Journal of Experimental Psychology:
Human Perception and Performance
1978, Vol. 4, No. 2, 210–223

Perception and Masking of Wholes and Parts

James L. McClelland
University of California, San Diego

These experiments show that the effects of masking on reports of target lines depend on the context in which the target lines appear. Subjects viewed brief presentations of target lines either alone or in drawings of three-dimensional objects, and each target display was preceded and followed by one of several different mask stimuli. There were two main findings: (a) A mask containing a haphazard array of lines interfered more with single lines than it did with lines in objects. (b) A mask containing drawings of the object displays interfered more with lines in objects than did either of two control masks containing relatively flat, less coherent patterns. In a control condition, the object mask interfered slightly less with reports of single lines than either of the control masks did. The discussion considers how the effects obtained here bear on models of the processing of wholistic stimuli and their component parts.

It is a well-known fact that one stimulus —a mask—can interfere with report of another—a target—when the mask precedes or follows the target closely in time. Researchers have used these masking effects to study the processing of a variety of types of visual stimuli. Several very specific sorts of target–mask interactions have been reported: A mask is only effective at peripheral levels of processing where brightness analysis takes place if it is presented to the same eye as the target (Turvey, 1973); a mask interferes with report of a target more effectively if mask and target have the same orientation and share spatial frequency components (Weisstein, Harris, Bernbaum, Tangney, & Williams, 1977; but see Corwin & Zamansky, 1976); and a mask containing curved lines is more effective for curved than for straight targets, while a mask containing straight lines is more effective for straight than curved targets (Smith, Haviland, Reder, Brownell, & Adams, 1976).

Masking effects of the sort just described can provide one important source of information concerning the processing of visual information. However, most previous research has considered only the more literal and analytic aspects of processing. The experiments I report in this article were motivated by the idea that it should be possible to extend the sudy of differential masking effects to an analysis of the process of perceiving coherent, wholistic stimuli.

It has, of course, been widely argued that the perception of a stimulus element is affected by the whole of which it is a part (e.g., Koffka, 1935). If indeed the whole influences the perception of its parts, then it might be possible to find masks that differ in the extent of their interference with the perception of a stimulus element, as a func-

This research was supported by National Science Foundation Grant BNS76-14830 to the author, and by U.S. Public Health Service Grant MH 15828 to the Center for Human Information Processing, University of California, San Diego. I wish to thank Marguerite Moreno for her assistance in all phases of the research; James Johnston, David Rumelhart, and the members of the LNR Research Group for stimulating discussions; and Robert Boynton, Vladimir Konečni, Jeffrey Miller, Elissa Newport, Donald Norman, Naomi Weisstein, and Amanda Williams for comments on earlier versions.

Requests for reprints should be sent to James L. McClelland, Department of Psychology, C-009, University of California, San Diego, La Jolla, California 92093.

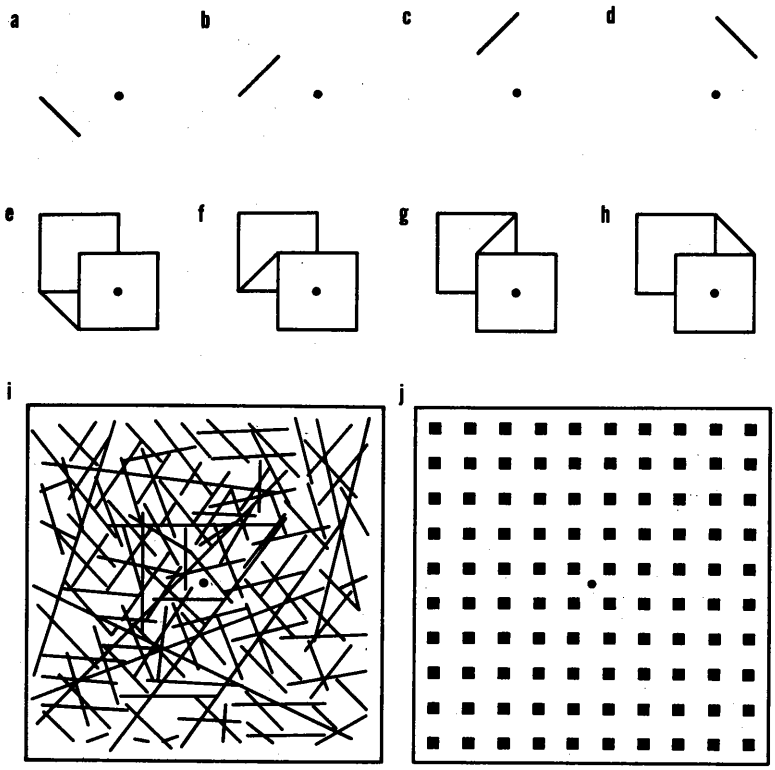

Figure 1. The target displays (a through h) and masks (i and j) used in Experiment 1. (The target displays and the dot mask are adapted from Weisstein and Harris, 1974.)

tion of the element's role (or lack of it) within a larger whole. Eventually, it may be possible to use such context-dependent masking effects to infer just how the perception of elements of wholistic stimuli differs from the perception of individual stimulus elements. Johnston and McClelland, (Note 1) have applied this approach to the study of perception of letters in words. In these experiments I apply it to the study of the perception of lines in objects.

Experiment 1

Let us suppose that a line in an object is perceived as a structural component of the object, while a single line is perceived as a mere independent element. Then if we use a mask that contains an array of independent elements, it may interfere more with the report of the identity of a single line than it does with report of a line in an object. Specifically, let us consider the perception of the stimuli in Figure 1a–h, used by Weisstein and Harris (1974). Line Segments a to d, in conjunction with two partially overlapping squares, produce Objects e to h. Thus, the four objects are differentiated only by the four segments. According to our analysis, a line mask like Figure 1i should interfere more with reports of individual lines than with reports of these same lines in objects.

To support the view that the expected advantage for lines in objects over single lines is produced by the line mask, and is not just the result of some general processing advantage for lines in objects, it is necessary to show that the advantage is obtained only under some masking conditions. There is already evidence from Weisstein and Harris (1974) that lines in objects do not have an advantage over single lines under one type of mask condition.

They used a posttarget mask made up of a regular array of small square dots like the one in Figure 1j, and they found a single-line advantage. However, their experimental conditions differed from those used in the present experiments. To control for these differences and to show directly that the expected object advantage depends on the nature of the mask used, I included a dot-mask condition as well as a line-mask condition in Experiment 1.

Weisstein and Harris (1974) did find an advantage for lines in objects over lines in contexts which were less coherent and three-dimensional. Such effects may be attributable to a general processing advantage for coherent displays (cf. Bell & Handel, 1976; Biederman, 1972). For present purposes, therefore, a comparison of mask effects on lines in objects versus single lines is more useful. It is difficult to interpret an advantage for lines in objects merely in terms of the coherence of the target display, since it is difficult to imagine anything more coherent than a single line.

All the experiments I am reporting used pre- and posttarget masking with the same masking stimulus: The mask was simply illuminated whenever the target was not. It is not yet clear just how these pre- and posttarget masking conditions differ from conditions in which the mask is used only before or after the target. In particular, it is important to avoid uncritical acceptance of the assumption that the effect of preceding and following a target with the same mask is the linear sum of the effects of preceding the target with the mask and of following the target with the mask.

Method

Subjects. Four students naive to the purposes of the experiment participated for pay in one 2-hr session each.

Design. Each subject viewed individual presentations of four line-segment targets in two types of display: displays containing a single target line (Figure 1a–d) and displays containing a target line as a part of an object (Figure 1e–h). Both types of display also contained a round fixation dot.

The experimental session was divided into two parts, one using the line mask (Figure 1i) and the other using the dot mask (Figure 1j). Within each mask condition, trials were further grouped into blocks of object trials and blocks of single-line trials to encourage maintenance of the most effective strategy for each type of display. Order of mask conditions and order of display type within mask conditions were counterbalanced.

In each mask condition, the first two pairs of blocks (24 trials/block) were used for practice and to find a target duration at which the subject performed at or near the 75% correct level. Threshold values were determined with a modified staircase procedure, working downward from a starting duration of 120 msec in small steps until the subject began to make errors, then adjusting upward or downward as appropriate after every fourth trial. The threshold values arrived at for each display type were averaged to provide a single duration to be used for both target types during the test phase. In the test phase each subject viewed four pairs of blocks. Each pair contained one 16-trial block of each display type, for a total of 64 trials of each type in each mask condition. Target duration was adjusted between pairs of blocks if average performance deviated much above or below the desired 75% correct level.

Visual conditions. The target displays and the masks were composed of black lines (or dots) on a white background, and all line segments were about .03° wide at the viewing distance of 90 cm.

The target segments themselves subtended .7° of visual angle, and the longer horizontal and vertical lines in the object display subtended 1.0°. The line mask was constructed by creating a haphazard pattern of lines of various lengths and orientations. Lines that actually superimposed on lines in the target displays or were parallel and adjacent to lines in the targets were avoided. Pilot testing revealed that the expected object advantage over single lines was not obtained unless a mask was used that contained a large number of segments intersecting with the target lines: If there were large gaps in the mask in the areas where the target lines were presented, they were not masked. Therefore, care was taken to ensure that the mask contained several segments intersecting the location of each of the target lines. The dot mask was constructed following the example of Weisstein and Harris (1974). Squares in the dot mask were .15° on a side and were spaced evenly about .35° apart. Both masks occupied an area 5° on each side. The luminance of the target field was 180 cd/m^2, and that of the mask field was 155 cd/m^2.

Procedure. Before testing began, subjects were given practice assigning the correct responses to each of the targets in each type of display until they could do this perfectly. The target segments in the single-line displays were designated 1, 2, 3, and 4 for Lines a through d, respectively (Figure

1). No subject had any apparent difficulty with this code. However, pilot testing revealed that some subjects had difficulty with the same code when the targets were presented in the object displays. To overcome this difficulty, I devised descriptive names for the lines in objects based on their role in the three-dimensional structure of the object. Object e was called *floor* (as in "the one with a floor"); f was called *ramp; g, divider;* and h, *wall.*

Each trial began with the subject fixating the round dot in the mask and initiating target onset with a button press. Target duration was set by the experimenter, as described above. After target offset the mask immediately reappeared, and the subject attempted to identify the target, guessing if necessary. Subjects were permitted to refer to a sheet that pictured the target displays paired with the responses. Feedback was provided after each trial.

Table 1
Probability Correct Target Report and Target Duration (Experiment 1)

Subject	Object	Single line	Duration (in msec)
	Line mask		
1	.90	.69	48
2	.92	.61	54
3	.95	.64	49
4	.98	.48	80
M	.94	.60	58
	Dot mask		
1	.64	.86	6
2	.73	.83	10
3	.69	.88	7
4	.73	.89	10
M	.70	.86	8

Results

The experiment produced a large advantage for lines in objects in the line-mask condition, and a smaller advantage for single lines in the dot-mask condition. Both effects held for each subject (Table 1) and for each of the four target segments, and both were significant over subjects in two-tailed *t* tests ($p < .05$). The interaction of mask by display type was highly significant, $F(1, 3) = 95.7$, $p < .01$. Since the data were obtained in each mask condition after obtaining an exposure duration at which the subject scored near the 75% correct level, it is not meaningful to compare actual performance levels across mask conditions. However, the exposure durations themselves provide an indication of the effectiveness of the different masks. On the average, durations were more than seven times longer in the line-mask condition than in the dot-mask condition, and each individual required a duration at least five times longer in the line-mask condition.

Discussion

The prediction that a line mask would interfere more with reports of single lines than with reports of lines in objects was nicely supported by the results of the experiment. In other experiments, I have replicated this finding several times with different line masks constructed according to the same principles as the mask used here.

The line mask used was much more effective than the dot mask in interfering with reports of both single lines and lines in objects: A mean target duration of 58 msec was required for 75% correct performance in the line-mask condition, while only 8 msec was required in the dot-mask condition. One possible reason for the greater overall effectiveness of the line mask may simply be that it had more patterned information—more lines, edges, etc.—intersecting the patterned information in the target display than the dot mask had. Pilot testing with different line masks suggested that the effectiveness of a line mask depends on the number of segments in the mask actually intersecting the locations of the target lines in the display area. Apparently, then, a large part of the masking effect of the line mask is due to *position-specific* interference. Of course, mask effectiveness might also be specific to line length, width, orientation, and to the spatial frequency composition of the target and mask. Any or all of these factors might have contributed to the diminished effectiveness of the dot mask. In any case, the target-duration data indicate that the line mask in-

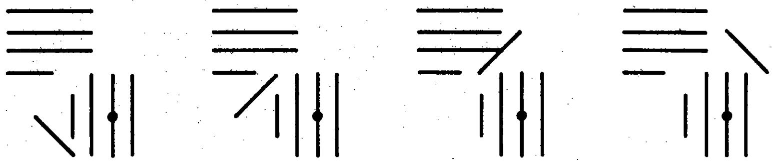

Figure 2. The unrelated context displays used in Experiment 2 (stimuli were also used by Weisstein and Harris, 1974).

terfered more than the dot mask with lines in objects as well as with single lines. This finding indicates that lines in objects are not immune to the interfering effects of the line mask—they are just somewhat less susceptible.

The dot-mask condition did not produce an advantage for objects over single lines. This finding accords with the view that the object advantage obtained in the line-mask condition is the result of a context-dependent masking effect. In fact, the dot-mask conditions produced an advantage for single lines, as previously reported by Weisstein and Harris (1974). As they noted, this single-line advantage may have nothing to do with differential masking. It may simply reflect the fact that extra contour information in the display will result in reduced accuracy of target report due to lateral interference (Eriksen & Rohrbaugh, 1970; Estes, Allmeyer, & Reder, 1976).

Experiment 2

There are several interpretations of the pattern of results obtained in Experiment 1 other than the one just considered. Experiment 2 tested two classes of such interpretations.

1. General facilitation by any context in the line-mask condition. The object advantage in the line-mask condition might be due to some facilitation produced merely by the presence of nontarget contours in the display. To test this hypothesis, I compared reports of lines in objects, single lines, and lines in an unrelated context (Figure 2) used by Weisstein and Harris (1974).

2. General object advantage over single lines. The object advantage in the line-mask condition might reflect a general processing advantage for lines in objects which was simply obscured in the dot-mask condition. One possibility is that the dots interfered with perception of objects because they formed horizontal and vertical rows and thus interfered with processing the horizontal and vertical lines in the objects. To address this and related possibilities, I compared reports of lines in objects, single lines, and lines in unrelated context under conditions in which the pre- and posttarget mask contained no patterned information at all. The mask was simply a blank white card with a fixation dot.

Experiment 2 incorporated two changes in methodology: (a) Within each mask condition, all three display types were presented in one mixed list; (b) subjects used the same numerical response code to indicate which target was presented for all three display types. These changes ensure equal motivation to perform accurately on each type of display and eliminate the possibility that accuracy differences between display types are due to differences in response availability.

Method

Subjects. Eight subjects naive to the purposes of the experiment participated in one session lasting a little over 1 hr. Subjects received either course credit or $3.00. One additional subject's data were not used since the experimenter was unable to adjust target-exposure durations rapidly enough to avoid ceiling effects.

Design. Four subjects viewed all three types of display in the line-mask condition, and four viewed the three display types in the blank-mask condition. Within each mask condition, trials were randomized over display type. Each subject viewed six blocks of 48 trials, with each target occurring equally often in each display type within each block. The first two blocks were used for practice and adjustment of exposure durations. The four remaining blocks were used for data collection. Durations were adjusted between blocks to achieve approximately 75% correct responding over all three display types.

Visual conditions. The luminance of a blank white card was approximately 120 cd/m² for both the target and the mask field.

Procedure. The procedures were the same as those of Experiment 1 except that subjects used the numerical response code previously used for single lines to report all three target types. After hearing the response code explained, each subject was shown each of the 12 target displays in the tachistoscope for 500 msec, preceded and followed by the appropriate mask. The experimenter gave the response for each display just before it was presented. Then the 12 targets were presented in random order for 500 msec each, and the subject was required to provide the correct response. Errors were corrected, and the experimenter made sure that the subject understood the differences between the targets before proceeding.

Table 2
Probability Correct Target Report and Target Duration (Experiment 2)

Subject	Object	Single line	Unrelated line	Duration (in msec)
		Line mask		
5	.98	.78	.55	64
6	1.00	.62	.75	82
7	.95	.80	.81	37
8	.98	.73	.78	75
M	.98	.73	.72	65
		Blank mask		
9	.78	.84	.75	3
10	.59	.70	.64	2
11	.68	.83	.67	3
12	.78	.84	.75	5
M	.71	.80	.70	3

Results

In the line-mask condition, Experiment 2 replicated the advantage for lines in objects over single lines. There was no advantage for lines in unrelated context over single lines. The object advantage over both the other display types held up for each subject (Table 2) and for each of the four targets. Analysis of variance produced a reliable main effect of target type in the line-mask condition, $F(2, 6) = 10.57$, $p < .05$, and lines in objects had a reliable advantage over single lines and over lines in unrelated context according to Tukey's test ($p < .05$ in both cases).

The pattern of results was quite different in the blank-mask condition. The interaction of mask condition and target type was reliable, $F(2, 12) = 14.18$, $p < .01$. With the blank mask, reports of single lines were slightly more accurate than reports of lines in objects or reports of lines in unrelated context. All four subjects were more accurate on single lines than on lines in either other display type. The main effect of display type was reliable, $F(2, 6) = 17.44$, $p < .01$, and Tukey's test revealed that the single-line advantage over both of the other two target types was reliable ($p < .05$ in both cases). The single-line advantage over lines in objects held for three of the four targets, with one tie, and the single-line advantage over lines in unrelated context held for all four targets.

Finally, it is clear that exposure durations required for 75% correct performance overall were drastically affected by type of mask. Mean target duration in the line-mask condition was more than 20 times greater than mean target duration in the blank-mask condition.

Discussion

The object advantage over single lines in the line-mask condition of Experiment 2 is somewhat smaller than the effect obtained in Experiment 1. Although this difference might be due in part to procedural changes, it is likely that Experiment 2 would have obtained a larger object advantage were it not for the fact that performance on lines in objects was up against the ceiling. In any case, it is clear that the procedural changes did not eliminate the object advantage.

Experiment 2 found no advantage for lines in unrelated context over single lines in the line-mask condition. This finding indicates that the advantage for lines in objects is not merely due to the presence of additional contours in the object displays.

We cannot, of course, conclude that the object advantage is unique to three-dimensional objects. Connectedness, closure, and a variety of other factors, as well as apparent three-dimensionality, differ between the object and unrelated line contexts. Further research is in progress to determine just which of these factors is critical.

In the blank-mask condition, the object advantage over single lines was not obtained, nor was there any difference in accuracy of target report for lines in objects and lines in unrelated context. These findings support the view that the object advantage under line-mask conditions is not simply a reflection of a general processing advantage for objects that was merely obscured by the dot mask used in Experiment 1. However, it now appears that there are conditions that do not involve masking in which a small object advantage over single lines can be obtained. Williams and Weisstein (in press) obtained a 9% advantage for lines in objects over single lines, using no mask at all. Their displays consisted of illuminated line segments on a dark background, with only a fixation dot before and after, and subjects were dark adapted before testing since luminance levels were quite low.

Just why the blank-mask condition of Experiment 2 should produce different results than the conditions of Williams and Weisstein is not clear. What is clear is that we cannot fix exactly a baseline accuracy level for reports of lines in objects relative to single lines. However, in view of the magnitude of the object advantage in the line-mask conditions of Experiments 1 and 2, it seems likely that the present results are due to context-dependent effects of masking.

Other context-depending masking effects. There are several experiments in the literature in which stimulus elements are reported more accurately when they occur in some structured context than when they are presented in isolation. Many of these effects may be due to context-dependent masking effects. The most well-known case in point is the finding of Reicher (1969) and Wheeler (1970) that letters in words are identified more accurately than single letters in a forced-choice test of tachistoscopic perception. Both Reicher and Wheeler used a postdisplay mask containing some visual pattern information. Johnston and McClelland (1973) obtained a large word advantage, using a mask consisting of curved and straight lines, but the effect was slightly reversed when a blank mask was used (see also Juola, Leavitt, & Choe, 1974) paralleling the present results exactly.

One other result may be due to a kind of context-dependent masking effect. Schendel and Shaw (1976) reported an advantage for line segments in letters over isolated line segments. They did not use a mask falling in the same location as the target, but they did present a pair of line segments serving as forced-choice alternatives next to the display just after target offset. In interpreting Schendel and Shaw's results, it is worth noting a finding of Wheeler (1970): Single-letter alternatives presented immediately after and adjacent to his targets produced a kind of masking of single letters but had no effect on letters in words. His subjects reported that single-letter targets appeared to move into one of the alternatives (not necessarily the correct one), and this movement made the targets more difficult to identify. It is possible that Schendel and Shaw's effect was produced by an analogous apparent motion of their single-line targets. Indeed, the effect disappeared, as we might expect from the present results, when the postdisplay field was blank and alternatives were given in advance of the trial.

We now return to our examination of context-dependent masking effects in the perception of lines and objects, to investigate the role of mask structure.

Experiment 3

If lines are perceived as parts of the larger wholes in which they are embedded, the ability to report lines in objects may depend on the structure of the masking pattern used to mask the object displays. In particular, an object mask containing coherent, three-dimensional objects similar to those in the object display might interfere more with reports of lines in objects than a control mask containing a less coherent, apparently flat array of lines. I looked for just such a differential masking effect in Experiment 3.

As mentioned above, it was clear from pilot testing that local mask properties are important in determining how effectively a mask will interfere with target report. To control for these factors, I equated the contours in the object and control masks in the vicinity of the four target segments. That is, any line segment in the object mask falling adjacent to or intersecting with the location of a target line segment was repeated exactly in the control mask. The two masks are shown in Figures 3a and 3b, and the set of segments used in both masks is shown with the target segments superimposed in Figure 3c. The two masks were also matched for the total number of line segments of a given length and orientation, and an attempt was made to make the two masks similar to each other in density in all parts of the mask. It is apparent that these constraints resulted in rather less structural difference between the two masks than there might have been.

As a check on the success of the matching of local properties of the two masks, single lines were tested along with object displays. It was originally anticipated that the perception of single lines would depend only on local mask properties. Thus, it was expected that the two masks would differ in their effects on object targets but not in their effects on single lines.

Pilot testing revealed that at least some subjects could report single lines much more accurately than lines in objects, with either of the two masks. This effect was so large in certain cases that it was impossible to look for differences between the mask's effects when both types of target display were presented at the same duration, because of simultaneous floor and ceiling effects. Therefore, it was necessary to set different exposure durations for single lines and lines in objects and to assess the effectiveness of the two masks separately for each display type.

Method

Subjects. Eight subjects naive to the purposes of the experiment were tested. One additional subject's results were discarded because she was ill and could not concentrate throughout the experiment. Each subject was paid $4.00 for participating in the experiment, which lasted about 2 hr.

Design. Each subject viewed object displays and single-line displays preceded and followed by the object mask on some trials and the control mask on other trials. The experiment was divided into two parts, one in which object displays were presented and one in which single-line displays were presented. Order of display conditions was counterbalanced. Within each display condition, trials were further subdivided into alternating blocks using the object mask and the control mask, and order of mask conditions was counterbalanced. Within each display condition, exposure durations were adjusted during the first pair of blocks (24 trials/block). The actual experimental

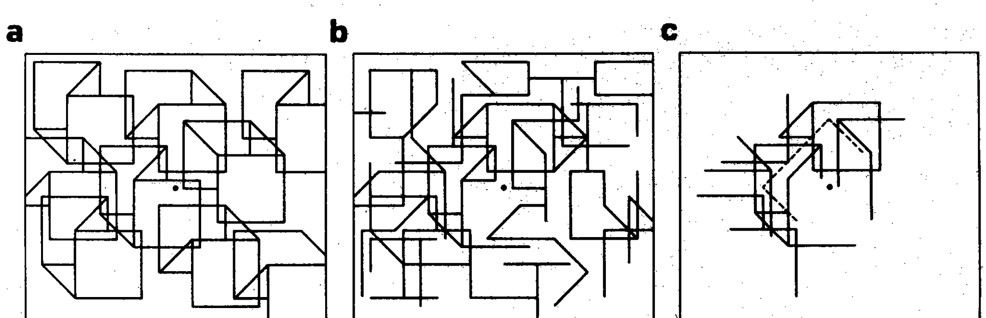

Figure 3. The object mask (a) and flat mask (b) used in Experiment 3. (The set of contours that are identical in the two masks is shown in c with the target segments [dotted lines] superimposed.)

Table 3
Probability Correct Target Report and Target Duration (Experiment 3)

	Object target			Line target		
Subject	Object mask	Control mask	Duration (in msec)	Object mask	Control mask	Duration (in msec)
17	.78	.90	87	.75	.75	10
18	.59	.66	72	.81	.78	35
19	.66	.80	78	.84	.73	60
20	.75	.81	54	.73	.69	7
21	.59	.75	53	.89	.80	48
22	.78	.70	79	.84	.84	15
23	.42	.55	70	.90	.75	64
24	.62	.77	50	.72	.67	51
M	.65	.74	68	.81	.75	36

data were obtained during the subsequent four pairs of blocks (16 trials/block). Exposure durations were adjusted between pairs of blocks to achieve the 75% correct performance level averaging over the two types of mask.

Visual conditions. As in Experiment 2, luminance was set at 120 cd/m^2 for both fields.

Procedure. The procedures used in the experiment closely followed those used in Experiment 2 except that subjects were introduced to the single lines and objects at different points in the experiment. As in Experiment 2, the numeric response code was used for each of the display conditions.

Results

As expected, the object mask used in Experiment 3 interfered more with reports of lines in objects than did the control mask. On average, subjects reported lines in objects correctly 9% more often in the control-mask condition than in the object-mask condition, $t(7) = 3.36$, $p < .025$. The results of seven of the eight subjects were consistent with this effect (Table 3), and it held for all four target segments.

The differential effects of the two masks were actually slightly reversed in the single-line condition. The interaction of mask and target type was reliable, $F(1, 7) = 13.53$, $p < .01$. On average, single lines were reported 6% more accurately with the object mask than with the flat mask. While this effect was reliable, $t(7) = 3.11$, $p < .025$, it was not in fact consistent over subjects, since only six of the eight subjects showed the effect.

Because target durations were adjusted separately for object targets and line targets, accuracy data cannot be compared directly between the different target conditions. However, the durations themselves reveal several important facts. On average, target durations were nearly twice as long for objects than for single lines. Some subjects contributed more to this effect than others; there were very large individual differences in exposure durations for single lines. While target duration ranged from 50 to 87 msec for object displays, it ranged from 7 to 64 msec for single lines.

Experiment 4

The masks used in Experiment 3 were not as structurally distinct as they might have been. The control mask did not actually contain any complete objects, but it did contain several recognizable fragments of the various object targets, and in certain places it does appear to have some three-dimensional structure. It seemed likely that the differential effects of the two masks on reports of lines in objects would have been larger if the two masks had been more distinct. In Experiment 4, therefore, I used a new control mask constructed to contain fewer recognizable components of the object targets and somewhat less apparent higher order structure to produce a more dramatic effect.

Experiment 4 also tested one interpretation of the finding that the control mask interfered more than the object mask with reports of lines in objects. This effect might be explained by supposing that subjects simply search for connected figures in the display. Since the control mask contained free ends but the object mask did not, the control mask might be expected to interfere less with this search process. A converse account might be given for the slightly greater interference of the control mask with reports of single lines, based on the idea that subjects identify single-line targets by searching for free ends. To test these interpretations, I designed the control mask used in Experiment 4 so that it contained no free ends.

Method

Experiment 4 was identical to Experiment 3 except that a new control mask was used. This new mask (Figure 4b) differs from the control mask used in Experiment 3 in that it has no free ends, fewer recognizable parts of the object targets, and, to the author's eye, less apparent three-dimensional structure. To achieve these differences, it was necessary to relax some of the constraints on mask construction that were enforced in constructing the control mask used in Experiment 3. All the contours that actually intersected or were closely adjacent to any of the target segments were kept in the new mask (Figure 4c). The total number of line segments of each orientation as well as the total line length of each orientation was still equated. However, 10 of the total of 70 individual horizontal and vertical segments contained in the object mask were permitted to vary in length by up to 25% to help break up components of objects (squares, triangles, etc.) that otherwise would have been present in the mask. For example, corresponding to a horizontal line 1° long in the object mask, there might be a line 1.25 or .75° long in the control mask.

Results

The masks used in Experiment 4 had strong differential effects on reports of lines in objects. Subjects reported lines in objects 19% less accurately with the object mask than with the control mask. The effect was reliable, $t = 5.28$, $p < .01$, and held for all subjects (Table 4) and all four target segments.

As in Experiment 3, the greater effectiveness of the object mask in masking lines in objects cannot be attributed to differences in local mask properties, since once again the effect was if anything reversed for single lines. The interaction of mask and target type was highly significant, $F(1, 7) = 22.02$, $p < .01$. Over all subjects, single lines were reported 7% more accurately with the object mask than with the flat mask. However, as in Experiment 3, the effect was not consistent over subjects and reached only marginal significance levels, $t(7) = 2.22$, $.1 > p > .05$.

The target duration results also closely mirror Experiment 3. Mean target duration was considerably longer for object targets than for single-line targets, but again there were larger individual differences in mean target duration for single lines (ranging

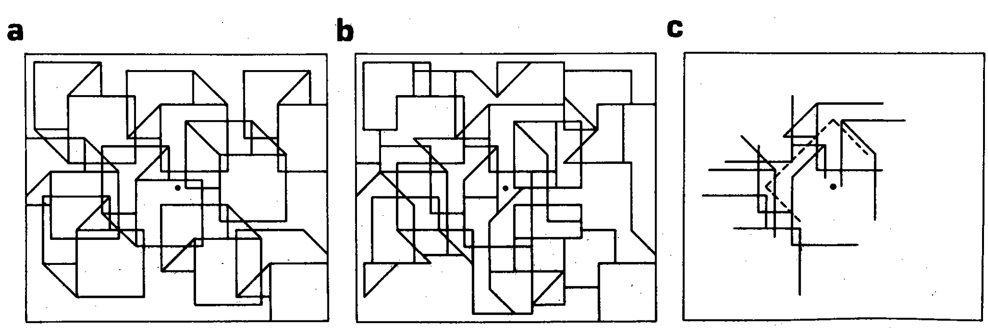

Figure 4. The object mask (a) and flat mask (b) used in Experiment 4. (The set of contours that were kept identical in the two masks is shown in c with the target segments [dotted lines] superimposed.)

Table 4
Probability Correct Report and Target Duration (Experiment 4)

Subject	Object target: Object mask	Object target: Control mask	Object target: Duration (in msec)	Single-line target: Object mask	Single-line target: Control mask	Single-line target: Duration (in msec)
25	.64	.77	80	.89	.84	56
26	.66	.78	66	.84	.86	10
27	.66	.88	81	.86	.81	10
28	.53	.94	78	.81	.73	7
29	.56	.64	94	.80	.78	86
30	.43	.61	73	.72	.55	72
31	.61	.78	58	.84	.86	23
32	.61	.86	62	.75	.52	78
M	.59	.78	74	.81	.74	43

from 7 to 86 msec) than for lines in objects (from 58 to 94 msec).

Discussion

Experiment 4 strengthens and clarifies the findings of Experiment 3. As expected, the object mask interfered much more with reports of lines in objects than the new control mask, by a margin of 19%. This effect was both larger and more consistent than the effect produced in Experiment 3. It is very unlikely that the difference in the masks' effects on reports of objects was due to differences in their local effects on the perceptibility of the target line segments: The masks were rather closely equated for local properties in the vicinity of the target segments, and the pattern of results was if anything slightly reversed with the single line targets. Furthermore, the control mask used in Experiment 4 contained no free ends, so the greater effectiveness of the object mask cannot merely be the result of differences in the number of free ends between the two masks. It appears, then, that we must consider the structural properties of the masks to explain their differential effects on reports of lines in objects. Several sorts of structural differences between the object mask and the two control masks remain. For the present we cannot determine which of these differences might be responsible for their differential effects.

Several subjects in each of Experiments three and four were able to perform at the 75% correct level on single lines at target durations far briefer than those required for the object targets, or for single-line targets in Experiments 1 and 2. A full discussion of the performance of these "short-duration subjects" would take us rather far afield. Suffice it to say for now that these subjects may be relying on diffusely localized transient signals generated by the onset and offset of the target to detect the general location, and hence the identity, of the target segments. This account assumes that these transients do not provide good enough information to identify lines in objects because the object context also generates transients obscuring those generated by the target segment itself. This account also assumes that the line mask used in Experiments 1 and 2 generates sufficient transients to render the transients generated by the target segments less salient. A final assumption is that only some subjects attended to these transient cues in the single-line target conditions of Experiments 3 and 4. In experiments not reported here, I have developed considerable support for this account. In the present context, the only reason to go into it is to indicate that under some conditions, it may be possible for subjects to short-circuit the effects of the mask, especially with single-line targets identifiable by location alone.

In Experiments 3 and 4, the control mask interfered slightly more with reports of single lines than the object mask did. This effect was small and not particularly consistent over subjects, so it is difficult to know what to make of it. Since there were no free ends in the control mask used in Experiment 4, it cannot be attributed to the presence of free ends in the mask. One possible interpretation is that the presence of structure in the object mask may have helped those subjects who were not relying on transients in the single line condition to distinguish between mask and target in a composite representation (Eriksen & Schultz, Note 2). However, accuracy reporting single-line targets appears to be sufficiently sensitive to subtle local properties of the masks that we cannot rule out the possibility that some minor local difference between the object and the control masks is responsible for the small differential effect.

General Discussion

The present experiments have demonstrated two rather striking context-dependent masking effects. (a) A mask containing a rather dense, haphazard array of lines interfered more with reports of single lines than with reports of lines in objects. (b) A mask containing objects interfered more with reports of lines in objects than either of two relatively flat, less coherent control masks containing some partial fragments of the objects. At the same time, the object mask actually interfered slightly less, if anything, with reports of single lines than either of the control masks did.

Three Possible Effects of Masking

In attempting to account for these results it is important to realize that there is more than one reason why a stimulus might fail to give rise to an overt response. Current processing models (e.g., Schneider & Shiffrin, 1977; Shriffrin & Schneider, 1977) distinguish between two kinds of processes: rapid automatic processes, which result in the activation of representational structures from stimulus input; and controlled, resource-limited processes, which are used to search for activated structures in the representational system and then to select overt responses. In the context of such models, mere activation of the appropriate representation corresponding to a particular briefly presented stimulus is not necessarily sufficient for the production of an appropriate overt response: Search processes could still fail to find an activated representation before its activation fell below the level of retrievability.

Given these considerations, there seem to be three principal ways in which a mask could operate to interfere with target report: (a) The mask could prevent the stimulus from activating the appropriate representation, (b) it could interfere with the persistence of a representation until it could be found by the search process, and (c) it could interfere with the search process itself. We now consider one interpretation of the object advantage over single lines consistent with each of these three possible effects of masking. Although the interpretations differ in the way masking has its effect, they agree on the basic assumptions that the reports of single lines are based on representations of single lines and that reports of lines in objects are based on representations capturing some of the structure of the object displays.

Activation. We might assume that there are representational units in the visual system activated by line segments of various orientations and positions, as well as representational units activated by higher order structural components of objects. If mask and target overlap temporally in the visual system, then the object advantage over single lines could be explained by supposing that the lines in the line mask produce inappropriate inhibitory input to the representational units sensitive to the single line target segments but produce less inhibitory input to the representational units corresponding to structural components of wholistic stimuli.

Persistence. As in the preceding interpretation, we might assume that single lines activate representational units corresponding to position-specific line segments and that objects activate representational units corresponding to structural components of objects. This interpretation differs from the previous one, however, in assuming that the target durations used in the line-mask condition are sufficient for unambiguous activation of the appropriate representations both for lines in objects and for single lines. The limitation on performance is thought to lie, instead, in the process of locating the appropriate representational unit and encoding an appropriate response before the activation of the unit ceases. As in the activation interpretation given above, we assume that the line mask produces stronger inhibitory effects on representations of single lines than on representations of higher order structural units contained in objects. As a result of this differential interference, there would be more time for search and decision processes to locate the representation of an object and decide upon the appropriate response than there would be in the case of a single line.

Search. A final interpretation assumes that both objects and single lines give rise to adequate representations but that the representation produced by the target is temporally and spatially overlaid upon the representation produced by the mask (Eriksen & Schultz, Note 2). In such a case, performance would be limited by the process of finding the representation of the target within a composite representation before decay of the target representation is complete. If lines in objects give rise to representations that are different from those produced by line segments and if the search process is slowed by similarity between background and target (Neisser, 1967), then we would expect the search process to find the representation of an object faster than it would find the representation of a single line against the background of the array of lines contained in the mask. On the assumption that representations activated by the line and object targets decay after target offset, the search process might be expected to succeed in finding the representation of an object target before decay was complete more often than it would succeed in finding the representation of the appropriate single line.

The present results provide little basis for choosing among these models. A choice will depend in part on a careful investigation of the temporal parameters of the masking effects reported here. In the meantime, it is worth considering two general issues independent of the details of the interactions of mask and target.

Role of Line Analysis in the Perception of Objects

At first glance, the results of these experiments might be taken as evidence against the view that representations of objects are formed from the results of a line analysis process. Indeed, the findings of the present experiments seem to pose a difficult paradox to such models: If formation of a representation of an object is based upon prior formation of a representation of its parts, then how can we be able to report the identity of a line in an object under conditions in which we cannot report that same line when it is presented in isolation? While this paradox may seem compelling, it disappears if we question the tacit assumption that the activation of a representation of a stimulus element can be mapped transparently into an overt response, as we have already done above (see also Pomerantz, Sager, & Stoever, 1977; Johnston & McClelland, Note 1). Thus, the results of the present experiments are just as consistent with the notion that representations of objects are based on representations of their parts as with the view that representations of objects are formed without an intervening stage of line analysis.

What Structural Properties Are Critical?

The present experiments have clearly demonstrated that the structure of the context with which a target element is presented has large effects on the reportability of that target. Recent studies in visual search and detection have reached a similar conclusion (Banks & Prinzmetal, 1976; Pomerantz et al., 1977; Prinzmetal & Banks, 1977). Exactly what structural properties are responsible for these effects is not yet clear. The results of the present studies should not be taken as evidence that three-dimensional objects have any special status. Ongoing research suggests that a variety of other kinds of context can facilitate performance in a line-mask condition. Thus, it appears that a variety of structural factors could have contributed to the differential effects of the object and control masks. It remains for further research to achieve the goal of a full account of the role of structure in perception. The present experiments suggest that the continued study of context-dependent masking effects can provide one important source of information to help us achieve that goal.

Reference Notes

1. Johnston, J. C., & McClelland, J. L. *A test of a hierarchical model of word perception.* Manuscript in preparation, 1978.
2. Eriksen, C. W., & Schultz, D. W. *Temporal factors in visual information processing.* Paper presented at the symposium "Attention and Performance VII," Marseille, France, August 1976.

References

Banks, W. P., & Prinzmetal, W. Configurational effects in visual information processing. *Perception & Psychophysics,* 1976, *19,* 361–367.

Bell, H. H., & Handel, S. The role of pattern goodness in the reproduction of backward masked patterns. *Journal of Experimental Psychology: Human Perception and Performance,* 1976, *2,* 139–150.

Biederman, I. Perceiving real world scenes. *Science,* 1972, *177,* 77–80.

Corwin, T. R., & Zamansky, H. S. Effects of texture on visual noise masking. *Journal of Experimental Psychology: Human Perception and Performance,* 1976, *2,* 162–166.

Eriksen, C. W., & Rohrbaugh, J. Visual masking in multielement displays. *Journal of Experimental Psychology,* 1970, *83,* 147–154.

Estes, W. K., Allmeyer, D. H., & Reder, S. M. Serial position functions of letter identification at brief and extended exposure durations. *Perception & Psychophysics,* 1976, *19,* 1–15.

Johnston, J. C., & McClelland, J. L. Visual factors in word perception. *Perception & Psychophysics,* 1973, *14,* 365–370.

Juola, J. F., Leavitt, D. D., & Choe, C. S. Letter identification in word, nonword, and single letter displays. *Bulletin of the Psychonomic Society,* 1974, *4,* 278–280.

Koffka, K. *Principles of Gestalt psychology.* New York: Harcourt, Brace, 1935.

Neisser, U. *Cognitive psychology.* New York: Appleton-Century-Crofts, 1967.

Pomerantz, J., Sager, L., & Stoever, R. Perception of wholes and and their component parts: Some configurational superiority effects. *Journal of Experimental Psychology: Human Perception and Performance,* 1977, *3,* 422–435.

Prinzmetal, W., & Banks, W. P. Good continuation affects visual detection. *Perception & Psychophysics,* 1977, *21,* 389–395.

Reicher, G. M. Perceptual recognition as a function of meaningfulness of stimulus material. *Journal of Experimental Psychology,* 1969, *81,* 274–280.

Schendel, J. D., & Shaw, P. A test of the generality of the word-context effect. *Perception & Psychophysics,* 1976, *19,* 383–393.

Schneider, W., & Shiffrin, R. M. Controlled and automatic human information processing: I. Detection, search, and attention. *Psychological Review,* 1977, *84,* 1–66.

Shiffrin, R. M., & Schneider, W. Controlled and automatic human information processing: II. Perceptual learning, automatic attending, and a general theory. *Psychological Review,* 1977, *84,* 127–190.

Smith, E. E., Haviland, S. E., Reder, L. M., Brownell, H., & Adams, N. When preparation fails: Disruptive effects of prior information on perceptual recognition. *Journal of Experimental Psychology: Human Perception and Performance,* 1976, *2,* 151–161.

Turvey, M. T. On peripheral and central processes in vision: Inferences from an information processing analysis of masking with patterned stimuli. *Psychological Review,* 1973, *80,* 1–52.

Weisstein, N., & Harris, C. S. Visual detection of line segments: An object superiority effect. *Science,* 1974, *186,* 752–755.

Weisstein, N., Harris, C. S., Bernbaum, K. Tangney, J., & Williams, A. Masking across extensive areas of the visual field by small localized stimuli. *Vision Research,* 1977, *17,* 341–350.

Wheeler, D. D. Processes in word recognition. *Cognitive Psychology,* 1970, *1,* 59–85.

Williams, A., & Weisstein, N. Line segments are perceived better in a coherent context than alone: An object-line effect. *Memory and Cognition,* in press.

Received September 2, 1977 ■