Perception & Psychophysics
1975, Vol. 17 (4), 375-386

Effects of cued-set spatial arrangement and target-background similarity in the partial-report paradigm

INGE FRYKLUND
University of Illinois at Chicago Circle, Box 4348, Chicago, Illinois 60680

In previous studies of selective attention using the Sperling partial-report paradigm, the selection criterion has been confounded with the spatial arrangement of the cued items, and target-background similarity has varied concommitantly. In this partial-report experiment, subjects are directed to report the identities of five red letters embedded in a 5 x 5 matrix. With selection criterion thus held constant, the arrangement of the cued items and the nature of the background material are varied. Both arrangement and background effects are highly significant, as is the interaction between them. Some constraints on models of visual selective attention are discussed.

Sperling (1960) demonstrated that subjects could select from the short-term visual store items designated by row location, but not those specified by semantic class (letters vs. numbers). Subsequent investigators have extended these observations on the differences in effectiveness of various selection criteria. Von Wright (1968, 1970) obtained selection using location, color, size, and brightness criteria (with the efficiency of selection decreasing in that order), but found no evidence for selection using letter orientation or semantic class (letters vs. numbers, consonants vs. vowels). Comparable results were reported by Clark (1969) for location and color selection, and by Turvey and Kravetz (1970) for location and shape selection.

Clarification of the operation of the selection criteria is fundamental to an understanding of the early stages of visual information processing, since selection success must be constrained by both the structural characteristics of the store and by the subject's strategies and decision processes. For example, items might be easily accessed by row location because the stored array is a two-dimensional pictorial representation and subjects are accustomed to scanning horizontally, or perhaps the representation might be a set of vectors with row names labeling the vectors.

In most theorizing based upon these selection data, it has been implicitly assumed (see Turvey & Kravetz, 1970, p. 172, for an exception) that in the partial-report paradigm the selection criterion is the only variable being manipulated, and that the measures of selection efficiency so obtained provide direct evidence concerning the subject's ability to attend to the cued dimensions. However, a consideration of previous research on visual selection and attention suggests that the situation must be considerably more complicated. Specifically, targets must appear at particular positions in space, and something must occupy the nontarget positions. It would thus appear that obtained selection data reflect not only the effect of the selection criterion, but also the effects of the target-set spatial arrangement and the similarity of target and nontarget material. It is the contribution of these two factors that the present experiment is designed to evaluate.

Target and nontarget material are typically drawn from the same class (e.g., letters, colored circles) for selection conditions in which physical attributes (e.g., location, color) are cued. Of necessity, material drawn from different classes must be used for figure and ground in the semantic conditions. The degree of target-background similarity must thus be confounded with the selection criterion. The implications of this confounding for interpreting the selection data are not immediately obvious, but the general effect of target-background similarity is well known (cf. Neisser, 1963, for visual search, and Gardner, 1973, for tachistoscopic detection), and other evidence (e.g., Mewhort, 1967) suggests that the subject is specifically influenced by the nature of the noncued row in the partial report task.

In all partial-report studies, different criteria have been associated with different spatial arrangements of the cued items. The cue for "spatial location" has always been a row cue; in all other conditions, the cued items have been spatially scattered. Besides

This report is based on a dissertation submitted to the Graduate School of the University of Michigan in 1971 in partial fulfillment of the requirements for the PhD degree. The author wishes to thank the members of her committee, Richard Pew, Robert Bjork, Robert Pachella, and Wilfred Kincaid, for their help. The research was supported by the Advanced Research Projects Agency, Department of Defense, and monitored by the Air Force Office of Scientific Research, under Contract No. AF 49(638)-1736 with the Human Performance Center, Department of Psychology, University of Michigan. Data were reanalyzed using the facilities of the University of Illinois Computing Center, and the final version of the paper was written at the University of Illinois at Chicago Circle.

being spatially adjacent, the individual positions in the row arrangement are more easily coded for memory (e.g., a row tag plus an ordered list of elements), while in the spatially dispersed conditions, the positions are difficult to encode (e.g., an element name paired with its Cartesian coordinate, or perhaps some pictorial representation). Further, the number of potential samples in the row condition is very small (typically two or three); the subject can become very proficient at directing his attention to any one, and also stands a good chance of guessing which will be cued. In other conditions, the number of samples is very large (the number of ways r-cued items can be selected from N display positions).

There appear to be two sets of factors underlying the spatial arrangement effect. These might be termed "retinal" and "pattern" factors. "Pattern" effects refer to the influence of the overall spatial design formed by the targets. Much of this effect must be global; if the subject apprehends a design which "stands out," he may be better able to locate the target items, "hold on to" the targets while identifying them, or reconstruct the target arrangement at the time of report. There is considerable evidence (e.g., Clement, 1964; Clement &Varnadoe, 1967; Garner, 1962) that pattern "goodness" is positively related to both pattern discriminability and describability. Speed and accuracy on these processes may well be crucial when the subject must attend to a swiftly decaying array, and retain the pattern long enough to report items in correct position. The characteristics of a "good" figure for tachistoscopic perception are undoubtedly those of any good figure. While just what makes for a good figure is still a matter of some debate, the simplicity and redundancy of the good Gestalt figure (Attneave, 1954) and the size of the equivalence class from which the pattern is drawn (Handel & Garner, 1966) are probably critical. By any such criteria, the row arrangement is a very good pattern, and any haphazard arrangement is a very poor one.

"Retinal" factors refer to differences in sensitivity at different parts of the retina, and to the lateral connections that permit interactions between adjacent areas. Differences in letter identification accuracy as a function of retinal eccentricity for horizontal arrays have been well documented (e.g., Heron, 1957). Eriksen and his colleagues (e.g., Eriksen & Hoffman, 1972; Eriksen & Lappin, 1967) have explored the spatial limits over which adjacent material can influence the perceptibility of a foveally presented target, and report that background interference seems to be limited to sources presented within 1 deg of the single cued target.

While it would not be expected that retinal factors per se interact with the selection criteria, interactions between pattern and retinal factors may well be important. For example, in previous experiments (as judged from published methods sections) there do not appear to have been systematic attempts to equate retinal locations for row and scattered-set conditions; the row samples partition the matrix, but randomly arranged targets may or may not have occupied all array positions equally often. It is also conceivable that conditions involving all letters and those involving mixed letters and numbers would be subject to different degrees of lateral masking just because of differences in the spatial distribution of features, light/dark ratio, etc. Further, if all array elements are of the same type (e.g., all letters), then the degree of interference from adjacent items will be the same for row and scattered-set conditions; when target and nontarget material differ, adjacent items will be more often dissimilar.

This experiment provides a test of the effect of target-background similarity, and explores the effect of the spatial design formed by the targets, while controlling for the retinal distribution of targets. In order to evaluate these spatial and similarity factors, an additional problem must be surmounted. In previous studies, the subject was required to determine (for different conditions) whether he should look for red elements, numbers, or elements at the top of the display. Cue interpretation times (estimated by Eriksen & Collins, 1969, to be about 200 msec for an assortment of cues designating clock positions) should vary due to the differing compatibilities between cue (e.g., high-pitched tone) and subset cued (e.g., top row, letters). In order to equate cue processing demands for different spatial arrangements, the subject was instructed always to attend to the 5 (out of 25) display positions occupied by red letters. With the (simultaneous) selection criterion thus held constant, the spatial pattern formed by the red letters and the nature of the material in the 20 background positions are varied independently. The pattern variable is investigated by varying two factors, adjacency and codability, which appear to be important aspects of a pattern. Two levels of each are combined factorially to yield four pattern types. Each pattern type is tested with four types of background material, chosen to represent four degrees of target-background similarity. To investigate further the hypothesis that differences in performance on different target arrangements are due to memory position-coding problems, the correct target pattern is provided on the subject's answer sheet at the time of report during one of the two experimental sessions.

METHOD

Subjects

The subjects were four men and four women students at the University of Michigan. Each was paid $5.50 for participating.

Stimulus Materials

The stimulus elements for each array formed a 5 x 5 matrix centered on a white 4 x 6 notecard. In each array, five of the positions were filled with red letters. The patterns formed by the red letters (Figure 1) represented the following types: (I) adjacent/codable (exemplified by a row arrangement), (II) adjacent/arbitrary (arbitrary patches with all elements either top-bottom or left-right adjacent), (III) separated/codable (left-right symmetric designs with no elements having top-bottom, left-right, or diagonal adjacency), and (IV) separated/arbitrary (arbitrary scatters having the same adjacency constraints as Pattern III). These pattern types were chosen to represent the often-tested row and haphazard arrangements, plus two rather different patterns thought to be of intermediate difficulty. It should be noted that Patterns III and IV represent extreme degrees of cued-element separation; with the smaller displays and randomly selected cued positions typically used, some adjacency is to be expected. For each of the four pattern types, five exemplars were constructed. These were chosen so that over the five exemplars, each of the 25 matrix positions was occupied exactly once with a red letter. Despite this equality in the number of exemplars, the effective number of potential samples may still be smallest in the row condition. In all four conditions, the matrix was partitioned into five samples, but the row partition is the only one possible; there are a large number of ways to partition a matrix into samples meeting the constraints of the other three pattern types. Thus the partitioning really serves only as a control for retinal position.

The four types of background material were black letters, black numbers, open black squares, and blank spaces. Thus, a total of 4 pattern types x 5 exemplars x 4 backgrounds, or 80 distinct item designs, were prepared. Each design was filled with two samples of target items for a total of 160 stimulus cards. (For the letters and numbers background items, two samples of background items were also used.) For each stimulus card, the letters for the five target positions were chosen randomly and without replacement from the population of all 26 letters. Over all 160 items, each letter was used in a red position approximately equally often, and in each matrix position at least once but not more than twice. Over all 40 items requiring letter backgrounds, each of the 26 letters was also used approximately equally often and at least once but not more than twice in each matrix position. No letter was repeated among the background 20, but since target and background letters were chosen independently, there were cases in which one or more letters appeared in both sets. Letter arrangements forming words or common abbreviations were avoided. For the 40 number items, the digits 0-9 were assigned randomly to the matrix positions with the constraint that each appear twice in each array and over the 40 items approximately equally often in each matrix position.

All letters and numbers were in Futura Medium 18-pt type, with the background elements made with Prestype No. 1280 and the red letters with Tactype No. 5518 lettering. Although the two brands are highly similar, they are not identical, the red letters having somewhat thicker strokes. Thus size was correlated with color and may have served as an additional selection cue. The open squares were Paratipe No. 55008, 1/8 in., chosen to be similar to the letters and numbers in stroke width and overall light/dark ratio. The stimulus array formed a square 4 cm on a side at 117 cm viewing distance (2 deg). The side-to-side and top-bottom distance between the centers of adjacent elements was 9 mm (.45 deg).

Apparatus

Stimulus cards were presented in Field 1 and a gray fixation dot in Field B of a Scientific Prototype three-channel tachistoscope. Since the lighted area in each field is rectangular, square masks were inserted to frame the arrays. Luminances in the 1 and B fields were approximately 18 and 8 fL, respectively. Field B was illuminated throughout the experiment except during the 30-msec stimulus exposures. The room was dark except for the experimenter's light, which was shielded from the subject, and a 25-W bulb positioned to provide just enough light to enable the subject to write his answers. The subject initiated stimulus presentation by means of a handswitch, and recorded his responses for each trial on a new page of an answer booklet. For the unaided recall session, each page showed a 5 x 5 matrix of dashes representing the matrix positions. For aided recall, the same matrices, with the addition of five boxes indicating the positions of the target elements, were used; the subjects were instructed to turn the page only after looking into the viewing hood preparatory for the next item in order to avoid seeing the pattern prematurely.

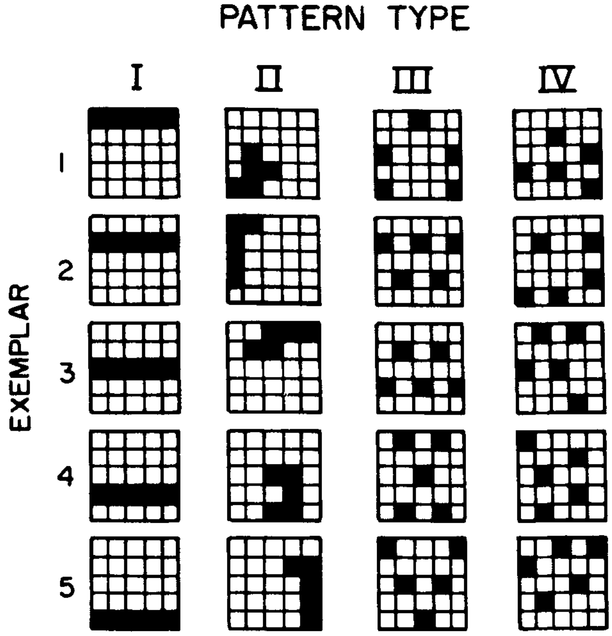

Figure 1. The four pattern types and the five exemplars of each.

Procedure

Each subject was tested in three sessions spaced approximately 24 h apart. Day 1 was practice, and Days 2 and 3 the experimental sessions. Half of the subjects (two males and two females) served in Group 1, having aided recall on Day 2 and unaided on Day 3. Subjects in Group 2 had unaided on Day 2 and aided on Day 3. The 160 items were arranged in a single random order, and within each group, half the subjects (one male and one female) saw the items in forward and half in backward order on Day 2; on Day 3, each subject received the items in the opposite order. During the practice session, each subject was tested on his Day 3 stimulus order, with the first 80 items having the recall condition of Day 3, and the last 80 the recall condition of Day 2.

At the beginning of the practice session, the subjects were shown five cards illustrating the four pattern types and four backgrounds. The 5-row x 5-column structure of each item (including that of the item with randomly arranged targets and blank background) was pointed out and the subjects were told that exactly five of the positions, forming "rows, patches, spread-out designs, or random scatters," would be filled with red letters. They were instructed to ignore the background elements and to report the identities of the red letters, specifying position whenever possible. Guessing was encouraged. Subjects were also told that the various combinations of pattern and background would be presented randomly throughout the session. The trials were self-paced, and session duration ranged from 25 to 45 min for different subjects, with a break permitted halfway through each session but rarely taken. The five demonstration cards were used for warm-up at the beginning of each session. At the end of Day 3, the last four subjects were tested for their memory of the configurations of red letters. They were given sheets of paper filled with matrices, as in the unaided recall condition, and were asked to reproduce the patterns they had seen.

RESULTS

The subjects' written protocols for the two

Table 1
Mean Number of Letters Reported as a Function of Cued Set Arrangement and Background

	Pattern							
Background	I	II	III	IV	I	II	III	IV
	Free Recall				Positioned Recall			
	Unaided Recall							
Letters	2.16	1.39	1.09	1.10	1.76	.92	.66	.61
Numbers	2.22	1.84	1.59	1.59	1.69	1.38	1.11	.96
Squares	3.44	2.50	2.46	2.52	2.85	1.84	1.96	1.66
Blank	3.70	3.10	3.52	3.32	2.70	2.18	2.07	1.36
	Aided Recall							
Letters	2.32	1.48	1.06	1.04	2.00	1.03	.86	.84
Numbers	2.56	1.85	1.51	1.46	2.22	1.56	1.33	1.26
Squares	3.55	2.49	2.55	2.54	3.13	2.05	2.48	2.40
Blank	3.89	3.11	3.61	3.51	3.49	2.63	3.40	3.31

experimental sessions were scored using two criteria, one lenient (free recall) and one strict (letters in correct position). The main results appear in Table 1, in which the mean number of cued letters reported (out of five) for each arrangement-background combination is shown, averaged over days of presentation, for the two recall conditions and the two scoring methods. The results are clear-cut and highly similar for the two scoring methods. There are evidently strong main effects of adjacency, codability, and background, and all effects are in the anticipated directions. There also appear to be strong interactions among these three main variables. Target arrangement is most important with the letters background; conversely, the nature of the background matters most when the targets are scattered, and the degree of codability of a scattered pattern is relatively unimportant. Performance is somewhat better overall when recall is aided, and the difference between the free recall and correct position scores is smaller for aided than for unaided recall.

These observations are confirmed by the statistical analyses. The number of letters recalled each day over the 10 exemplars of each of the 16 main conditions was totaled for each subject and these totals entered into a 2(levels of adjacency) by 2 (levels of codability) by 4 (backgrounds) by 2 (days) by 2 (groups) by 4 (subjects within groups) analysis of variance. Separate analyses were performed for the two scoring measures. While the performance of Group 1 (aided-unaided) was somewhat better overall, and the subjects generally performed better on the second experimental day, neither main effect was statistically significant under either scoring method.

The results of greatest interest concern the main effects of adjacency, codability, and background, and the interactions among them. All main effects were highly significant ($p < .001$) under both scoring methods: adjacency, $F(1,6) = 87.2959$ and 58.0122 for free recall and correct position, respectively; codability, $F(1,6) = 67.4214$ and 64.4591; background, $F(3,18) = 140.4911$ and 68.2816. Performance was better on the high than on the low adjacency arrangements, better on high codability than on low, and performance increased as target-background similarity decreased, with the largest improvement being between the numbers and squares backgrounds. The Adjacency by Codability interaction, not surprisingly, was highly significant, $F(1,6) = 158.2635$ for free recall and 49.9917 for correct position, $p < .001$ in both cases. Clearly, the arrangement effect is not simply decomposed into additive adjacency and codability components, and conclusions to be drawn about these factors can be only suggestive. The row pattern may be easier than the other three because of the subject's reading habits, and perhaps because of the smaller effective number of potential samples in this condition. In addition, there is recent evidence (e.g., Corballis & Roldan, 1974; Julesz, 1971) that symmetry (Patterns I and III) is a special and readily perceived property of a pattern.

The Adjacency by Background interaction was significant for both analyses, $F(3,18) = 17.1336$, $p < .001$, for free recall, and 3.9352, $p < .05$, for correct position; the importance of target adjacency decreases systematically across the letter, number, and squares backgrounds. The difference in the size of the interaction for the two scoring methods reflects the effect of the blank background. Under correct position scoring, the systematic decrease in the adjacency effect continues in the blank background, performance being slightly higher for the high adjacency items. Under free recall scoring, performance is virtually identical for the two levels of adjacency. Evidently, if there are no interfering background items, it matters scarcely at all where targets are placed, and target identification is quite accurate. This is a point of particular theoretical interest. It suggests that target arrangement per se is not the critical factor determining performance, but rather that the arrangement serves to control the degree of interference from similar background material. This will be considered further below. While target identification is apparently facilitated by the blank background, target placement at recall is very difficult in this condition, as there is no background or frame to provide an anchor for absolute position. Subjects made a large number of position errors, particularly in the separated conditions (thus the finding of an adjacency difference for the blank background under correct position scoring); relative position was generally preserved, but interrow and intercolumn distances were often distorted. The Codability by Background interaction was not significant under either analysis. Evidently, the degree of background interference is controlled primarily by target adjacency. The Adjacency by Codability by Background interaction was significant only under correct position scoring, $F(3,18) = 4.1916$, $p < .05$.

The Days by Groups interaction, which is interpretable as the main effect of aided vs. unaided recall, did not approach significance under free recall scoring, $F(1,6) < 1.00$, but was highly significant under correct position scoring, $F(1,6) = 20.6950$, $p < .001$. This difference between the measures is not surprising. Subjects are far more accurate in placing items in the correct five positions when these five are indicated, but this increase in placement accuracy is irrelevant under free recall scoring.

The remaining interactions are of lesser interest. Groups did not interact with either codability or background, and the Groups by Adjacency interaction was marginally significant only under correct position scoring, $F(1,6) = 6.3160$, $p < .05$. The Days by Adjacency effect was significant only under free recall scoring, $F(1,6) = 14.3350$, $p < .01$, with performance being relatively better on the second experimental day for the high adjacency patterns. The Days by Codability interaction was marginally significant for both analyses, $F(1,6) = 9.4250$ and 8.1924, $p < .05$ in both cases; there was relatively more improvement in item identification and item placement for the high codability patterns. The Days by Background effect was not significant, $F(3,18) < 1.00$ in both cases; relative amounts of interference from the different backgrounds would not be expected to change much over a few days of practice.

For free recall scoring, the three triple interactions involving the aided-unaided variable (Groups by Days by Adjacency, Groups by Days by Codability, and Groups by Days by Background) were not statistically significant. Of the other triple interactions, only the Groups by Adjacency by Backgrounds reached significance, $F(3,18) = 3.9484$, $p < .05$. Neither the five-way nor any of the four-way interactions approached significance. These higher order interactions show somewhat different results under correct position scoring, and all significant interactions involve the aided-unaided (Groups by Days) comparison. The Groups by Days by Adjacency interaction was significant, $F(3,18) = 18.2031$, $p < .01$; performance was better on the low adjacency patterns under aided recall. The Groups by Days by Backgrounds interaction, $F(3,18) = 22.5724$, was also significant, $p < .001$. Under unaided recall, there was virtually no difference between the squares and the blank backgrounds, while under aided recall there was an advantage for the blank condition. Again, this reflects the difficulty of perceiving or remembering accurate position information in the absence of any background.

Finally, the Groups by Days by Adjacency by Background interaction was also significant under correct position scoring, $F(3,18) = 11.1103$, $p < .001$. Under unaided recall, performance is worse on the low adjacency patterns at all levels of background. Under aided recall, with the blank background, performance is actually better on low than on high adjacency patterns. As is apparent from Table 1, performance in this background condition is highly similar for Patterns, I, III, and IV, and is considerably worse for Pattern II. This finding may well reflect the effect of simultaneous masking. Independence of perception apparently requires about 1 deg of element separation (Eriksen & Lappin, 1967), and in the present matrices, the centers of the elements were separated by .45 deg and the edges by only about .25 deg. Considerable interaction would be expected, but for the three filled backgrounds, it should not vary with pattern (assuming that the degree of interaction is the same for the squares and the different letters and numbers used). Only in the blank condition is degree of interaction correlated with pattern. Targets are closest together in Pattern II, so there should be considerable masking and hence depression of performance. The elements in Pattern I are also very close together, and this may help to account for the reduced advantage of the row arrangement in this background condition. Masking should be of almost negligible importance for Patterns III and IV; element borders are separated by at least .75 deg, and in some cases by more than 1 deg.

To summarize, all the anticipated effects were obtained. Target arrangement is a highly significant variable, with adjacency and codability proving to be important, but not the sole, determinants of the effect. Target-background similarity has a strong influence on performance, with the degree of background interference controlled more by target adjacency than by target codability. The aided-unaided manipulation had little effect beyond aiding the subject in positioning the elements at output.

A few overall observations are also of some interest. First, the absence of any recall condition differences under free recall scoring indicates that the position aid affects only the accuracy of element placement and not item identification; when the subject knew he need maintain only relative position information, he did not use (or did not have) spare capacity to devote to processing more elements. Perhaps the limit in this experiment is perceptual; the subject can extract only so many features regardless of what he is trying to do with position information. It is also possible that the subject encodes only relative position information in both aided and unaided conditions, and the increased position accuracy in the aided condition may be purely an output phenomenon.

Second, while the degree of background interference is clearly different for the four backgrounds, the nature of background effect is not so clear as two factors, heterogeneity (or redundancy) and feature similarity, are confounded. The squares background is composed of only two features, horizontal and vertical lines (and the angles between them), and the overall arrangement is highly redundant. The letters and numbers are high in both heterogeneity and similarity, with the letters background being somewhat higher on both factors. The blank background, besides having no features in common with the targets, is completely homogeneous. Effects of both factors have been demonstrated (Estes, 1974; McIntyre, Fox, & Neale, 1970) for the detection paradigm, and it is only reasonable to expect them to be operating in the current task as well.

Third, there are some interesting differences in the subjects' ability to remember the different target arrangements. For Pattern IV, incorrect placements at report were as arbitrary as those presented, with the constraints on row and column adjacency frequently violated. For Pattern III, even if the arrangement was not that presented, the subject's version was generally some original symmetric pattern, although with spacing constraints often ignored. Further, the subjects who were asked to reproduce the patterns at the end of the experiment were able to produce about half of the exemplars for Types II and III but none of those for Type IV. Thus, although codability generally appears to be less important than adjacency, the subjects were clearly noting this aspect of the display.

Fourth, intrusions in the letters background condition provide some clues about the source of the Adjacency by Background interaction, which is to say, about the subject's ability to attend to the target positions rather than the background. Because of the ambiguity resulting from the independent choice of target and background letters, intrusion data were not completely analyzed. It appears, however, that intrusions come from positions immediately adjacent to target positions; evidently, attention is spatially imprecise. If the subject has any ability to attend primarily to targets, there would appear to be more potential for interference with the scattered targets. There is also some indication that attention is "pegged" to the targets, and then distributed over the targets and any spatially intermediate items.

Finally, all data have been presented in terms of the absolute number of targets reported rather than as availability estimates (the mean number of items reported per sample multiplied by the number of equiprobable samples). For this experiment, the conversion seemed irrelevant as the issue was the variation in selection efficiency as a function of arrangement and background rather than the capacity of a visual store. If a conversion is applied, availability estimates range from 5.1 to 18.5 letters (unaided recall, free recall scoring) for different conditions. These estimates are still not comparable to those obtained in experiments in which a postcue truly samples from a visual trace (Clark, 1969; Sperling, 1960; Turvey & Kravetz, 1970; von Wright, 1968, 1970), or even those in which a simultaneous cue is used (Sperling, 1960). In the present experiment, the cue was not only simultaneous, it was part of the display; no preliminary cue processing stage served to delay the effective time of cue presentation.

DISCUSSION

The first point to be made is practical and methodological. Performance in the partial report situation is evidently strongly dependent upon the spatial configuration of the cued items and on the similarity of target and background material. These factors must have been operative in all previous cued-selection experiments, rendering the interpretation of those data somewhat difficult. For example, the size of the difference in performance between the row and haphazard arrangements in the present experiment is similar to the size of the difference between location and scattered-set criteria reported in other studies. Even allowing for the effects of the larger number of array positions used here, much of previous differences must be attributable to the unfavorable positioning of the nonrow criteria. Thus, in the standard partial-report design, it is not possible to obtain clean comparisons of row and nonrow selection-dimension processing unconfounded by differences in spatial positioning of targets. Further, when any of the selection criteria are semantic rather than physical, differences in target-background similarity will be a confounding factor. Consequently, a study comparing (for example) row, color, and class criteria, and using the conventional ways of distributing targets, will yield no clean comparisons of selection efficiency. Evidently, if one wishes to know something about the operation of selection criteria per se, something other than a partial-report experiment is called for. A very promising, although neglected, approach to this problem is represented by the second experiment reported by von Wright (1970).

While the partial-report paradigm is not particularly useful for comparing selection criteria, it is of considerable value as a tool for studying the more general problem of attending to a particular set of designated input channels. Thus, the more theoretically interesting matter to which this study is relevant concerns the constraints imposed by these data upon models of selective readout from the visual store. First, the pattern main effects imply that, for any given number of targets, spatial arrangement is critical; models must be concerned not only with the number of attended channels, but with the interrelationships among the particular spatial locations occupied by these channels. Second, it is obvious that background elements are attended; at some stage of processing, nontargets are treated as targets, and this has consequences extending to the time of report. Third, the nature of these attended background items matters; it would appear that feature similarity is critical, but as was pointed out above, some effect of the degree of background redundancy cannot be ruled out. Finally, the effects of the difficulty of the selection criterion (assuming that it can be adequately assessed) must be incorporated in any model of cued selection. In the remainder of this paper, the ability of two classes of models of tachistoscopic perception to meet these constraints will be discussed, and minimal requirements for any satisfactory model of partial-report performance will be outlined.

An adequate model of cued selection must make assumptions about both the operation of the feature-extraction process responsible for element identification and about the processes responsible for the selection of target elements. The two classes of models to be considered differ in the assumption they make about the feature-extraction process, assuming either than feature extraction capabilities are unlimited and performance is less than perfect only because of imperfect memory and decision systems, or that limited feature-extraction capabilities are themselves the primary bottleneck. No attempt will be made to argue for or against either of these assumptions about the feature extraction process; the discussion will instead focus on the way in which assumptions about the selection process can be articulated with either model of feature extraction.

Given that there is some limit on information-processing capacity, the subject must make sure it is the "correct" items that are labeled, held in short-term memory (STM), and made available for report. Item selection could logically occur before or after the feature processing required to assign names to the items; the use of the term "selection" in the preceding paragraphs was deliberately vague enough to be compatible with either possibility. When selection is thought to occur will depend primarily on the assumption made about the capacity of the feature extraction process. In general, limited-capacity models require selection prior to (or at least very early into) feature extraction; unlimited-capacity models at least permit the completion of feature extraction prior to selection. While there are many possible varieties of limited and unlimited capacity models—depending on further assumptions about whether the searches for targets (and labels for those targets) are carried out in serial or in parallel, are self-terminating or not, and so on—it is the capacity issue per se that is most crucial for analyses of selection. Therefore, this discussion will be restricted to a single type of model for each class.

Limited Capacity Models

Limited capacity models assume that a given amount of feature-extraction capability must be shared among all attended channels. In either a detection or a whole-report task, performance must then decrease as the number of display elements is increased, even given appropriate controls for retinal interaction (Gardner, Note 1). If the subject's response should be based on only a portion of the display, as in the partial-report task, it would be advantageous for the subject to locate the cued items as quickly as possible, and then devote all his capacity to these elements alone; selection must come prior to feature extraction (cf. Treisman & Geffen, 1967). This is basically the idea proposed by von Wright (1968). He considers performance in the partial-report paradigm to be a two-stage process of target location followed by target identification. For any given response criterion, accuracy should reflect the level and difficulty of the tests required for first-stage screening of the display.

These ideas were formalized in Rumelhart's (1970) multicomponent model, the only model in the literature specifically designed to handle performance in both the partial-report and detection paradigms. It is assumed that all display elements are registered in the visual information store, and that pattern analysis proceeds independently in each channel at a rate proportionate to the amount of attention assigned that channel. At the time of cue presentation, the subject immediately restricts processing to the set of cued items, and the consequent increase in rate of feature extraction accounts for the relative superiority of cued over whole-report performance. The processes of labeling and transfer to verbal memory are assumed independent in the different channels. While the data of Sperling's (1960) experiments (and of the Estes detection studies, e.g., Estes & Wessel, 1966; Wolford, Wessel, & Estes, 1968) are nicely fit by the model, there are a number of problems that appear when the model is applied to the newer data on selection criteria, cued-set arrangement, and background effects.

Criticisms of the model fall into two categories, the first dealing with the initial selection stage, and the second with the element identification stage. Coltheart and Coltheart (1972) have summarized evidence against various of the Rumelhart assumptions about the first stage. Target selection is clearly not immediate in view of the Eriksen and Collins (1969) data, and subjects do not restrict element processing to the cued set as was shown by Mewhort (1967). They also point out that Rumelhart's suggestion of differential attentional weights to handle unequal distribution of attention becomes very cumbersome when all the possible retinal and strategic factors that influence accuracy at different display positions are considered. The current experiment corroborates and extends these observations. Performance is influenced by the nature (similarity and redundancy) of the nontarget material;

either the processing of nontargets prior to cue perception is not without consequence, or the eventual restriction of attention is inexact. The model cannot account for the effect of target-set spatial arrangement; since it includes provision only for a restriction in the number of attended targets, there is no way of handling variation in arrangement of a fixed number of targets. Because the set of exemplars for each condition here partitioned the matrix, it cannot be argued that some fixed distribution of attentional weights accounts for the pattern differences, and it is unlikely that the subject could effect some strategic reassignment of weights given the unpredictability of the condition ordering employed. The model also, of course, makes no provision for handling the different aspects of the pattern effect, namely the differing contributions of target adjacency and codability. It might also be pointed out, on logical grounds that selection is not only not immediate for any condition, the time required to select items should vary substantially across conditions since the compatibility of cue and subset cued varies with selection condition, as does the complexity and brain location of the processing required for the different dimensions.

In a sense, it is somewhat unfair to pose these selection stage problems as criticisms of the Rumelhart model, since it is not properly a model of selection at all. It is essentially a model of Stage 2 prefaced by an ellision over Stage 1. It was designed to deal with element recognition, and selection considerations enter only by way of the capacity limitation assumption; if feature extraction is limited, it is necessary to select on some basis. Immediacy and efficiency of selection were reasonable first approximations given that the only cue-delay data in the literature at the time the model was formulated were Sperling's row-cue functions, and the row criterion is indeed very easy to use. Further, the mathematics of the model refer only to the decay of the icon and the extraction of features; the selection stage is not formalized.

It would probably not be difficult to modify the Rumelhart model enough to generate reasonable fits to a selection condition main effect, and to at least some pattern effects. A parameter corresponding to the delay between cue presentation and the effective restriction of attention to the targets could handle the selection condition differences. The assumption of a certain amount of "slop" in the allocation of attention to channels (perfect target selection is a rather unreasonable assumption for any model) could deal with the adjacency component of the pattern effect. The only truly serious criticism of the model concerns the second, or element identification, stage. Not only are nontargets attended (presumably a Stage 1 error), but their nature matters a great deal. Since Rumelhart assumes the processes of target identification and transfer to memory to be independent for the different channels, there is no way to account for any interaction between channels. It is possible to handle the effect of background similarity by means of the parameter c (the criterion determining the number of features that must be accumulated before an item is identified), but this works only if the subject is informed of the nature of the trial in time to raise or lower c appropriately; it cannot handle the results of the present experiment in which the nature of the background is unpredictable. Clearly, some more general means of handling element identification is needed. The most promising possibility would seem to be a decision-comparison process at the element identification stage. Such a comparison mechanism has been proposed in the context of an unlimited capacity model, and this case will be considered next.

Unlimited Capacity Models

An unlimited capacity model was first proposed by Eriksen and Spencer (1969) in order to account for the absence of any effect of the rate of presentation of the elements in a yes-no detection task. The effect of a decrease in performance as the number of such elements is increased was explained by positing a decision mechanism which evaluates the analyzed features to decide whether or not the target is present. Decision making is inherently imperfect, given imperfect perceptibility under tachistoscopic conditions, and the possibility of error increases as the number of distractors increases. These ideas were formalized and generalized to the two-alternative forced choice (2-AFC) case by Gardner (1973, Note 1) in his "independent channels-confusions" (ICC) model. Gardner (1973) and Shiffrin and Gardner (1972) have made specific tests of the predictions of the Rumelhart and ICC models for various 2-AFC paradigms, and find data to be better predicted by the ICC model. (For comments concerning the ICC model's ability to handle various other aspects of the detection data, see Estes, 1972, 1974; Kinchla, 1974.)

There are three main matters—the decision process, the capacity limitation assumption, and the possibility of selection—to be considered in applying the ICC model to the partial-report task. Since feature processing is carried out by independent parallel channels, the decision stage is the only point at which it is possible for the perception of one element to be influenced by the rest of the display. Assuming that the decision process evaluates nontargets, this model would have no difficulty accounting for target-background similarity. It should also be noted that the decision maker must, in addition, be responsible for the effects of all relational aspects of the display such as the target pattern variables.

The capacity and selection questions arise because, unlike Rumelhart's model, which handles 2-AFC detection and partial report in the same framework, Gardner's model has been applied only to the former. Since the capacity question has been tested only for the detection case, it is not clear that conclusions about capacity and the resulting implications for the selection process are applicable to the partial-report case. It is conceivable that the task of distinguishing two potential targets may be rather different from the task of labeling five letters selected randomly from the alphabet (although the ICC model formally generalizes to any number of potential stimulus inputs).

In the absence of any application to conditions in which the subject's response should be based on a limited aspect of the display, it may only be inferred that if the subject processes all features prior to decision making, any ICC selective process must operate at the level of the decision maker (cf. Deutsch & Deutsch, 1963). The only reference to the partial-report situation comes in the Shiffrin and Gardner (1972) paper in which they comment that the improved performance under partial report instructions might be explained without recourse to capacity limitation by assuming that "postperceptual memory effects would be increasingly bypassed as the cued set becomes smaller" (p. 73). This, of course, makes sense if the set of items entered into STM is reduced on the basis of the selection criterion, thereby reducing the possibility of decision-level confusions. They do not, however, explain how this reduction is to be accomplished, and this is precisely the issue at hand.

Their comment suggests that an additional decision stage—responsible for weeding out inputs to the decision maker—should be inserted between feature extraction and the decision processes that take place in STM, the two components of the current model. Target adjacency and pattern codability could then both be important. For example, the decision maker might be instructed to exclude from consideration "all targets not from Row 2." The more codable patterns might be characterized by more easily applied exclusion rules. Adjacency effects would be particularly easy to handle. "Attend to this general area" is a simple instruction encompassing few potentially interfering nontargets for compact patterns. Assuming that pattern effects are thus accounted for, and the imprecision of selection is pattern-related, then the pattern-background interaction falls out. Needless to say, the term "exclusion rule" is used rather loosely here, and would be a bit difficult to formalize. The one crucial point seems to be the necessity of spatially based selection rules. The operation of any such postfeature analysis "selection" mechanism is not, incidentally, incompatible with the Shiffrin and Gardner findings about the absence of attentional control at the feature stage. A cognitive, decisional variety of selection is rather different from an assumption that feature extraction capacity is shifted around to meet the exigencies of the situation.

As an alternative to postulating an intermediate decision-selection stage, consider the option of retaining the present two-part ICC model. In this case, all selection activity must take place in STM. If all elements are processed and their names entered into STM, selection then becomes a matter of retaining the cued items for rehearsal and report, and discarding the remainder. Such selection could be accomplished by a Sternberg-type (1966) scan that checks the items to see if they meet the selection criterion. Selection should then be faster for physical than for semantic criteria. However, if this scan takes as long as the 40 msec/character estimated for letter matching (Sternberg, 1966), many of these unrehearsed items would not survive long enough to be scanned. It is also not clear why such a scan would allow confusions with adjacent items if STM is indeed verbally rather than spatially organized. Further, is it reasonable to assume that the STM can hold 25 identified elements long enough to "throw out all but the five red ones?" There are simply no data on the possibility of flexibility of STM capacity. It has generally been found experimentally that capacity is rather limited, but the experimental paradigms have involved presentation conditions designed to insure entry into the store, and recall of less than a span's worth of elements. The possibility of flexibility dependent upon the clarity of the items entered and on the processing required (e.g., matching, naming, coding for long-term memory) have been largely unexplored by memory theorists. The Atkinson and Shiffrin (1968) model, in which the size of the buffer is a parameter of the model, is the closest approach to this problem.

Thus, even if all elements are processed by an unlimited capacity feature extraction process, it appears most reasonable to assume that selection occurs prior to entry to the short-term store (at least for partial report). It should, however, be pointed out that while Shiffrin and Gardner (1972) demonstrated that subjects did not exercise attentional control during the feature extraction stage, it is not clear that they cannot do so, or might not do so under some circumstances. While parsimony argues against inferring such attentional control in partial report but not in detection, it may be equally unparsimonious to place all the burden of selection on a decision process—whether a postperceptual filter or the identification decision processes operating in STM. Some thought should also be given to the possibility of subject strategies. It is conceivable that the subject could test for features meeting the selection criterion before or during feature extraction, and then stop processing in the nontarget channels. This would result in no gain of efficiency for the target channels, but might be a convenient way of eliminating inputs to the decision process(es). A model of such unlimited capacity strategic early selection would mimic a model of limited capacity mandatory early selection.

Spatial Considerations

Throughout this discussion of capacity limitation and time of selection, the problem of interaction among spatially adjacent channels has come up again and again. Whenever and however applied, attention to designated locations is spatially imprecise, and the results of such interaction are in accord with well-established principles of similarity and redundancy. One major question concerns the stage(s) of processing at which such interaction occurs. Another concerns the spatial distribution of the interaction; is the range of interaction built in, or is it in any part determined by more cognitive factors such as the subject's ability to attend to some patterns more easily than others?

There are three processes, perhaps corresponding to three stages of processing, that have been suggested in the recent literature as possible loci of the background interference effect. First is a structural restriction on the spatial spread of attention independent of, and perhaps prior to, feature identification. Second is interference dependent upon, and occurring during, feature extraction. Third is response selection. The problem of automaticity vs. flexibility of interactive area is closely intertwined with the level issue, since it is possible that both fixed and variable effects are present within each stage.

The best evidence for the existence of some built-in spread of attention comes from a series of experiments by Eriksen and his colleagues (e.g., Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1972; Eriksen & Lappin, 1967). In a number of studies investigating the effect of background material on the identifiability of a single cued target, they find that background items are sources of interference only if presented within 1 deg of the target; it is as though there was some minimal channel size, and processing of all encompassed material was automatic. While the emphasis here is on the fixed aspect of attentive spread, there is implicit the assumption of cognitive control; the subject is evidently able to pick the position that serves as the center of the fixed focus.

There are, however, some difficulties in generalizing these conclusions to the present results. The Eriksen studies (with the exception of the Eriksen & Eriksen, 1974, study which used a centrally presented target and no spatial uncertainty) have all used a single cued target presented somewhere within a circular array 2 deg or less in diam, while typical partial-report studies present multiple targets embedded in matrices 2-5 deg in horizontal extent. Eriksen's 1-deg figure is likely specific to the foveal area tested; data from other studies may well reflect a variety in sizes of attentional focus for the different matrix positions. More important than the location problem is the matter of the multiplicity of targets. Perhaps each target is the center of a fixed focus of attention, with interactions possibly occurring among foci. Alternatively, it is possible that the subject will adopt one manner of distributing attention when he deals with a single target, and quite another when forced to consider a span's worth of items distributed over a matrix. In any case, the fact that there was a strong adjacency component in the current data is quite consistent with Eriksen's contention that there is a minimal size to the spread of attention, and that attention encompasses more than one item position.

The response level has been implicated in some very recent work from Eriksen's laboratory (Eriksen & Eriksen, 1974; Eriksen & Hoffman, 1973). They present evidence that the locus of background interference is at the response end of the system; the subject must inhibit his response to the nontargets. Response competition is, of course, an issue only when attention allocated earlier encompasses both target and nontarget items. The present experiment provides no information on the question of response competition.

The feature extraction possibility has been proposed by Estes (1972). The activation of feature analyzers at particular positions has an inhibitory effect on adjacent channels, with the degree of inhibition and its spread dependent upon the complexity of the analysis (and on the retinal location of the channels), an idea modeled on the concept of lateral inhibition (Ratliff, 1965). The spread and intensity of interaction is thus not fixed, but it is automatic. One question to be considered in extending this model to the partial report case is whether the subject can choose locations that will serve as primary sources of inhibition while being themselves little inhibited (a modification of the lateral inhibition idea), or whether mutual inhibition of complex items will reduce the detectability of both (the pure lateral inhibition analog). Predictions for the partial report experiment are not obvious, but the current data do not deny the possibility that feature-analysis stage interactions may be an important source of background interference.

It thus appears that some pure adjacency component (whether fixed or mediated by feature analyzers) is involved in selective attention. The loose end is the possibility of pattern effects not accounted for by the adjacency of elements within the pattern. The finding here of a codability main effect, and a codability-adjacency interaction raises the possibility that pattern per se does indeed matter. Since elements used here were within 1 deg of one another, and average target separation varied somewhat with pattern type, this conclusion is only suggestive. The suggestion is, however, in line with a long line of research going back to the early Gestalt work (see also Attneave, 1954; Garner, 1962). The test for pattern effects requires the variation of pattern while holding constant retinal separation, and separations should be tested for distances both larger and smaller than 1 deg. These conditions are partially met in the recent Banks, Bodinger, and Illige (1974) study, which involves a circular display, a single target, and two or four distractors at various distances from the target. Their unanticipated finding was that target detection accuracy was actually higher with four (Condition 41) than with two (Condition 21) nontargets one position removed. Their favored explanation was that, in Condition 41, subjects would more easily group the nontargets and distinguish them from the target; nontargets in Condition 21 were more likely to be grouped with the target.

The Banks et al. (1974) data, the present results, and various other hints in the literature are individually only suggestive, but taken together point very strongly to the possibility that target arrangement influences the allocation of attention. The problem now is to determine whether such pattern effects do indeed exist, and to discover how they might operate. Target pattern might influence the subject's ability to distribute attention prior to feature analysis, or it could control the age of the icon at which the subject settles on the distribution of attention; the pattern might determine the choice of positions to serve as sources of feature inhibition, and might influence the ease of discriminating relevant from irrelevant responses.

Conclusions

The data of the present experiment do not necessitate the rejection of either the limited or the unlimited capacity feature extraction assumption for the partial-report experiment. What is clear is that the spatial arrangement of the cued items is a very important variable, and that attention to targets is imprecise, resulting in confusions with background material. Models must include cross-channel comparison sufficient to permit the occurrence of background interference, and must meet the constraint that sources of background interference be spatially distributed around the targets. It appears that some portion of selection must occur prior to entry into verbal memory in order to account sensibly for the effect of nontarget adjacency. Resolution of the capacity question, and the formulation of a model of partial-report performance require an understanding of the level at which adjacency matters, and the exploration of the possibility that target arrangement is important above and beyond the contribution of adjacency per se.

REFERENCE NOTE

1. Gardner, G. T. Spatial processing characteristics in the perception of brief visual arrays. Human Performance Center Technical Report No. 23, The University of Michigan, Ann Arbor, 1970.

REFERENCES

Attneave, F. Some informational aspects of visual perception. *Psychological Review*, 1954, **61**, 183-193.

Atkinson, R. C., & Shiffrin, R. M. Human memory: A proposed system and its control processes. In K. W. Spence and J. T. Spence (Eds.), *The psychology of learning and motivation*. New York: Academic Press, 1968. Pp. 89-195.

Banks, W. P., Bodinger, D., & Illige, M. Visual detection accuracy and target-noise proximity. *Bulletin of the Psychonomic Society*, 1974, **2**, 411-414.

Clark, S. E. Retrieval of color information from preperceptual memory. *Journal of Experimental Psychology*, 1969, **82**, 263-266.

Clement, D. E. Uncertainty and latency of verbal naming response as correlates of pattern goodness. *Journal of Verbal Learning and Verbal Behavior*, 1964, **3**, 150-157.

Clement, D. E., & Varnadoe, K. W. Pattern uncertainty and the discrimination of visual patterns. *Perception & Psychophysics*, 1967, **2**, 427-431.

Coltheart, M., & Coltheart, V. On Rumelhart's model of visual information processing. *Canadian Journal of Psychology*, 1972, **26**, 292-295.

Corballis, M. C., & Roldan, C. R. On the perception of symmetrical and repeated patterns. *Perception & Psychophysics*, 1974, **16**, 136-142.

Deutsch, J. A., & Deutsch, D. Attention: Some theoretical considerations. *Psychological Review*, 1963, **70**, 80-90.

Eriksen, B. A., & Eriksen, C. W. Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, 1974, **16**, 143-149.

Eriksen, C. W., & Collins, J. F. Temporal course of selective attention. *Journal of Experimental Psychology*, 1969, **80**, 254-261.

Eriksen, C. W., & Hoffman, J. E. Temporal and spatial characteristics of selective encoding from visual displays. *Perception & Psychophysics*, 1972, **12**, 201-204.

Eriksen, C. W., & Hoffman, J. E. The extent of processing of noise elements during selective encoding from visual displays. *Perception & Psychophysics*, 1973, **14**, 155-160.

Eriksen, C. W., & Lappin, J. S. Independence in the perception of simultaneously presented forms at brief durations. *Journal of Experimental Psychology*, 1967, **73**, 468-472.

Eriksen, C. W., & Spencer, T. Rate of information processing in visual perception: Some results and methodological considerations. *Journal of Experimental Psychology Monograph*, 1969, **79** (No. 2, Part 2).

Estes, W. K. Interactions of signal and background variables in visual processing. *Perception & Psychophysics*, 1972, **12**, 278-286.

Estes, W. K. Redundancy of noise elements and signals in visual detection of letters. *Perception & Psychophysics*, 1974, **16**, 53-60.

Estes, W. K., & Wessel, D. L. Reaction time in relation to display size and correctness of response in forced-choice visual signal detection. *Perception & Psychophysics*, 1966, **1**, 369-373.

Gardner, G. T. Evidence for independent parallel channels in tachistoscopic perception. *Cognitive Psychology*, 1973, **4**, 130-155.

Garner, W. R. *Uncertainty and structure as psychological concepts*. New York: Wiley, 1962.

Handel, S., & Garner, W. R. The structure of visual pattern associates and pattern goodness. *Perception & Psychophysics*, 1966, **1**, 33-38.

Heron, W. Perception as a function of retinal locus and attention. *American Journal of Psychology*, 1957, **70**, 38-48.

Julesz, B. *Foundations of cyclopean perception*. Chicago: University of Chicago Press, 1971.

Kinchla, R. Detecting target elements in multielement arrays: A confusability model. *Perception & Psychophysics*, 1974, **15**, 149-158.

McIntyre, C., Fox, R., & Neale, J. Effects of noise similarity and redundancy on the information processed from brief visual displays. *Perception & Psychophysics*, 1970, **7**, 328-332.

Mewhort, D. J. K. Familiarity of letter sequence, response uncertainty, and the tachistoscopic recognition experiment. *Canadian Journal of Psychology*, 1967, **21**, 309-321.

Neisser, U. Decision-time without reaction-time: Experiments in visual scanning. *American Journal of Psychology*, 1963, **76**, 376-385.

Ratliff, F. *Mach bands: Quantitative studies on neural networks in the retina.* San Francisco: Holden-Day, 1965.

Rumelhart, D. E. A multicomponent theory of the perception of briefly exposed visual displays. *Journal of Mathematical Psychology*, 1970, **7**, 191-218.

Shiffrin, R. M., & Gardner, G. T. Visual processing capacity and attentional control. *Journal of Experimental Psychology*, 1972, **93**, 72-82.

Sperling, G. The information available in brief visual presentations. *Psychological Monographs*, 1960, **74**, 1-29.

Sternberg, S. High-speed scanning in human memory. *Science*, 1966, **153**, 652-654.

Treisman, A., & Geffen, G. Selective attention: Perception or response? *Quarterly Journal of Experimental Psychology*, 1967, **19**, 1-17.

Turvey, M. T., & Kravetz, S. Retrieval from iconic memory with shape as the selection criterion. *Perception & Psychophysics*, 1970, **8**, 171-172.

von Wright, J. M. Selection in visual immediate memory. *Quarterly Journal of Experimental Psychology*, 1968, **20**, 62-68.

von Wright, J. M. On selection in visual immediate memory. *Acta Psychologica*, 1970, **33**, 280-292.

Wolford, G. L., Wessel, D. L., & Estes, W. K. Further evidence concerning scanning and sampling assumptions of visual detection models. *Perception & Psychophysics*, 1968, **3**, 439-444.

(Received for publication September 27, 1974;
revision received January 10, 1975.)