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Perception is No Accident

Seeing is believing, right? Or is it? Look at Figure 1. To most people, the square region in the center looks brighter than the surrounding white area, but actually they're physically the same. To many, the square region appears to be a flat surface that sits above the rest of the figure and partially covers the lines. The illusory surface has clear illusory contours (edges) that delimit it. Figure 2 was created by adding lines that terminate at the same points as the lines in the first figure, one being added for each line in the first figure. But now the illusory surface and illusory contour are much weaker. Why? After all, the endpoints of the lines are still just as nicely lined up as the previous figure, there are still just as many points of contact to "guide" the illusory contour, and they are spaced apart in the same way as in the previous figure. In fact, since we have added more lines, we might reasonably expect the illusion to be strengthened instead of weakened.

Similarly, in Figure 3, an illusory square appears to be covering the black "Pacman" regions. But when a little more black is added to that figure so that the sharp convex corners of the pacmen are smoothed out (*i.e.*, the corners where the outlines of the Pacmen meet the illusory edges of the surface), as in Figure 4, then the illusion is again weakened.

One explanation of these observations is based on the principle of "genericity." Consider the Necker cube in Figure 5. It appears to be a picture of a three-dimensional object (*i.e.*, a cube), even though it is only a set of lines on a flat page. Figure 6 also could be an image of a "wire frame" cube in a three-dimensional space, but people rarely see it that way. Instead, most people see this figure as flat.

What makes some collections of lines look like a picture of something

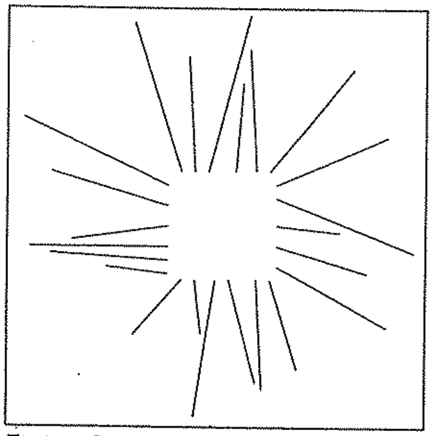

FIGURE 1

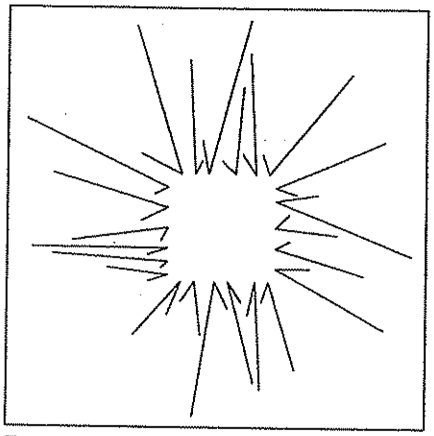

FIGURE 2

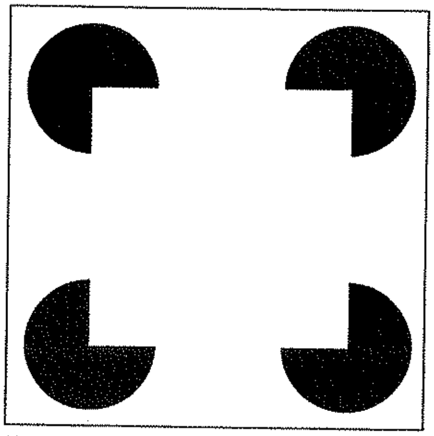

FIGURE 3

three-dimensional, while others just look flat? Figure 6 could be an image of a cube, but in such an interpretation our line of sight would have to be exactly aligned with one of the diagonals of the cube. According to the principle of genericity, a collection of lines (or regions) in an image will be more likely to appear three-dimensional if they represent "generic" as opposed to "accidental" views of a three-dimensional scene. Thus, in Figure 6 there is an accidental coincidence of two distinct corners of the cube, and this destroys the three-dimensional percept.

In Figures 1 and 2, we can understand, by using the principle of genericity, why the first display can produce an illusory surface that appears to partially cover the lines while the second one cannot. In the second display, the edges of the (potential) illusory surface would go right through the intersections of the inducing lines. If the illusory edges were perceived as being closer to the observer than the inducing lines, then the observer would have to be looking at the scene from an accidental viewpoint. (For a similar example involving "neon color spreading," see page 88.)

A similar idea explains why there is no occluding surface perceived in Figure 4. In general, when one object occludes another, the image of the occluded object has a sharp convex corner at the point where its boundary meets the boundary of the occluding object. Only from an accidental viewpoint could the boundary of the occluded object go smoothly into the boundary of the occluding one. This fact makes it highly improbable that there could be an occluding surface in Figure 4, and most human subjects do not perceive one.

Still, many subjects do perceive weak illusory edges in Figures 2 and 4. However, they describe these edges as being at approximately the same depth as the inducers, not as occluding them.

A number of theories of illusory contours have been proposed. Rock and Anson[1] proposed that illusory-contour perception is a two-stage process. First, something cues a figure-ground reversal: In the "literal" percept, all of the black elements are seen as figure, and all of the white area is seen as ground. But when the

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illusory surface is perceived, it is seen as figure, and all of the black elements along with the surrounding white area is seen as ground. In the second stage of the process, the visual system checks the display for its consistency and compatibility with the hypothesis of an occluding illusory surface.

Gregory[2] claims that the human visual system, using the probabilistic information available to it, selects perceptual interpretations on the basis of what is the most likely state of the external world. According to Gregory, an illusory surface is perceived in Figure 3 to "account" for the "gaps" in the inducers. In other words, the visual system has decided that this is the most likely state of the external world.

The view proposed by Kanizsa[3] is that the Gestalt principles of perceptual organization can explain illusory contours. According to this theory, perceptual interpretations that maximize "simplicity" and "regularity" are favored by human vision. Thus, in Figure 3, we prefer to see four complete circles that are partially covered by a square, rather than four Pacmen.

Coren[4] claims that when depth cues in a display allow the visual system to construct a "simpler" perceptual organization by introducing an illusory surface, then an illusory surface will be perceived. So, in Figure 3 it is argued that the depth cue of "interposition" is present, and this allows the perception of four complete circles that are partially covered by an illusory square. The central claim here is that the presence of depth cues is necessary for the perception of an illusory contour.

Grossberg and Mingolla[5] proposed a neural network model of the human visual system. In their theory, illusory contours occur because of short-range competitive interactions and long-range cooperative interactions that are fundamental to all contour-generating processes within the visual system. The contours generated by these interactions define boundaries for diffusive "filling-in" processes that allow the contour to be perceived.

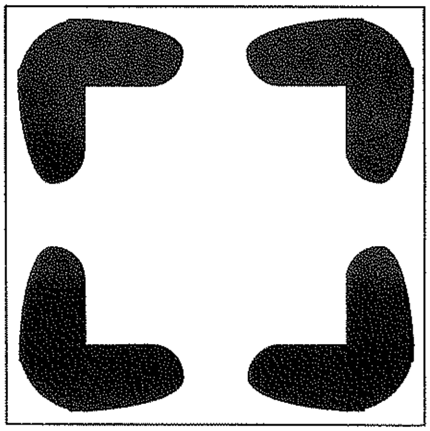

FIGURE 4

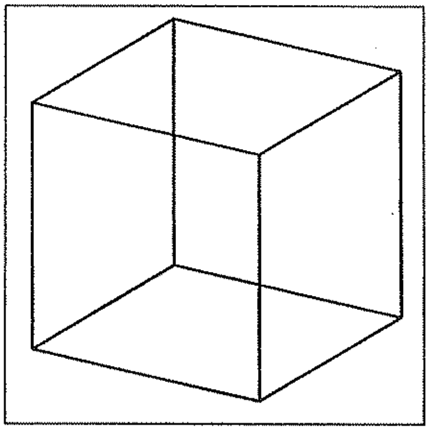

FIGURE 5

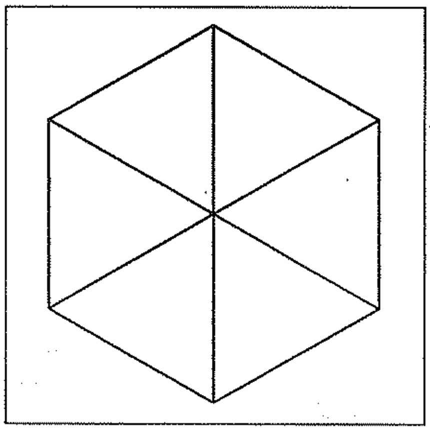

FIGURE 6

According to Kanizsa, a tendency toward "closure" of lines can explain illusory contours generated by line endings. His theory can also account reasonably well for the effects seen in Figures 1 and 2. On the other hand, our fundamental assumption is that the human visual system generally prefers perceptual interpretations that are more likely to "correspond" to the actual state of the external world. This assumption is based on the idea that human vision is biased toward perceptual interpretations that are useful for survival. It means that in the face of uncertainty, human vision must resort to whatever probabilistic information it has at its disposal to decide which, among the logically possible perceptual interpretations of an image, is most likely to be "correct." This is central to the cognitive approach to perception proposed by Gregory. One source of probabilistic information, based on this viewpoint, leads to the generic viewpoint assumption. Kanizsa's theory is not explicitly based on a preference for more probable interpretations. For this reason, we feel that the explanation based on genericity is more satisfactory.

Thus, it appears that human vision prefers to attribute coincidences that occur in images to "special" arrangements in 3-D (as long as they have a reasonable prior probability of occurring), rather than to its own viewpoint. Its prior probabilities about the arrangement of objects lead it to more readily accept, for example, that a bunch of "blobs" could be crowded around a square (*e.g.*, the blobs could be soft and flexible), than that the eye views the square and the blobs from an accidental viewpoint. So while accidents can happen, human vision prefers to maneuver around them if it can.

References

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3. G Kanizsa, "Contours without gradients or cognitive contours?" Ital. J. Psych. 1, 1974, 93-112.
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5. S. Grossberg and E. Mingolla, "Neural dynamics of form perception: boundary completion, illusory figures, and neon color spreading," Psych. Rev. 92, 1985, 173-211.