be retarded when the semantic representations of the response and distractor words share (+VERT) or (–VERT) features. Follow-up tests for the dot naming condition failed to provide much support for this prediction. When response was held constant, the different distractor words did not affect the latency of the responses "above" or "left." There were weak effects for "below" and "right," which were significant at the .05 level. The effect for "below" reflected facilitation when the distractor word was *below*, but not retardation attributable to distraction by

Table 2
Table of F Ratios and Associated Probability Values for Tests on Effects of Distractor Words, With Response Held Constant, or on Effects of Responses, With Distractors Held Constant (Experiment I)

Task		Distractor Effects				Response Effects			
		"Above"	"Below"	"Left"	"Right"	Above	Below	Left	Right
Name Dot	F(3,21)	1.50	3.52	2.63	3.66	< 1	2.50	3.98	2.38
Location	p		< .05		< .05			< .05	
Name Word	F(3,21)	6.62	12.47	3.28	11.05	31.04	3.32	11.90	4.94
Location	p	< .01	< .001	< .05	< .001	< .001	< .05	< .001	< .01

above. In the case of "right," there was some evidence of retardation when the distractor *left* was present, but not of facilitation for *right*. When distractors were held constant, differences among responses were not significant for *above, below,* or *right*, although there was a marginally significant effect for *left* ($p < .05$) that reflected retardation of the response "right" relative to "above" and "below," but not facilitation for "left." In general, therefore, the dot naming task provided evidence supporting the hypothesis of the study only for the response "right" and the distractor *left*. Comparable analyses of the data for naming the location of the word showed much more clear-cut effects for distractors. Table 2 summarizes the F ratios obtained in tests of the effects of distractors, with responses held constant, or of differences among responses, with distractors held constant. Differences among distractors were significant at the .05 level for "left," at the .01 level for "above," and at the .001 level for "below" and "right." The data for "below" and "right" responses conform nicely to prediction, since the "below" response was retarded by the distractor *above*, and the "right" response by the distractor *left*; these cases also show evidence of facilitation. For "above," there was some evidence of facilitation but not of retardation attributable to distraction by *below*. "Left" responses also showed a facilitation effect, but not retardation. Analyses of differences among responses, with identity of the distractor held constant, showed effects significant at the .05 level for *below*, at the .01 level for *right*, and at the .001 level for *above* and *left*. The distractor *above* facilitated the response "above" and retarded the response "below"; the distractor *left* retarded the response "right," but did not facilitate "left." The distractor *right* facilitated the response "right," but did not retard "left" relative to "above" or "below." In the case of *below*, there was facilitation of the response "below" relative to "left" and "right," but no evidence of retardation of "above."

In summary, the analyses of the latency data for naming the location of the distractor word produced evidence of facilitation and retardation effects which were consistent with the assumptions underlying this research. The response "right" was retarded by the distractor *left*, and the response "below" by the distractor *above*. However, the reaction time for "above" was not affected by the distractor *below*, nor was the reaction time for "left" affected by the distractor *right*.

Ss made errors on only 1.6% of trials in naming the location of the word and 1.8% of trials in naming the location of the dot.

EXPERIMENT II

An assumption of this paper has been that both locative terms and spatial locations may be assigned abstract descriptions at the level of a semantic memory system (Clark & Chase, 1972). Seymour (1973b) argued that an abstract coding of this type mediated between analysis of perceptual features of an object and selection of a verbal naming response, as well as being involved in the interpretation of a printed name or sentence. A further conclusion was that a comparison between a sentence and a picture involved a consideration of two abstract propositional statements. If one accepts a model of the comparison process of the type proposed by Schaeffer and Wallace (1970), it will follow that a response indicating that a sentence and picture are *different* will be delayed if these abstract statements share common components.

In the present context, an implication is that a decision that one of the locative terms *above, below, left*, or *right* is incorrect as a specification of a particular location will be subject to delay whenever the representations of the word and the location share (+VERT) or (−VERT) features. This prediction was tested in a second experiment, in which Ss matched word meaning against word location or word meaning against dot location.

Method

Subjects

The 20 Ss were students at the University of Dundee. They were volunteers and were not paid for their services.

Apparatus

This was as for Experiment I.

Displays

These were the same as those used in Experiment I.

Table 3
Mean Reaction Times (Msec) for "Yes" Responses in Verification of Word Location and Dot Location (Experiment II)

	Above/ ABOVE	Below/ BELOW	Left/ LEFT	Right/ RIGHT
Word Location	784	836	845	808
Dot Location	821	834	881	830

Procedure

Ss were assigned to one of two groups of 10 Ss. Ss in Group 1 were instructed to report "yes" whenever the word on the display correctly named the location it occupied (e.g., the word *above* printed *ABOVE* the dot), and "no" when it did not. Ss in Group 2 reported "yes" if the word correctly named the location of the dot relative to itself (e.g., the word *above* printed *BELOW* a dot), and "no" for all other displays. All Ss received preliminary practice in use of the voice key and in classification of the displays. A total of 120 observations was then taken for each S, of which half required the response "yes" and half, the response "no." The four slides requiring the response "yes" occurred 15 times each, and the 12 slides requiring the response "no," 5 times each. The displays were presented in random orders which were independently determined for each S. Error responses were discarded and replaced, as in Experiment I.

Results

Table 3 gives the mean reaction times for "yes" responses for the two groups. In the case of Group 1 (verification of the location of the word), there were significant differences among responses to the different displays, $F(3,27) = 4.24$, $p < .025$. This effect was not significant for Group 2 (verification of the location of the dot), where $F(3,27) = 2.49$. For Group 1, *above/ABOVE* displays were classified faster than *below/BELOW* displays ($p < .01$), but the difference between *right/RIGHT* and *left/LEFT* was not significant. The results for *above* and *below* are consistent with previous findings of bias towards *above* (Seymour, 1969; Chase & Clark, 1971). Olson (1972) has recently reported a similar bias towards *right*, but this is not replicated in the present instance.

Data for "no" responses have been summarized in Fig. 2. Table 4 shows the outcomes of analyses of variance in which the identity of the word was held constant, and the effects of variation in location were assessed. For Group 1, there were no significant differences among locations for the words *above* or *below*. This indicates that the difficulty of rejecting *above* as an incorrect specification of the *BELOW* location was no greater than the difficulty in rejecting *above* as incorrect for *LEFT* or *RIGHT*. In the case of Group 2, the effects of location were significant at the .001 level for both *above* and *below*. These effects occurred because Ss were slower to respond "no" to a dot *BELOW* the word *above* than to a dot to the *LEFT* or *RIGHT* of the word by about 215 msec. Similarly, the word *below* was rejected more rapidly when the dot was to the *LEFT* or *RIGHT* than when it was *ABOVE*; in this case, the mean difference was about 183 msec. Thus, substantial confusions occurred within the vertical dimension for Ss in Group 2, but not for Ss in Group 1.

Tests on the effects of location for the words *left* and *right* showed highly significant differences for both groups of Ss. For Group 1, these effects occurred because *left* was rejected from the position *RIGHT* less rapidly than from the positions *ABOVE* or *BELOW*, and because *right* was rejected from the position *LEFT* less rapidly than from *ABOVE* or *BELOW*. The mean difference was somewhat greater than 100 msec in both cases. Very similar results occurred for Group 2. Thus, both S groups showed evidence of substantial confusion effects within the horizontal dimension.

Table 4 also summarizes the results of analyses of the effects of words when location was held constant. For Group 1, the words effect was not significant for the *BELOW* location, but there were significant effects for *LEFT* ($p < .05$), *ABOVE* ($p < .025$), and *RIGHT* ($p < .001$). The significant effects were in each case consistent with the predictions of this experiment, since "no" responses to the *ABOVE* location were slow when *below* was printed there relative to *left* or *right*, and to the *LEFT* or *RIGHT* locations when the word was *right* or *left* relative to *above* and *below*. The differences were in the range of 60-100 msec. For Group 2, the effect for words was significant at the .01 level for the *RIGHT* location and at the .001 level for the *ABOVE*, *BELOW*, and *LEFT* locations. These effects again reflected delays in rejection of word-location combinations which shared (+VERT) or (−VERT) features.

In this experiment, errors occurred on 1.1% of trials for verification of the position of the word and on 3.1% of trials for verification of the position of the dot.

DISCUSSION

Two experiments have been reported, involving naming and verification of spatial locations. In the naming task, the word on the display was an irrelevant stimulus insofar as its meaning was concerned, and S was required to consider only the location of the word

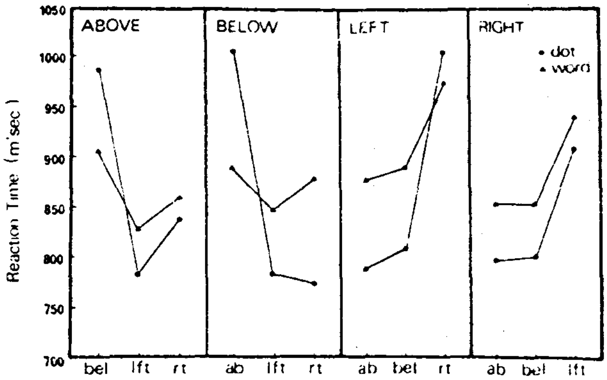

Fig. 2. Summary of latencies to respond "no" to displays in which word location or dot location was different from the location specified by the word (Experiment II).

Table 4
Table of F Ratios and Associated Probability Values for Tests on Effects of "No" Response Times of Different Locations, Holding the Word Presented Constant, or of Different Words, Holding Location Constant (Experiment II)

Task		Location Effects				Word Effects			
		Above	Below	Left	Right	ABOVE	BELOW	LEFT	RIGHT
Verify Word Location	F(2,18)	< 1	< 1	18.00	9.21	5.26	1.81	4.31	13.04
	p			< .001	< .001	< .025		< .05	< .001
Verify Dot Location	F(2,18)	13.85	13.39	14.01	12.30	14.99	13.05	12.35	9.85
	p	< .001	< .001	< .001	< .001	< .001	< .001	< .001	< .01

relative to a dot, or the location of a dot relative to the word. Where the word was to be regarded as a reference object and the task was to state whether a dot was above, below, left, or right of it, word meaning had only slight effects on naming latency. This absence of Stroop interference in naming the location of the dot implies that a word may be used as a reference point without incidental analysis of its meaning occurring. On the other hand, naming the location occupied by a word does show evidence of interference, since the response "below" was slow when the word *above* occupied the *BELOW* location, and the response "right" was slow when *left* occupied the *RIGHT* location. Hence, incidental representation of the meaning of a locative word is likely to occur when S must consider the word as an object having a variable location relative to a reference point. Where the distractor correctly specified the response to be made, some facilitation effects occurred. These were also most apparent when Ss were naming the location of the word.

The differences between the dot location and word location naming tasks confirm that Stroop interference depends critically on the extent to which S must focus attention on the word component of the display. The displays used for word naming and dot naming were identical, but Stroop effects were less likely to occur when Ss named the location of the dot than when they named the location of the word. Hence, the effect cannot be assigned merely to the presence of a word on the display. S must, in Neisser's (1967) terminology, pay "focal attention" to the word in order to determine the color of its lettering or, in the present experiments, its location relative to a reference point.

Experiment I, therefore, extends the previous work on semantic effects in Stroop tasks by demonstrating that semantic gradients may also be observed within the domain of a particular naming task. However, the data were not wholly consistent with the prediction that interference would be maximized whenever the word and location components of the display shared (+VERT) or (−VERT) features, since both the vertical and the horizontal dimensions show asymmetries in the magnitude of the effect. The response "below" was subject to interference from the distractor *above*, but the response "above" was not delayed by *below*. This asymmetry appears intuitively consonant with Clark's proposal that the semantic representation of *below* may consist of a verticality feature, which implies the positive or upper end of the dimension, plus a negative feature that indicates that it is the negative, "marked," or restricted end of the dimension that is intended. Thus, the meaning of *below* might be glossed as "above, but negative." In terms of the representations suggested in Table 1, *above* might be written simply as (+VERT), and *below* as [+VERT(−polar)]. If S must respond "above" to the location occupied by the word *below*, (+VERT) features will be established for both the location and the word, and will tend to facilitate selection of an "above" response. The negative (−polar) feature may not be represented at all, or may be established too late to interfere with selection of the "above" report. When the response "below" is required, a retardation effect will occur, because the (−polar) feature for the location takes extra time to set up and because the (+VERT) feature for the word and location will favor selection of an "above" response. In order to handle the asymmetry observed on the horizontal dimension, it would be necessary to argue that this dimension is also bipolar and that *left* defines the affirmative or unmarked end. This conclusion would be contrary to Olson's (1972) suggestion that *right* defines the unmarked end of the horizontal dimension.

Accurate performance on the verification task of Experiment II necessarily involved processing of the word component of the display. S must assign an interpretation to the word *above, below, left*, or *right* if he is to determine whether the location occupied by the word or dot is correct. This interpretation could be treated as an instruction to examine a certain location on the display and to respond "yes" if the location was occupied and "no" if it was not. An account of this type was considered by Seymour (1969) and was rejected by Chase and Clark (1971), who argued that both the word and the location must be assigned abstract representations prior to the operations of comparison and response execution. The present data are consistent with the Chase and Clark account, since the delays in selection of a "no" response observed here would not occur if S was merely checking that a specified location was empty. The occurrence of interference effects suggests that both the location and the meaning of the word are represented at an abstract or semantic level, and that the comparison involves tests on the equivalence of these representations. A further implication is that meaning is represented as sets of components or features, and not in a unitary or undifferentiated form. If the representation of a location was a somewhat abstract symbol or name, each location being defined by a different symbol, and S determined whether or not two symbols were "same," one would again not expect to observe interference effects in "no" reaction times.

The data of Experiment II suggest, therefore, that the comparison task involves the representation of the meanings of a location and a locative term in an abstract format which includes a specification of a dimension, (+VERT) or (−VERT), and of a direction on the dimension. The delays observed when Ss make a "no" response to name-location pairs which share a (+VERT) or (−VERT) feature are comparable to those reported for comparisons of word meanings by Schaeffer and Wallace (1970) or for comparisons between names and geometric shapes by Seymour (1973a). The effect appears to be consistent with a serial model of the comparison operation, in which it is assumed that the dimensional (+VERT) or (−VERT) feature is checked first, and a "no" response is initiated if a mismatch is obtained. Alternatively, the effect might arise if overlap of features [i.e., duplication of the (+VERT) or (−VERT) feature in the word and location representations] was coded as affirmative evidence, tending to favor selection of a "yes" report (Schaeffer & Wallace, 1970). If nonoverlapping features are given a negative coding, the evidence considered at the response selection stage will be predominantly negative for such pairs as *above/LEFT*, but will include a positive component in such cases as *right/LEFT*. In practice, there is not a great deal of difference between these interpretations, since both assume some form of sequential sampling of information deriving from feature matching operations and argue that selection of a "no" report will be retarded if a proportion of these comparisons have affirmative outcomes.

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