The role of redundancy in the object-line effect

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Subjects' identification of briefly presented target lines can sometimes be facilitated by including noninformative lines of context in the display (the object-line effect). Previous explanations for this effect have claimed that stimulus properties such as three-dimensionality, connectedness, structural relevance, line-masking, or fixation-point detail, allow line-in-context stimuli to be processed more efficiently than single-line stimuli. Instead of postulating special processing consequences for these stimulus properties, we propose two general preconditions for the object-line effect. Three experiments demonstrate that the effect occurs when lines-in-context have perceptual attributes that are correlated with the target lines and when the lines-in-context are perceptually more dissimilar from one another than the single target lines.

A number of experiments have shown that the identification of briefly presented target lines can be facilitated under some conditions by adding noninformative context lines to the display (Chen, 1982; Earhard, 1980; Klein, 1978; McClelland, 1978; McClelland & Miller, 1979; Pomerantz & Garner, 1973; Pomerantz, Sager, & Stoeve, 1977; Weisstein, Williams, & Harris, 1982; Williams & Weisstein, 1978; Womersley, 1977). For example, Williams and Weisstein (1978) reported that the diagonal lines in Figure 1 could be identified more accurately in the context of the overlapping squares than when the same lines were presented alone. This result was dubbed the "object-line effect" in order to emphasize its similarity to a finding in letter-detection experiments known as the "word-letter effect" (see Baron, 1978, for a review of this literature). The object-line effect (OLE) has generated considerable theoretical interest because it runs counter to several widely accepted principles of visual target detection. These principles include lateral masking of targets by background elements (Flom, Weymouth, & Kahneman, 1963), a decrease in the signal-to-noise ratio accompanying the addition of background elements (Estes, 1972; Estes & Taylor, 1966), and interfering effects of "good" context configurations on target detection (Banks & Prinzmetal, 1976; Gottschaldt, 1926; Millspaugh, 1978).

Much of OLE research has been aimed at specifying particular stimulus properties that facilitate the perception of target lines within a context of other lines. Weisstein and her colleagues (Lanze, Weisstein,

& Harris, 1982; Weisstein & Harris, 1974; Weisstein et al., 1982; Williams & Weisstein, 1978) proposed that lines and contexts that form well-structured, three-dimensional figures are processed more rapidly and accurately than single lines or flatter figures because of the special status the visual system affords to representations of three-dimensional objects. Chen (1982) proposed that the visual system is tuned to pick up "topological invariants" such as connectedness and thus predicted that stimuli with these properties would have a processing advantage. McClelland and Miller (1979) proposed that the processing of line figures is preferentially directed to line segments that are "structurally relevant" to the interpretation of the figure as an object. Since the OLE is generally greater when stimulus displays are followed by a mask of haphazardly placed lines, McClelland (1978) proposed that single lines and lines-in-context activate different representational systems. A line mask is thought to interfere more with the line representational system than the object representational system. Finally, a related view is that lines-in-context may engage either local or global processing systems, depending on the amount of line detail at the point of fixation (Earhard, 1980; Earhard & Armitage, 1980).

A problem that soon becomes apparent in reviewing this literature is that none of the theories have been successful in specifying necessary conditions for the OLE. For example, a reliable OLE has been obtained with flat, two-dimensional stimuli (McClelland & Miller, 1979; Pomerantz et al., 1977), with disconnected lines of context (Earhard, 1980), with structurally irrelevant target lines (Lanze et al., 1982), without using a line mask (Williams & Weisstein, 1978; Klein, 1978), and with line detail at the point of fixation (Weisstein et al., 1982). Rather than searching further for specific stimulus properties, we will develop a more general theoretical account of the OLE.

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Previous theories of the OLE hold several assumptions in common. First, they assume that particular stimulus properties have specific psychological or processing consequences. Coherent three-dimensional stimuli are claimed to be processed more rapidly than flatter stimuli; stimuli with connected or structurally relevant line segments are thought to be favored in processing over stimuli without these characteristics; postdisplay line masks and line detail around the fixation point are believed to interfere more with the visual representation of lines than of objects.

Secondly, the stimulus properties proposed by these accounts are thought to maintain their processing advantage independently of the other stimuli in the experiment. If three-dimensionality, connectedness, or structural relevance facilitate the identification of target lines under certain exposure conditions, or if line masks interfere more with line representations than with object representations, they should do so regardless of the other stimuli in the experiment. Sebrechts and Garner (1981) describe an effect as "stimulus specific" if the effect maintains regardless of the other stimuli in the experiment, that is, the effect is determined by a specific property of the stimulus and is not influenced by its discriminability relative to other stimuli. The theories outlined above all describe the OLE in terms of stimulus-specific effects.

Finally, the facilitation in performance for lines-in-context is often attributed to these lines' being more perceptible in a phenomenal sense than single lines (Weisstein et al., 1982; Williams & Weisstein, 1978; but see also Pomerantz, 1981, for an alternative view). Although this is not a necessary component of these theories, it follows naturally from the view that lines-in-context with certain properties are processed more rapidly or efficiently than single lines. The possibility that contexts aid identification by permitting target lines to be inferred has been rejected because the context lines are identical for all targets and thus are thought to contribute no unique information about the target line (Pomerantz, 1981).

The present paper advances an explanation of the OLE that differs from the previous proposals in all three of these ways. First, we do not advance any claim for the effects of particular stimulus properties on perceptual processing. Our account of the OLE does not, for instance, claim processing priority for stimuli that are three-dimensional, connected, or even "good" in the Gestalt sense. Secondly, we reject the idea that the OLE is stimulus specific. Instead, we demonstrate that the OLE for any context is critically dependent on the characteristics of the other stimuli in the experiment and not an inescapable consequence of any particular stimulus property. Finally, we reject the claim that target lines are "seen" more clearly in the context of other lines than when they appear alone.

The present proposal is that the OLE may be obtained when two conditions are met. First, the lines-in-context must be more dissimilar from one another than the lines alone. This condition acknowledges that individual line segments are not the only visual features that mediate perception and that adding the same context lines to different targets may result in stimuli that differ psychologically in more ways than is suggested by examining individual lines. Second, a correlation (i.e., redundancy) must exist between the target lines and one or more perceptual attributes of the lines-in-context. Note that the redundancy referred to here is not between target and context lines but between target lines and perceptual attributes that are formed by the interaction of target and context lines. Such attributes have been called higher-order, configural, or emergent to distinguish them from the primitive features used to create a display, such as dots or lines. Thus, stimuli with particular properties, such as three-dimensionality, will not inevitably lead to better detection performance than lines alone. A particular stimulus property will only result in an OLE if stimuli with that property happen to be more dissimilar from each other than the lines alone and if there are salient attributes of the stimuli that are redundant with the target lines.

A view that is similar to that expressed here is given by Pomerantz (1981, Pomerantz et al., 1977). Pomerantz suggests that the OLE is due to the presence of emergent features that are more directly related to the functional units of perception and so are processed faster than individual line segments. The correct target line is then inferred from knowledge of the components of the emergent features. Our view differs from that of Pomerantz in that we do not assume that emergent features are the functional units of perception or even that some stimulus attributes are processed more rapidly than others. We assert only that line-in-context attributes can provide additional information for observers to use in identifying target lines. It may be that some stimulus attributes, emergent or otherwise, are processed more efficiently than others, or it may be that some attributes simply provide an additional source of information about the target's identity (cf. Townsend & Ashby, 1982).

For the purpose of the present argument, it is not necessary to specify the precise nature of the additional information in OLE stimuli. Useful information exists at several levels of analysis, and one or all of these levels may contribute to an identification advantage. Consider as examples some correlated attributes that are present in the displays used by Williams and Weisstein (1978), shown in Figure 1. Note that the identification task for the single-line condition is simply one of position in the visual field. The line-in-context displays, however, provide several levels of additional information. Perhaps target-

Figure 1. Target lines A and B can be identified more accurately in the context of the overlapping squares than when they are presented alone (Williams & Weisstein, 1978). Several sources of information in the lines-in-context that are not available for the single lines are illustrated.

line identification is based on the type of object that is represented by the stimulus as a whole. In this case, the figures might be perceived as a "step" versus a "wall." However, the additional information need not be this global. A more local source of information might be the type of corner formed by the interaction of target and context lines. One corner can be perceived as viewed from below, while the other can be interpreted as viewed from above. At an even more local level of analysis, the angle type formed by the interaction of the target and one context line (an acute vs. an obtuse angle) may be sufficient to provide an identification advantage over the single-line case (indeed, this is shown by Berbaum, Weisstein, & Harris, 1975). These examples are presented simply to demonstrate that, regardless of the precise nature (or level) of the information in the line-in-context displays, additional information is potentially available at several levels of analysis. The important question for us was whether the OLE could be obtained when such attributes were rendered uninformative by reducing their correlation with the target lines.

Three experiments are reported that support this view. The first experiment demonstrates that the OLE is not stimulus specific but depends on the characteristics of the entire set of stimuli in the experiment. In this experiment, a robust OLE obtained with individual contexts is reversed when other, equally facilitating contexts are included and presented under identical conditions. The second experiment systematically manipulates the correlation between target lines and certain attributes of the lines-in-context. Identification accuracy is predicted by the correlation that exists in the stimulus displays between these at-

tributes and the target lines. Finally, the third experiment explores the idea that the redundant attributes of the lines-in-context must not only be physically present, but must also make the lines-in-context more perceptually dissimilar from each other than the target lines alone.

EXPERIMENT 1

As stated in the introduction, the OLE is in apparent conflict with target-detection literature, which demonstrates the interfering effects of context on performance. Contributing to this confusion is the fact that both context effects have been attributed to Gestalt or configural factors influencing the perception of targets. Experiment 1 was designed to examine a previously unexplored difference between experiments reporting superiority and inferiority effects. Although experiments finding inferiority effects typically employ a large number of contexts, superiority effects are usually obtained using a small number of contexts. We wondered whether simply increasing the number of contexts could turn a superiority effect into an inferiority effect.

There were two conditions in this experiment. In a first session, observers were presented with single-target lines as well as target lines embedded in one "object" context. In a second session, target lines were presented alone as well as in 10 different "object" contexts. The number of contexts was not increased by simply adding stimuli with similar attributes associated with each target. Weisstein et al. (1982) had no difficulty obtaining an OLE under these conditions. Instead, we sought to limit the usefulness of the additional attributes by varying the way in which they mapped onto the two target lines. If "object" contexts were more rapidly processed than single lines, or if "object" contexts facilitated the perception of component line segments, they should do so regardless of the number of different "objects." Alternatively, if an OLE was obtained only when a single "object" was presented, it would suggest that the OLE was not due to any special processing afforded by these properties. Instead, this result would suggest that target lines could be identified more accurately in the single context condition because of the additional information carried by the lines-in-context.

Method

Procedure. Ten "object" contexts, patterned after the context used by Williams and Weisstein (1978), were used in Experiment 1 (see Figure 2). All observers participated in two sessions. In the first session, each observer saw trials of only one of the 10 contexts along with an equal number of single-line trials. In the second session, observers received all 10 contexts and the single lines.

The sequence of trial events is shown in Figure 3. Each stimulus display was preceded and followed by a field containing a fixation point and a line mask similar to the mask used by McClelland (1978). Pilot tests had indicated that, although the mask was not necessary for an OLE, it tended to increase the magnitude of the

Figure 2. The 10 contexts, with target lines, used in Experiment 1.

Figure 3. The sequence of trial events in Experiment 1. In all three experiments, stimulus presentations were preceded and followed by the haphazard line mask shown.

OLE obtained for individual contexts. Thus, it was used to establish a baseline OLE for individual contexts that was as large as possible. The experimenter initiated each stimulus display. The observers responded verbally "A" or "B" according to which target line was present in the display. The observers were instructed to respond as accurately as possible and to guess when uncertain. Reaction time was not measured.

In the first session, each observer was presented with displays containing the target lines and only one of the contexts shown in Figure 2. Two observers were assigned randomly to each of the 10 contexts. Data were collected over 10 blocks of 40 trials. Half the stimulus displays contained only target lines and half contained lines-in-context. Target lines A and B were equally represented in both types of displays. Stimuli were presented in a different random order in each block.

In the second session, each observer received all 10 contexts and the single target lines. A block consisted of 40 trials of equal num-

bers of single lines and lines-in-contexts presented in random order. As in the first session, there were 10 blocks of trials and all other details were identical for both sessions.

Each session began with a review of the displays that would be presented. This was followed by a period of practice in which all the displays were presented at exposure durations beginning at 200 msec. During the practice period, at least 80 displays were presented as the exposure duration was adjusted, until an accuracy level of 70%-80% was obtained. Stimulus exposure durations were adjusted if necessary by 10 msec after each block of 40 trials to maintain an overall accuracy level of 70%-80%. This resulted in an average stimulus duration of 69 msec in the first session and 63 msec in the second session (the means of individual observers ranged from 35 to 114 msec). Feedback was provided at the end of each block of trials and was available within a block at the request of the observer.

Stimuli. The stimulus displays included the 10 contexts shown in Figure 2 as well as single-line displays. The two target lines differed only in their position in the visual field and subtended 0.5 deg visual angle. Each display subtended no more than 1.5 deg in the vertical or horizontal direction.

The stimulus displays and mask were constructed with 0.79-mm black matte LETRALINE on 5 × 8 in. standard white index cards. Masking and display fields were equated for luminance between 100 and 130 cd/m². Displays were presented using two fields of a Scientific Prototype Model GB three-field tachistoscope.

Subjects. Twenty Princeton University students with normal or corrected-to-normal vision were paid to participate for two 1-h sessions. Different observers participated in each of the experiments reported in this paper.

Results

The proportions of correct responses in Experiment 1 are presented in Table 1. Each proportion represents the mean of two observers, grouped according to the context they received in Session 1. Inspection of the mean proportions collapsed over all contexts and observers indicates an OLE (context-superiority) of 16.4% in Session 1 [$t(19) = 5.47$, $p < .001$]. No significant differences in proportions were observed between contexts in Session 1 [$F(9,10) < 1.0$, $MSe = 0.527$]. In Session 2, a significant negative OLE (context-inferiority) of -9.5% observed [$t(19) = 4.19$, $p < .001$]. The session (1 vs. 2) × display (line-

Table 1
Proportion Correct in Experiment 1

Context	Session 1		Session 2	
	Single Lines	Lines-in-Context	Single Lines	Lines-in-Context
1	.76	.87	.88	.71
2	.68	.88	.85	.83
3	.64	.90	.77	.80
4	.65	.89	.85	.76
5	.68	.87	.81	.67
6	.78	.82	.84	.67
7	.70	.88	.79	.80
8	.79	.84	.81	.74
9	.63	.92	.84	.74
10	.78	.86	.82	.73
Mean	.71	.87	.82	.73

Note—Each proportion represents the mean of two observers, grouped according to the context they received in Session 1.

in-context vs. single line) interaction was significant [$F(1,19) = 86.56, p < .001$].

Two additional analyses were conducted to ensure that this pattern of results was not artifactually due to the limited number of trials associated with each context in the second session. First, performance in Session 2 was examined for only those contexts observers had received in the first session. The context-inferiority effect maintained even when performance on only these highly practiced contexts was considered. The proportion correct for these contexts in Session 2 was not significantly different from the proportion correct for all other contexts in Session 2, .75 vs. .73, respectively [$t(19) < 1.0, SE = 0.024$], and was still significantly below performance on the single-line trials in Session 2, .82 [$t(19) = 6.01, p < .001$]. Second, performance on the first block of trials in Session 1 (20 context trials) was compared with performance on the same context in Session 2 (20 context trials). The difference between lines-in-context and single lines was 12.8% and -7.4% for Sessions 1 and 2, respectively. This difference was significant [$t(19) = 3.73, p < .001$], and reflected the identical pattern of results obtained in the main analyses.

Discussion

The results of Experiment 1 are not consistent with explanations of the OLE, which suggest that some stimulus properties are invariably processed more rapidly than others. Nor are these results compatible with the view that processing a line figure makes individual line segments more perceptible. The same contexts that facilitated target identification when presented alone in Session 1, interfered with target identification in Session 2, in which they were presented along with the other equally "facilitating" contexts in the same trial block.

These data support the notion that some information about target identity is contributed by the addition of context lines to the display. However, such information appears to be useful only when it corresponds closely to, or is redundant with, the target lines. The OLE may have been reversed in the second session of Experiment 1 because there was no consistent mapping for the attributes associated with each target line. This interpretation can be understood intuitively by considering attributes of the lines-in-contexts that may contribute additional information to the target-identification task. As mentioned earlier, one candidate for a line-in-context attribute that could be used to facilitate performance on the stimuli shown in Figure 1 is the interpretation of A as a "step" and B as a "wall." The heuristic of responding A when the stimulus was a "step" could be beneficial in the single-context condition but would be deleterious in the multiple-context condition, as

some of the contexts containing B also were "steps" (e.g., Figure 2, context 6).

A second possibility is that although line-in-context attributes may have been predictive of the target even in the multiple-context condition, there were too many of these relations to be effectively used. For example, if each of the 20 lines-in-context had one unique attribute, observers would have to retain 20 different attributes as well as their respective targets in memory. This may have been too difficult to learn in this short experiment.

Both of these interpretations suggest that stimulus properties such as three-dimensionality, or postdisplay line masks, do not lead inevitably to context-superiority or context-inferiority effects. Williams and Weisstein's (1978) context facilitated target identification only when a correspondence existed between a particular line-in-context and the target lines. McClelland's (1978) line mask also facilitated target identification only when context-line redundancy existed. The same context and line mask interfered with target identification when the line-context correspondence was reduced. The possibility that three-dimensional stimuli contain attributes that are perceptually more informative than flatter stimuli, or that masks can interfere with specific levels of representation, is deserving of further study. However, Experiment 1 clearly shows that these stimulus properties do not inevitably result in an OLE.

The results of Experiment 1 also suggest that the object-superiority and object-line effects are not strictly analogous to the word and scene effects to which they are often compared. Word-superiority effects (Baron, 1978) as well as scene-superiority effects (Biederman, 1981) seem to rely on observers' well-established knowledge about these classes of stimuli. For example, the magnitude of the word-superiority effect is correlated with reading ability (Baron, 1978). Most importantly, word-superiority and scene-superiority effects hold up strongly when a large number of stimulus contexts are used (e.g., Biederman, Glass, & Stacy, 1973; Reicher, 1969). In the present experiment there was no evidence of observers' using a priori knowledge of structural relations in the stimuli to facilitate target identification. They seemed to rely only on redundancy they could detect in the stimulus set to facilitate their performance. This suggests that the paradigm used in Experiment 1 may be useful in distinguishing other effects based on observers' prior knowledge from effects based on knowledge acquired during an experiment.

EXPERIMENT 2

Experiment 2 used the set of simple contexts shown in Figure 4 to systematically manipulate the degree

Figure 4. The target lines and contexts used in Experiment 2.

of redundancy between target lines and certain attributes of the lines-in-context. This stimulus set was derived from figures used by Pomerantz et al. (1977) in a task involving discrimination of differently oriented target lines. Pilot tests had indicated that each of these contexts presented alone resulted in a robust OLE using the paradigm of Experiment 1 (Session 1). Furthermore, it was observed that some combinations of these three contexts were sets in which particular attributes of the lines-in-context were correlated with the target lines; contexts 1 and 3 created a stimulus set in which the attributes of "triangle" and "arrow" mapped consistently onto the target lines. Other context combinations resulted in sets in which these attributes were only partially correlated (contexts 1, 2, and 3) and not at all correlated (contexts 1 and 2) with the target lines.

In addition to systematically manipulating line-context redundancy, Experiment 2 sought to generalize the results of Experiment 1 to other stimulus figures and to a target-identification task based on line orientation.

Method

The stimulus displays were constructed in the same way as Experiment 1 and are shown in Figure 4. The only change in stimulus presentation from Experiment 1 was that the stimuli appeared equally often in one of four positions around the fixation point: above, below, left, and right. The distance from the center of each target line to the fixation point was 1.25 deg visual angle. Observers responded verbally "A" if the stimulus contained a positively sloped diagonal line and "B" if the stimulus contained a negatively sloped diagonal line.

Three experimental conditions were used to vary the degree of line-context redundancy in the displays. Condition 1, the zero-redundancy condition, included contexts 1 and 2. The correlation between the presence of a triangle and target line A was zero. In other words, knowledge that a display contained a triangle would allow the observer to guess the correct target line with 50%, or chance, accuracy. Condition 2, the partial redundancy condition,

included contexts 1, 2 and 3. Here the correlation between the presence of a triangle and target line A was .33. Knowledge that a display contained a triangle in this condition would permit the correct target line to be inferred with 67% accuracy. Condition 3, the complete redundancy condition, included contexts 1 and 3. The correlation between the presence of a triangle and target line A was 1.00. In this condition, knowledge that a triangle had been presented would permit the target line to be guessed with 100% accuracy.

Each observer participated in all three conditions on separate days, in completely counterbalanced order. During each session, 384 trials were equally divided between single-line and line-in-context displays. Exposure durations were adjusted after each block of 48 trials by 10 msec in order to maintain accuracy on the single lines at 70%-80%. Mean stimulus duration was 79 msec (the means of individual observers ranged from 61 to 102 msec). Six observers, selected as in Experiment 1, served in three 1-h sessions. Practice before each session, feedback, and all other details were the same as in Experiment 1.

Results

The proportion of correct responses in Experiment 2 are shown in Table 2. The OLE obtained in each condition is the difference between the mean proportion correct for lines-in-context and the mean proportion correct for single lines. These mean differences are plotted in Figure 5 against the degree of line-context redundancy. The increase that is observed in the OLE as a function of the degree of redundancy represents significant differences in performance for the three conditions [$F(2,10)=17.35$, $p < .001$], as well as a significant linear component [$F(1,10)=33.75$, $p < .001$] that captures virtually all of the variance in these differences [$r^2 = .99$]. The OLE for the zero redundancy condition was not significantly different from zero [$t(5) < 1.0$, $SE = 0.022$], while both the partial and complete redundancy conditions had OLEs that were significantly different from zero [$t(5)=3.67$, $p < .02$, and $t(5)=5.30$, $p < .01$, respectively].

Discussion

Experiment 2 demonstrated that target identification was facilitated when a perfect correlation was maintained between target lines and certain attributes of the lines-in-context. When this correlation was

Table 2
Proportion Correct in Experiment 2

Subject	Degree of Line-Context Redundancy		
	Zero	Partial	Complete
1	.79(.80)	.80(.74)	.89(.80)
2	.75(.83)	.79(.78)	.87(.70)
3	.78(.71)	.82(.71)	.90(.63)
4	.80(.79)	.84(.76)	.90(.76)
5	.82(.81)	.79(.75)	.93(.84)
6	.82(.78)	.77(.74)	.85(.72)
Mean	.79(.79)	.80(.75)	.89(.74)

Note—The values outside parentheses indicate line-in-context performance, the values inside parentheses indicate single-line performance.

Figure 5. The object-line effect (line-in-context accuracy minus single-line accuracy) as a function of the line-context redundancy in Experiment 2. The regression line accounts for 99% of the variance.

reduced to zero, identification accuracy was no better than that for single lines, even though there were only two contexts in this condition. Furthermore, Experiment 2 showed that even partial redundancy could be used by observers to facilitate target identification.

Whereas the zero redundancy condition in Experiment 1 included 10 contexts and the complete redundancy condition only one context, in Experiment 2 these conditions included an equal number of contexts. The two contexts in each condition consisted simply of one horizontal and one vertical line segment. Yet, in one condition these contexts led to a large OLE, and in the other case they led to an OLE that was not significantly different from zero. The magnitude of the OLE was related to the degree of redundancy between attributes of the lines-in-context and target lines. These results argue even more forcefully than those of Experiment 1, that, to obtain an OLE, a correlation must exist between attributes of the lines-in-context and the target lines. Target lines were not made more perceptible by virtue of being embedded in certain contexts.

The implications of Experiment 2 extend beyond findings of object-line effects to the larger domain of object-superiority effects (the finding that some contexts facilitate target identification better than other contexts). Weisstein et al. (1982) recently reviewed the problems inherent in conducting properly controlled object-superiority experiments and provided several guidelines. These suggestions included only comparing stimuli that had the same total line length, comparing stimuli in which the local environments for the target lines were as similar as possible, and

carefully controlling or varying differences in the subjective impressions of three-dimensionality, connectedness, and structural relevance of the lines-in-context. The stimuli in the three conditions of Experiment 2 are identical in all these respects. Only the redundancy that exists between target lines and other attributes of the lines-in-context distinguish these three stimulus sets. Yet, when conditions 1 and 3 are compared, a large object-superiority effect is evident. This performance difference between the two sets of stimuli cannot be due to differences in the specific properties of the stimuli themselves, but can only be due to differences in the line-context correlations that exist in each stimulus set.

Additional insights into Experiment 2 can be gained by applying Garner's (1974) notions of perceptual "filtering" and "condensation" to the observer's task. The line-in-context stimuli can be thought of as representing a stimulus space in which the two dimensions of target type (A vs. B) and context ($\sqcap$ vs. $\sqcup$) have been varied. The zero redundancy condition is a task in which the target line must be perceptually filtered from the irrelevant contexts in order for the response to be accurately made. The complete redundancy condition is a task in which both dimensions can be perceptually condensed and correctly responded to on the basis of a single higher order attribute such as "triangle" or "arrow." The partial redundancy condition is a task in which these attributes are imperfectly correlated with the target lines. However, observers were able to utilize this limited information to their advantage. It is of interest to note that the performance gain in the partial redundancy condition is consistent with observers' uniformly applying the condensation strategy to the partial correlation between targets and other line-in-context attributes.

Pomerantz (in press) recently used stimuli like those in Experiment 2 to measure reaction time in condensation and filtering tasks. Although the data were presented in order to address a different set of issues, the results were similar to ours. Conditions in which the two responses correlated perfectly with the attributes of triangle and arrow yielded the fastest reaction times, conditions in which the responses correlated only with the target lines yielded intermediate times, and conditions in which responses were not correlated with either the triangle-arrow dimension or the target lines yielded the slowest times.

EXPERIMENT 3

In the previous experiments, no stimulus-specific property was found to be sufficient for an OLE. Robust OLEs obtained with particular contexts were eliminated or reversed by including other equally facilitating contexts and by eliminating the correlation between line-in-context attributes and target

lines. The significance of these experiments is not that stimulus variables are unimportant to the OLE. Rather, in order to obtain an OLE there must be some attribute of the line-in-context that provides information about the target line. From the observer's point of view, an OLE would be obtained if the problem of discriminating a pair of lines-in-context is easier than discriminating the two target lines. This idea was tested by using dissimilarity ratings, made under free viewing conditions, to predict the magnitude of the OLE. Five line-in-context pairs were chosen from a larger pool of rated stimulus pairs. An additional condition that included all five contexts served as a multiple-context control for comparison with the other single-context conditions.

Method

Dissimilarity ratings. Twenty-three line-in-context pairs were designed to create a set of figures that varied in judged intrapair similarity. Each pair contained the two target lines as well as two to four additional lines of context. Each stimulus pair was drawn in black ink in the center of a 4 × 6 in. white index card. At a viewing distance of 40 cm, the target lines subtended approximately 0.5 deg visual angle.

Raters were individually instructed to first look through the shuffled deck of 24 cards, noting that some pairs of figures appeared more similar/dissimilar to one another than other pairs. Raters were then asked to assign to the most similar pair in the deck a value of 0 and to the most dissimilar pair a value of 10. These two cards were set aside and the rater proceeded through the reshuffled deck of cards, assigning values of 0 through 10 to each pair of figures, corresponding to their perceived dissimilarity.

Five contexts, shown at the top of Figure 6, were chosen for the second phase of Experiment 3 on the grounds that they spanned the entire range of ratings at approximately equal intervals. The mean dissimilarity ratings (standard deviations in parentheses) for these contexts were 8.6 (2.2), 6.5 (2.1), 4.4 (1.8), 2.4 (1.5), and 1.0 (0.8), respectively. The mean dissimilarity rating of lines alone was 1.4 (2.1).

Procedure. The stimulus displays were constructed and presented in the same way as in Experiment 2. There were six conditions, one condition corresponding to each of the five contexts chosen from those rated and a sixth condition that included all five contexts.

Observers participated in three sessions of 1-h duration. Two conditions were run in each session, with the order of conditions

counterbalanced across sessions, using an incomplete Latin square. Each of the single-context conditions included 192 trials of the line-in-context and single-line displays in 48-trial blocks. The multiple-context condition included 240 trials in 80-trial blocks. The order of presentation was random within each block. Exposure duration was adjusted after each block to maintain identification accuracy for single lines at 70%-80%. The mean exposure duration was 89 msec (the means for individual observers ranged from 75 to 98 msec).

Subjects. Fifteen Princeton University students with normal or corrected-to-normal vision were paid to participate as raters in Experiment 3. Six different students were paid to participate for three sessions in the second phase of Experiment 3.

Results

The proportion of correct responses in Experiment 3 are shown in Table 3. The difference between the mean proportion for lines-in-context and the mean proportion for single lines represents the OLE for each condition. The OLEs for the five single-context conditions are plotted in Figure 6 as well as the OLEs for the same contexts in the multiple-context condition, against their mean dissimilarity ratings. These ratings predict the magnitude of the OLE for the single-contexts quite well [$F(1,4)=21.43$, $p < .02$; $r^2 = .88$], whereas performance on the same contexts in the multiple-context condition is not significantly predicted by these ratings [$F(1,4)=4.08$, $MSe=2.21$].

Conditions 1 and 2 had OLEs not significantly different from zero [both t values < 1.0], while the OLEs of conditions 3, 4, and 5 were all significantly greater than zero [$t(5)=4.35$, $p < .01$, $t(5)=8.08$, $p < .001$, and $t(5)=8.60$, $p < .001$, respectively]. No significant differences were observed between performance on the contexts in the multiple-context condition [$F(4,20) < 1.0$, $MSe=0.458$] and the mean OLE for this condition was also not significantly different from zero [$t(5)=1.43$, $SE=0.542$].

Discussion

In a similar way to the first two experiments, Experiment 3 demonstrated that an OLE was obtained only when a correspondence was maintained between

Table 3
Proportion Correct in Experiment 3

Subject	Single Contexts					Multiple Contexts
	Condition					Six
	One	Two	Three	Four	Five	
1	.74(.82)	.77(.79)	.88(.79)	.91(.69)	.92(.75)	.78(.82)
2	.83(.76)	.74(.74)	.75(.71)	.82(.71)	.84(.65)	.71(.73)
3	.92(.80)	.82(.76)	.82(.79)	.99(.70)	.96(.80)	.80(.80)
4	.86(.78)	.77(.75)	.79(.70)	.97(.71)	.88(.71)	.85(.79)
5	.74(.80)	.76(.79)	.74(.69)	.93(.76)	.89(.75)	.75(.83)
6	.55(.77)	.76(.77)	.86(.72)	.95(.72)	.94(.65)	.71(.78)
Mean	.77(.79)	.77(.77)	.81(.73)	.93(.72)	.91(.72)	.77(.79)

Note—The values outside parentheses indicate line-in-context performance, the values inside parentheses indicate single-line performance. Context conditions 1-5 are listed in descending order of rated dissimilarity.

Figure 6. The object-line effect in Experiment 3 as a function of dissimilarity ratings for the line-in-context pairs. Solid circles represent the single-context conditions and open circles represent the same contexts in the multiple-context condition. The regression line accounts for 88% of the variance.

target lines and other attributes of the lines-in-context. However, this experiment also showed that a simple correspondence between target lines and one context was not in itself sufficient to yield an OLE, as evidenced by conditions 1 and 2. It was not until the perceived intrapair dissimilarity of the lines-in-context exceeded the perceived dissimilarity of the single target lines that an OLE was obtained. A simple linear model associating perceived dissimilarity of the lines-in-context with the magnitude of the OLE for individual contexts seemed to characterize this relation quite well.

No attempt was made to tightly control total line length, the local environment of the target line, or the judged connectedness, three-dimensionality, or structural relevance of the stimuli (Weisstein et al., 1982). Nonetheless, an inspection of the relative magnitudes of the OLEs obtained does not suggest that the contexts are ordered along any continuum based on these stimulus properties. Whereas any or all of these properties may make two lines-in-context more dissimilar from each other than two target lines under some conditions, Experiment 3 reinforces the findings of

the first two experiments that the mere presence of these properties was not sufficient to yield an OLE.

These results also demonstrate that direct dissimilarity ratings provide at least a first approximation to the prediction of OLEs. One way in which to consider such ratings is as a relative measure of the "information gain" associated with the addition of contexts to target lines. Used in this way, dissimilarity ratings may be useful to other experimental paradigms that attempt to predict superiority effects in target detection, including face-superiority (Mermelstein, Banks, & Prinzmetal, 1979; Homa, Haver, & Schwartz, 1976) and other context-superiority experiments (Weisstein et al., 1982). For instance, dissimilarity ratings between faces that differ only in one feature could be used to predict which combinations of features would result in a face-superiority effect. The extent to which intrapair ratings differed between faces could be used as a measure of the information contributed by emergent or configural attributes to the identification task.

GENERAL DISCUSSION

The three experiments reported here demonstrated that none of the stimulus properties that have been proposed to account for the OLE, such as three-dimensionality, connectedness, structural relevance, line-masking, or fixation point detail, constitute sufficient conditions for the OLE. The results of these experiments also suggest that no assumptions need to be made regarding the processing that target lines receive in context versus when they appear alone. We observed failures to obtain an OLE that were not due to the absence of particular stimulus properties or to the choice of a particular presentation method. Whether an OLE was obtained with a particular context was shown to be critically dependent on the other contexts in the experiment. In the first experiment, a robust OLE was reversed by increasing the number of contexts that were presented, even though each of the contexts alone was equally "facilitating." Increasing the number of contexts appeared to make it impossible for observers to use additional line-in-context information, either because no redundancy remained between targets and other attributes or because the number of attributes associated with each target exceeded the observers' ability to remember them. In the second experiment, the magnitude of the OLE was shown to depend on the redundancy between certain line-in-context attributes and the targets, in a situation in which the number of attributes associated with each target did not exceed the observers' ability to remember them. The final experiment showed that a line-context correlation was perceptually useful only when the lines-in-context were more dissimilar from each other than the target lines alone.

Despite the obvious differences between this and earlier interpretations of the OLE, the present account agrees with Weisstein and Harris (1974) that theories postulating single-line segments as the critical features in pattern recognition are fundamentally inadequate. Both the present view and earlier explanations are based on the observation that the visual system is sensitive to attributes other than straight-line segments. Previous accounts used this observation to claim that the visual system was more sensitive to stimuli with such properties as three-dimensionality, connectedness, or structural relevance, than it was to single lines. Our view is that the visual system uses additional information in a more straightforward manner. If the additional attributes are correlated with the target lines, and if they make the lines-in-context more dissimilar from one another than the lines alone, they apparently can be used to the observer's advantage in identifying the target. Explaining the OLE in terms of interstimulus similarity and redundancy does not, in our view, trivialize its potential contribution to an understanding of context effects. Instead, it provides a framework in which stimulus properties such as three-dimensionality, connectedness, and structural relevance can contribute to the OLE without having to postulate stimulus-induced changes in the nature of perceptual processing. These properties can apparently be used effectively to create strikingly different stimuli simply by changing one line segment (the target line) in a stimulus. It is the perceptual dissimilarity between the context pairs that these properties affect rather than the way in which the stimulus is processed.

We have described the effect of context in the OLE in terms of attributes that make the stimuli more or less dissimilar, but have not addressed the fundamental question of what determines perceptual similarity. One way similarity can be expressed is in terms of feature overlap between stimuli (Tversky, 1977). Following this suggestion, lines-in-context have additional features that single lines do not have. If the additional features are unique for particular target lines they may permit a redundancy gain to occur. Alternatively, similarity can be expressed as the distance between stimuli or objects in a multidimensional psychological space (Shepard, 1974). In this conceptualization, lines-in-context are located further apart in similarity space than lines alone because they differ on a greater number of dimensions. For example, the lines-in-context in Experiment 2 may be distributed along a "triangle-arrow" dimension as well as a "target line A vs. B" dimension. If the values of the stimuli are correlated on these two dimensions, they may permit a redundancy gain to occur. Both of these descriptions of psychological similarity are consistent with our results.

It is important to note that these experiments do not mean that pattern goodness, in the Gestalt sense, has no important consequences for other information processing tasks. Several experiments demonstrate that it is harder to identify a target when it is embedded in a context that is "good" (Banks & Prinzmetal, 1976; Mermelstein et al., 1979; Millspaugh, 1978; Prinzmetal & Banks, 1977). In contrast to these context-inferiority effects, several studies have demonstrated that "good" contexts have an advantage in memory. For example, Sebrechts and Garner (1981) found that pattern goodness facilitated performance in a successive same-different comparison task only when the good pattern was presented first and thus had to be held in memory for the comparison process. When good patterns were presented second, there was no effect of pattern goodness on observers' performance. Mermelstein et al. (1979) reported a similar finding using a target-detection task. When schematic faces were presented and had to be held in memory, targets in coherent faces were easier to detect than were targets in scrambled faces. However, when the target was presented first, target detection was better with scrambled faces. Pattern goodness can also influence the way features are integrated. Prinzmetal (1981) demonstrated that features from the same perceptual units (defined by the Gestalt laws) were more likely to combine than were features from different perceptual units.

In conclusion, previous explanations of the OLE held that target lines were more perceptible when embedded in certain types of contexts. Kinchla (1977; Kinchla, Solis-Macias, & Hoffman, 1983) has pointed out that such a position is difficult to distinguish from the view that higher order attributes allow lower order attributes to be inferred through the knowledge of structural redundancies. For example, the perception of a human face is so closely correlated with the presence of two eyes that it is difficult to determine whether both eyes have been "seen," or whether the presence of one of the eyes has simply been inferred. The present experiments were able to distinguish these two positions for the OLE by artificially manipulating the structural redundancies that were present in the displays. Under these conditions, the same contexts did not invariably give rise to an OLE. Contexts facilitated target identification only when the lines-in-context were "informative" in the sense that they contributed redundant information about the target line that the observer could use.

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