Apparent depth and texture differences in illusory figure patterns: A paradox resolved

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In the first of three experiments, a pattern that induced an illusory figure was presented upon a field of small dots. In confirmation of a previous suggestion, the effect the illusory figure had on the apparent relative density of those dots was opposite to that which would be expected for a figure that appears to be nearer than the surround. Two subsequent experiments showed, however, that this anomaly was simply due to a confounding of illusory depth with illusory lightness.

Illusory figures occur when certain patterns, presented upon homogeneous backgrounds, induce the appearance of stepwise lightness gradients upon the background. Generally, if not always, if those patterns are in the form of ink on paper (as opposed to free-standing constructions, e.g., Ware & Kennedy, 1978), the figure that results is seen at a depth that is different from that of the surround, and that has led to a striking paradox. Kennedy and Lee (1976) discovered, albeit informally, that if texture is introduced in the form of dots within and around a pattern that produces an illusory figure that appears to be in front of the surround (e.g., Figure 1), those dots will seem to be less concentrated (less dense) "on" that figure than in the surround. This, of course, is exactly the opposite of what would be expected according to the principle of size scaling: the nearer appearing of retinally identical distances ought to appear to be smaller, including distances between the centers of texture elements. Needless to say, this contrary effect has served as a major obstacle to a thoroughly consistent understanding of illusory figures (see the comments of Pritchard & Warm, 1983). The present research first formally confirmed, but later also resolved, this difficulty.

EXPERIMENT 1

Method

A total of 32 naive undergraduate volunteers were each individually shown the pattern depicted in Figure 1. The pattern was 11.5 cm in height and was viewed from a distance of 1.8 m under ordinary room illumination.

After general comments requesting that the subject observe the rectangular area and its surround carefully, each subject was instructed as follows: "I'm going to ask you three things about those two areas; that is, about the size of the dots inside and out, the whiteness of the paper between the dots inside and out, and finally about the concentration of the dots. This last one is the hardest to explain, but what we mean is the distance from the center of one dot to the center of the next regardless of how big they are. To take an example of this, as long as there is one person sitting in each seat of a theatre, the concentration is the same whether they are small children or large adults."

It will be noted that although primary interest was in an apparent difference in concentration, it was also of interest to ask about an illusory lightness difference and an illusory difference in the size of the dots. The former was necessary for reasons that will become clear later; the latter was important because size, like apparent concentration, should be influenced by an illusory depth difference.

It will also be noted that the way in which each subject was queried concerning these qualities was "sequence-free" in the sense that all three questions were presented together. The intention, of course, was to prevent the subject from feeling the need to report one illusory effect (e.g., a lightness difference) as a positive response to a qualitatively different question (e.g., as a difference in concentration). Finally, after viewing the display for approximately 15 sec, the subject was asked, for each quality in turn, whether there appeared to be a difference between the inside of the rectangular area and the area outside it with respect to that quality (i.e., the subjects were permitted to respond that there was not), and, if so, what that difference was.

Results and Discussion

As expected from Kennedy and Lee's (1976) informal demonstration, if not from theory, a majority of the present observers (i.e., 21 of 32) reported a lower concentration within the area of the illusory rectangle,

Figure 1. The pattern employed in the first experiment.

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whereas only a few (7 of 32) reported more concentration there [$\chi^2(1) = 7.00$, $p < .01$]. In striking contrast, however, a majority of these subjects (i.e., 22 of 32) also reported that the dots within the illusory rectangle appeared to be smaller, whereas only a small group (again, 7 of 32) reported the opposite effect [$\chi^2(1) = 7.76$, $p < .01$]. This latter result is, of course, what would be predicted from size scaling if the illusory surface appeared to be nearer and, in fact, confirms an earlier finding by Coren (1972) that a small circle located within an illusory figure appears to be smaller than an identical circle outside it (see also Porac, 1978, Experiment 1). In sum, then, the reports concerning the apparent relative size of dots were consistent with the possibility that the illusory figure would appear to be closer than its surround and that size scaling was operative, but yet, for some reason, the latter was not apparent with respect to relative concentration.

One potential explanation stems from still a third expected result: Twenty-nine of these subjects reported that the illusory figure appeared to be lighter than its surround, and only 1 reported it as darker [$\chi^2(1) = 26.13$, $p < .01$]. In fact, all 21 of the subjects who reported less concentration inside also reported that the inside tended to be lighter. The intriguing suggestion was, therefore, that the relatively lighter areas between the dots within the illusory figure tended to produce the impression of less concentration there—a tendency which, if strong enough, could have overpowered the tendency toward increased concentration that would otherwise have resulted from size scaling. A second experiment sought to demonstrate such an effect of a very similar, but physically real, lightness difference on apparent concentration.

EXPERIMENT 2

Method

Two additional groups of 32 naive observers were each individually tested using exactly the same procedure as was employed in the first experiment, except for the stimulus pattern that each was shown. In this case, the subjects were asked to compare the areas inside and outside a real contour (thick black lines forming a rectangle; see Figure 2). In addition, a real, but exceedingly small, difference in lightness was present (luminance of 73 vs. 88 cd/m^2), the inside being slightly darker than the outside for one group and slightly lighter for the other. The black elements of Figure 1 were omitted so that the effect of lightness on density would be examined when pictorial depth effects (which should also affect concentration) were minimized.

Results and Discussion

As hypothesized, relative lightness did, indeed, tend to produce an illusory appearance of differing concentration. For those subjects who observed a pattern in which the rectangle was lighter, 23 reported less concentration within that rectangle: the opposite appearance was reported by 29 subjects in the other group [for this interaction, $\chi^2(1) = 25.91$, $p < .01$]. Moreover, the real difference in lightness that produced this effect was very

Figure 2. The black elements of the two patterns employed in the second experiment. In the originals, a very small lightness difference was present between the enclosed area and the surround. This was so slight as to go unreported by a few subjects and to be irreproducible here.

similar, in detectability at least, to the illusory lightness differences induced by Figure 1: in each group, 30 of 32 subjects detected the present difference, and 29 of 32 detected an illusory difference in the first experiment.

This is not to say, however, that the only determinant of apparent concentration was relative lightness. As noted, the concentration effect seen in the darker area tended to be slightly stronger in the group for which the darkening occurred in the interior, a result that is consistent with the general principle that areas that are darker tend to appear as figure rather than ground, as do areas that are surrounded (see Rock, 1975, p. 261). Since both of these conditions are true of the dark rectangle, it is probable that a strong tendency toward seeing the outlined rectangle as figure was present there, a tendency that would be expected to contribute to apparent depth and, therefore, to increase apparent concentration. That the tendency to see the dark rectangle as nearer was, in fact, stronger than the tendency to see the light rectangle as further was supported by the finding that a reliable majority of 22 (vs. 5) subjects reported that the dots within the dark rectangle were smaller [$\chi^2(1) = 10.70$, $p < .01$], whereas only 14 (vs. 14) did so for the dark surround seen by the other group. In the latter case, darkness and surroundedness conflict in determining figure-ground.

Returning to the major point, however, it would appear that the troubling difference in apparent concentration inside and outside an illusory figure that was discovered by Kennedy and Lee (1976), and confirmed in the present first experiment, might be due to a difference in illusory lightness which counteracts the expected effect of illusory depth. That being the case, it should be possi-

Figure 3. The inducing pattern used in the third experiment. In this case, as an effect of illusory depth would predict, the majority of subjects reported that the dots appeared to be more concentrated "on" the illusory surface.

ble to devise an illusory figure inducing pattern that *would* show the effect of depth on concentration that size scaling predicts, simply by removing that conflict.

EXPERIMENT 3

Method

This experiment replicated the first two with a final set of 34 individual observers, who were shown the inducing pattern depicted in Figure 3. As can be seen, in this case the inducing elements were white and were presented on a darker background, a situation that has long been known to tend to produce an illusory figure that appears to be darker, rather than lighter, than the region surrounding it (Kanizsa, 1974). Additional elements were added to this pattern (as compared with Figure 1) because white elements on gray were found to be not as powerful as black elements on white in inducing an illusory figure.

RESULTS AND GENERAL DISCUSSION

Despite the fact that Figure 3 was so weak as to fail to elicit reports of two of the expected aspects of an illu-

sory figure in a reliable majority of these unpracticed observers—only 20 reported an appropriate lightness difference and only 15 reported an appropriate size effect—the majority of observers reported an increase in apparent concentration where size scaling would be expected to produce such an illusion: within (rather than around) the illusory rectangle. To be precise, 24 subjects so reported, whereas only 6 gave the opposite report [$\chi^2(1) = 10.80, p < .01$]. In other words, when conditions are arranged such that illusory lightness and illusory depth (and their respective effects on apparent density) are not placed in conflict, the anomaly that had seemed so troublesome disappears. Apparently, the depth effect presented here was too weak to affect size judgments, but concentration, because it is a joint product of that (very weak) depth effect and (a slightly stronger) darkness effect, was reliably altered in the expected direction. At any rate, the point is that the density differences observed here, unlike the results for Figure 1, do not contradict expectations based upon the illusory depth aspect of illusory figures. On the contrary, the concentration effect is, in this case, the best evidence that an illusory figure occurred. In summary, while there may be other difficulties concerning depth effects within illusory figure inducing patterns, including even the issue of their universality (see Ware & Kennedy, 1978, Figure 2), the present difficulty seems to be, quite literally, illusory.

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