Emergent features: A new factor in the object-superiority effect?

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Lanze, Weisstein, and Harris (1982) reported object-superiority effects in which subjects' accuracy for identifying target lines in patterns was correlated more with the patterns' apparent three-dimensionality than with structural relevance of target line to overall pattern. This result (Lanze et al., 1982, Experiment 3) was potentially confounded by the presence of triangular- and arrow-shaped emergent-feature patterns in the pattern that was high in three-dimensionality and low in structural relevance. We report two experiments in which these emergent features and perceived depths are independently varied in a target-identification task. In both experiments, patterns that were high in perceived depth yielded higher accuracy scores than did those low in perceived depth (regardless of emergent features). Similarly, high-emergent-features patterns yielded higher accuracies than did low-emergent-features patterns (regardless of perceived depth). It is argued that each of these factors independently contributes to the object-superiority effect.

In 1974, Weisstein and Harris reported that line segments were more accurately identified in object-like contexts than in control contexts matched to these object contexts in basic features (e.g., number, length, and orientation of nontarget line segments). The basic result has been replicated numerous times (see Klein, 1978; Lanze, Weisstein, & Harris, 1982; Williams & Weisstein, 1978; Womersley, 1977). McClelland (1978) and Williams and Weisstein (1978) have even shown that, under certain conditions, an object-line effect occurs (i.e., that the target line is more accurately identified when presented in an object context than when presented alone).

A strategy in subsequent research has been to specify the properties of contexts that facilitate or impede line identification. A number of such factors have been identified. Earhard (1980) and Earhard and Armitage (1980) have shown that the location of the fixation point, relative to the target and remaining display lines, affects identification accuracy. In their experiments, target-identification accuracy decreased when the fixation point was moved from an empty space to a line or an area of converging lines, despite constant target-to-fixation-point distance.

The location of the target line relative to other lines in the display is known to affect identification accuracy. McClelland and Miller (1979) have shown that a target forming an outside boundary of a pattern is identified more accurately than one that is surrounded by other lines.

A major problem has been specifying global pattern characteristics that contribute to object superiority. Overall pattern connectedness and perceived depth of pattern are two such factors (Chen, 1982; Genter & Weisstein, 1980; Weisstein & Maguire, 1978; Weisstein, Williams, & Williams, 1979). Weisstein, Williams, and Harris (1982) directly compared these two factors and demonstrated that target-identification accuracy is more highly correlated with perceived depth of patterns than with perceived connectedness of the same patterns. Structural relevance of the target line to the overall pattern has been suggested also to be a factor in object superiority (McClelland & Miller, 1979). In a previous investigation, Lanze et al. (1982) directly compared these two factors that had generally covaried in earlier studies. Their independent contributions to the object-superiority effect were assessed in a factorial design. The results showed that perceived depth appeared to be the more important determinant of identification accuracy in the detection task.

In the Lanze et al. (1982) study, the pattern perceived most accurately by subjects was the one that was rated high in depth but low in structural relevance of the target lines and formed local "arrow" and "triangle" configu-

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rations with the target line. These local configurations might have contributed to the high accuracy of this condition, confounding earlier conclusions.

The high discriminability of arrow and triangle configurations when they form isolated contexts matched for all but the orientation of a target line segment has been demonstrated a number of times (see Pomerantz, 1981; Pomerantz, Sager, & Stoever, 1977; Pomerantz & Schweitberg, 1975). Pomerantz has hypothesized that the high discriminability is due to the sensitivity of the pattern-recognition process to "emergent features" (Pomerantz et al., 1977). Pomerantz posited that emergent features (configurations of basic features) might be directly registered by the visual system.

In a recent paper, Enns and Prinzmetal (1984) argued that the object-line effect is due to correlations of emergent features with particular target-line alternatives in the particular contexts. They demonstrated this effect for isolated arrow and triangle configurations, essentially replicating the work of Pomerantz et al. (1977), but they did not directly demonstrate the salience of these local configurations when they were embedded in the more complex contexts usually used in object-superiority studies.

We undertook the present experiments to verify that emergent features are effective in the object-superiority effect and to look at the effect of depth when structural relevance is low and formation of local emergent features is unlikely.

EXPERIMENT 1A

The stimuli used in this experiment are shown in the first two columns of Figure 1. Patterns A and C were considered to be high in emergent features since, in both cases, the target lines form triangles and arrows with the immediately surrounding context lines. Patterns B and D, with their target lines pulled away from the context boundaries, were considered to be low-emergent-features conditions.

Method

Ten subjects, naive as to the purpose of the experiment, rated the patterns shown in Columns 1 and 2 of Figure 2 for perceived depth. Five different subjects performed the line-identification task, judging which of the two possible target lines (Row E in Figure 1) appeared in each briefly presented display. These subjects, too, were unaware of the purpose of this experiment. All 15 observers had normal or corrected-to-normal vision.

The rating task. The ten patterns shown in Figure 1 were drawn in random order. Patterns 2A-2D were all 2.45 cm in width and 2 cm in height. Pattern 2E was .8 cm in width and .8 cm in height. Written instructions accompanied these stimuli, directing the subjects to rate the patterns for perceived three-dimensional quality.

The patterns were rated against a standard figure that was designed to be particularly high in perceived depth. The standard figure used for the ratings was a drawing of a pyramid: four sides (each equilateral triangles) on a square base. Only the front and the right sides of this figure were visible; the right side was shaded and drawn in perspective. A fixation point was located in the center of the figure.

For the depth ratings, subjects were instructed to assign a rating of 10 to a pattern if it appeared to be as three-dimensional as the standard figure. Lower ratings were to be used for patterns that appeared less three-dimensional, down to a rating of 1 for a pattern that appeared perfectly flat. A fixation point was placed slightly below the center of the long diagonal target line in each pattern. The subjects were asked to gaze at the fixation points while making their judgments. Subjects rated each pattern once and were allowed as much time as needed to make their judgments.

The line-identification task. The stimuli shown in Figure 1 were presented as bright lines on a dark CRT screen, for a display duration of 20 msec. The stimuli ranged from .5 to 1.2 cm in width (.29° to .69° visual angle) and from .5 to 1.1 cm in height (.29° to .63° visual angle). Each diagonal target line was .55 cm in length (.32°). To facilitate fixation, the fixation point was slightly brighter than the target and context lines and was present continuously. No pre- or postmasks were used.

Subjects were instructed to gaze at the fixation point before and during display presentation. A chinrest maintained viewing distance at 1 m. Subjects initiated each display presentation by depressing a foot switch. They were instructed to judge which of the two target lines was present in the display and to indicate their judgment by depressing one of two keys on a DECwriter terminal. A plus or minus sign appeared on the screen after each trial indicating whether the subject had responded correctly or incorrectly. A PDP-11 computer controlled stimulus presentation and recorded responses.

The task was carried out in a darkened room. Subjects dark-adapted for 10 min and were then given 15 min of practice. Dur-

	1	2	3 Depth Rating	4 Accuracy (% Correct)
A			8.8	69.7
B			9.0	61.9
C			2.7	60.0
D			3.0	51.2
E			—	88.7

Figure 1. The patterns used in Experiment 1A are shown in Columns 1 and 2. Column 3 gives mean depth ratings. Column 4 gives mean accuracy on the line-identification task.

ing the practice period, display illumination was adjusted to produce an overall accuracy level of approximately 70%–75% correct. The luminance levels for the different subjects ranged from 2.5 to 3.5 cd/m².

Each subject completed a total of 320 randomly ordered experimental trials—64 for each context pattern and 64 for lines alone. The two target lines appeared equally often. Rest periods were given after every 80 trials.

Results

Ratings. A single-factor ANOVA was performed on the ratings for Patterns 2A–2E. A significant effect was found for depth [$F(4,36) = 83.9$, $p < .001$]. Mean ratings for the four context patterns used in the line-identification task are shown in Figure 1, Column 3. Newman-Keuls tests on the depth ratings showed that Patterns A and B each differed significantly from Patterns C and D, but the patterns in these two pairs did not differ significantly from each other [A vs. C: $q=124$, $p < .01$; A vs. D: $q=116$, $p < .01$; B vs. C: $q=128$, $p < .01$; B vs. D: $q=120$, $p < .01$; A vs. B: $q=4$, ns; C vs. D: $q=8$, ns]. Additionally, Patterns A, B, C and D all differed significantly from Pattern 2E [$q=147$, $p < .01$; $q=151$, $p < .01$; $q=23$, $p < .05$; $q=31$, $p < .05$].

Accuracy. Mean accuracies for the target-identification task are given in Figure 1, Column 4. T tests showed that accuracy for the lone target lines was significantly higher than for all of the target-in-context patterns [A vs. E: $t(4)=5.24$, $p < .01$; B vs. E: $t(4)=9.4$, $p < .01$; C vs. E: $t(4)=5.44$, $p < .01$; D vs. E: $t(4)=10.84$, $p < .01$]. For the two pairs of patterns that differed in rated depth, the mean accuracy levels were 65.8% for the high-depth pair and 55.6% for the low-depth pair. The pairs of patterns which differed in emergent features yielded mean accuracies of 64.8% for the high-emergent-features pair and 56.6% for the low-emergent-features pair. A 2×2 ANOVA on depth (high or low) and emergent features (high or low) showed significant effects for each of these factors [$F(1,4) = 45.7$, $p < .005$; $F(1,4) = 13.0$, $p < .025$]. The interaction of depth and emergent features was not significant [$F(1,4) = .09$].

Discussion

The results of Experiment 1A are predicted, to a large extent, by the findings of Lanze et al. (1982). Rated three-dimensionality (of the patterns) was shown to be strongly correlated with subjects' abilities to identify target lines embedded in patterns. As in Lanze et al. (1982), the pattern that yielded the highest accuracy was that which satisfied two conditions: the overall pattern was highly three-dimensional, and the target lines formed arrow or triangle emergent features with context lines in their immediate environment. The superior target identification rendered by patterns high in both three-dimensionality and emergent features over other types of patterns appears to support a role for both three-dimensionality and unique configurational properties in the object-superiority effect. Of further interest was the apparently independent contribution of each factor to the object-superiority effect. Since

we felt this was an important finding, albeit a null result, we attempted to replicate these results in a second experiment, using a slightly different stimulus set.

EXPERIMENT 1B

The patterns used in Experiment 1B are shown in Figure 2. The stimulus set is the same as in Experiment 1A except the baseline condition (Row E) tested the emergent-features patterns alone rather than lines alone. The task was still for subjects to judge which of the two diagonal target lines was present on a given trial.

Method

Nine new subjects, all naive as to the purpose of the experiment, performed the line-identification task. The apparatus and procedure were the same as in Experiment 1A. Each subject completed a total of 240 experimental trials—48 trials each for Patterns 2A–2E.

Results and Discussion

Mean accuracy scores are given in the last column of Figure 2. The baseline condition (Figure 2, Row E) again yielded higher accuracies than Patterns A, B, C, and D. T tests, however, showed that these differences were significant only for Patterns C and D [$t(8)=2.42$, $p < .05$; $t(8)=4.40$, $p < .01$]. A 2×2 ANOVA was performed

	1	2	3 Depth Rating	4 Accuracy (% Correct)
A			8.8	72.2
B			9.0	72.0
C			2.7	66.7
D			3.0	59.7
E			4.5	79.2

Figure 2. The patterns used in Experiment 1B are shown in Columns 1 and 2. Column 3 gives mean depth ratings. Column 4 gives mean accuracy on the line identification task.

for Patterns A-D with depth and emergent features the factors. The results correspond closely to the previous experiment. The effect of depth was significant [$F(1,8) = 14.0$, $p < .01$]. The high-depth patterns yielded a mean accuracy of 72.1%, and the low-depth patterns yielded a mean accuracy of 63.2%. The effect of emergent features also was significant [$F(1,8) = 6.27$, $p < .05$]. High-emergent-features patterns yielded a mean accuracy of 69.5%, and the low-emergent-features patterns yielded a mean accuracy of 65.9%. The interaction of depth and emergent features again was not significant [$F(1,8) = 1.72$], although a completely independent contribution of the two factors is not as clearly indicated by these data.

The 3.6% difference between high- and low-emergent-features conditions is somewhat smaller than the 8.9% difference between pairs of patterns differing in three-dimensionality and is smaller than the differences found in the previous experiment.

Enns and Prinzmetal (1984) have reported that the accuracy associated with particular conditions in object-superiority experiments can be affected by the other conditions included in the experiment. In particular, the correlation between target-line orientation and the presence of particular emergent features can be affected by the full set of conditions presented. Such reasoning would predict increased salience of the emergent features in the present experiment and, therefore, does not explain the present differences. The differences in the two sets of results seem less compelling overall than the similarities, but admittedly the overlap in the sets of conditions is greater than in studies demonstrating such differences (Enns & Prinzmetal, 1984).

GENERAL DISCUSSION

Taken together, these experiments provide evidence that, in addition to perceived pattern depth, emergent-features is an important factor in producing object(context)-superiority effects. In both experiments, pattern depth was significant in a two-way ANOVA, and the three-dimensional patterns yielded higher accuracies than the relatively flat patterns. In both experiments, the emergent-features effect was significant in a two-way ANOVA. Subjects had higher accuracies in high-emergent-features conditions, whether or not the particular pattern appeared three-dimensional.

In these experiments, the emergent-features effect was operationally defined in terms of configurational aspects of the stimuli. Specifically, stimuli in which the oblique target formed triangular- or arrow-shaped figures with the immediate local environments, were defined as high-emergent-features conditions. In a low-emergent-features condition, the target line was situated away from the context border and was relatively isolated from the remaining context line segments.¹ Pomerantz et al. (1977) gave evidence for the perceptual salience of the triangular- and arrow-shaped configurations in RT tasks. Whether local, global, or other aspects of these figures are responsible

for their salience is not clear from existing data. Pomerantz et al. (1977) noted that local features emerged (e.g., vertices and intersections) as well as global features (e.g., symmetry and closedness) when the L-shaped context was placed around the oblique targets. Their Experiment 2, however, showed that (bilateral) symmetry alone is not a sufficient condition for a pattern to be perceptually salient. Furthermore, as Earhard (1980) and Earhard and Armitage (1980) have shown, placing a target line and fixation point near additional line detail and intersections serves to impair, rather than facilitate, identification of the target. It is possible that the triangular and arrow shapes are directly detected by relatively smart perceptual devices and not derived from simpler features (see Pomerantz, 1978; Runeson, 1977).

The experimental results support the contentions of Pomerantz et al. (1977) and, more recently, of Enns and Prinzmetal (1984) that (arrow, triangle) emergent features are an important factor in producing object(context)-superiority effects. When the target lines are shifted so that "arrow" and "triangle" configurations are formed by target and context lines, response accuracy increases with no other changes in pattern configuration.

Consistent with previous studies (see Lanze et al., 1982; Weisstein & Harris, 1974; Williams & Weisstein, 1978; Womersley, 1977), we also found a robust effect of apparent depth of the context upon identification accuracy when the patterns were closely matched for local intersections which might give rise to local emergent features. This depth effect was also present when the target lines were not connected to any context lines.

We find ourselves, therefore, in general disagreement with the conclusions of Enns and Prinzmetal (1984). They conclude that the object-line effect and, by implication, the object-superiority effect are caused by the context creating emergent features, which come to be correlated with one or another of the target alternatives. The crux of our disagreement centers on whether Context B can be said to contain emergent features that correlate with the target lines and that are absent or less salient in Context D. It is admittedly difficult to deny this possibility when the state of present research does not allow us to specify in advance the full range of pattern attributes that may function as emergent features in pattern recognition. Such features may include symmetries or other unspecified global aspects of patterns. Nonetheless, we feel there are no obvious local cues in the figures we selected to test.

In this study, as in a number of others, the most salient characteristic of contexts yielding the highest accuracies is their apparent three-dimensionality. This is true even when other factors, such as number and total length of context lines, are controlled for. This stimulus property was never correlated with any of the targets in these studies, and so the perception of three-dimensionality per se as an emergent-pattern feature did not determine the subjects' responses.

We believe that the three-dimensionality of the context may contribute to detection of the target line. It is possible that pattern three-dimensionality is effective because

three-dimensional patterns of the type we have used are more likely to form unique emergent features with the target lines; however, in the absence of compelling candidate features, we feel less than compelled by this argument. In the light of present evidence, it is just as likely that configural properties that create pattern depth directly contribute to target line perception without mediation of emergent features in the way that Enns and Prinzmetal (1984) suggest.

The general effect of adding context to target lines is to reduce target accuracy through masking and related interruptive processes. For certain contexts, rated high in perceived depth, these effects are considerably attenuated, and accuracy remains high despite local conditions which appear to reduce accuracy as part of other contexts. This object-superiority effect may be caused by facilitative feedback by higher order representations to lower-level line-detection elements. Alternatively, enhanced target detection might result from filtering of target information by such representations having greater efficiency (Weisstein & Maguire, 1978). When these enhancement effects exceed masking effects associated with the contexts, an object-line effect is expected. The creation of emergent features by addition of context can also be expected to contribute to both object superiority and object-line effects. This contribution appears to be largely independent of and in addition to context three-dimensionality per se.

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NOTE

1. The argument can be raised that "pulling" the target line away from the context borders to create the low-emergent features conditions is equivalent, in effect, to turning a structurally relevant target into a structurally irrelevant target. The structural relevance ratings for the patterns in Figure 1 show, however, that subjects do not perceive the oblique lines making up the triangle and arrow configurations (e.g., Pattern 1A) as structurally relevant when compared to the same oblique lines in other configurations.