Notes and Comment

A note on a second stage in the formation of illusory contours

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It has recently been argued (Day & Jory, 1978; Jory & Day, 1979) that the formation of illusory contours involves two stages, local enhancement and suppression of brightness contrast in contiguous regions and a spreading of these effects across areas whose boundaries are minimally defined by line-ends and points. The outcome of the first stage is an apparent difference in brightness between regions, and that of the second, the formation of the illusory contours themselves. It is argued that in the first stage local enhancement of contrast results from both simultaneous brightness contrast and dissimilation of brightness at the ends of lines and from suppression of contrast from assimilation of brightness between repeated lines and other elements. All three effects have been demonstrated independently of illusory contours. Evidence for their involvement in the first stage of formation of illusory contours has already been reported (Day & Jory, 1978; Jory & Day, 1979). The second stage, the spread of the effects to boundaries indicated by features such as line-ends and points and the consequent formation of clear illusory contours, has been suggested but so far has not been convincingly demonstrated. The purpose of this paper is to demonstrate the second stage using a figure from Koffka (1935) to which Landauer (1978) has recently drawn attention. It is shown that illusory contours form about a shape whose boundary is defined by four or eight points. As the arrangement of these points is changed, so the shape and the enclosing illusory contours are changed.

The cross shown in Figure 1 appeared originally in Koffka's (1935) *Principles of Gestalt Psychology* to demonstrate the "filling in" of that part of a retinal image falling on the blind spot. Landauer has pointed out that the region of enhanced brightness at the center of the cross is sometimes seen as a square and sometimes as a disk, with perception of the first occurring more frequently. Inspection of Figure 1 confirms this observation.

It can be assumed that the bright region is a consequence of enhanced contrast due to dissimilation of brightness in the gaps between line-ends and reduced contrast due to suppression of contrast between pairs of parallel lines, as shown earlier (Day & Jory, 1978). The even spread of enhanced

Figure 1. The Koffka figure with an indefinitely shaped region of enhanced brightness at the center.

Figure 2. Formation of illusory contours in the Koffka figure by minimal marking of shapes by line-ends and four or eight dots.

brightness to the boundaries of various shapes indicated by line-ends and dots is shown in Figure 2. With four regularly spaced and suitably arranged dots, the bright central area forms a square (Figure 2A) or a diamond (Figure 2B) with clearly defined illusory contours. However, the shape in Figure 2C is by no means as definite; it can be seen as a square or as an indefinite circular shape similar to that in Figure 1. With eight dots, three shapes—a square (Figure 2D), diamond (Figure 2E), and a circle (Figure 2F)—are all clearly defined and enclosed by illusory contours. The line-ends and dots in Figures 2C and 2F fall on the circumference of a circle. It is to be noted that for this figure, unlike the square and the diamond, eight dots together with the line-ends are necessary to form a definite circular shape with an illusory contour. In comparing Figures 2A-2C with Figures 2D-2E, it seems reasonable to suppose that shapes with corners are fully resolved by fewer boundary markers when these indicate the corners than when there are no such abrupt changes in boundary direction. Continuous change in direction of the boundary, as with circles and ellipses, would seem to require relatively more markers for resolution and illusory contour formation.

That minimally defined boundaries without brightness enhancement is not sufficient for the formation of illusory contours is demonstrated in Figure 3. While the dots and short lines by themselves define identifiable shapes, no illusory contours are visible. Thus the occurrence of both contrast effects *and* boundary markers is necessary to form the contours.

The role of minimally indicated boundaries in the formation of illusory contours as shown here has been recognized by Gregory (1972) and Kennedy (1976). The same view is implicit in Landauer's (1978) commentary on Koffka's figure. The additional point made here is that, given enhancement and suppression of brightness contrast as described above, illusory contours correspond with boundaries indicated by small features such as line-ends and points. It is as if the region of enhanced brightness, once formed, spreads to fill the shape outlined by these features. Without such marking, the region of enhancement is indeterminant in shape and the contour fuzzy. Such apparent spread of induced changes in brightness is not unlike the extensive spread of narrow bands of increased and decreased brightness in the Craik-O'Brien effect (Craik, 1966; O'Brien, 1958) and the spread of simultaneous contrast effects to boundaries formed by very fine lines (Berman & Leibowitz, 1965).

Evidence for a spreading or "filling-in" process envisaged here was adduced by Walls (1954) from a consideration of physiological (blind spot), migrainous, and pathological scotomata. Walls suggested that without such a process only the contours of objects

Figure 3. Control figures; the dots and lines alone are not sufficient for the formation of illusory contours, although the shapes are identifiable.

would be visible. Using an artificial scotoma in the form of a dark suction cap on the cornea, Gerrits and Vendrik (1970) confirmed the occurrence of filling-in within a contoured region and attributed it to a postretinal "higher center." They have argued that changes in retinal ganglion cell activity at light on and light off in the region of the imaged contour is transmitted to a higher center where the spreading occurs. The involvement of the spreading of brightness in the formation of illusory contours has also been recognized by Spillman, Fuld, and Gerrits (1976).

In summary, induced changes in contrast represent a first stage in the formation of illusory contours. The occurrence of the induced effect is necessary, but not sufficient, for a sharp illusory contour to form; boundary marking by line-ends, points, and, presumably, other small features is also necessary.

REFERENCES

- BERMAN, P. W., & LEIBOWITZ, H. W. Some effects of contour on simultaneous brightness contrast. *Journal of Experimental Psychology*, 1965, 69, 251-256.

- CRAIK, K. J. W. Brightness discrimination borders, and subjective brightness. In S. L. Sherwood (Ed.), *The nature of psychology*. London: Cambridge University Press, 1966.
- DAY, R. H., & JORY, M. K. Subjective contours, visual acuity and line contrast. In J. C. Armington, J. E. Krauskopf, & B. R. Wooten (Eds.), *Visual psychophysics and physiology*. New York: Academic Press, 1978.
- GERRITS, H. J. M., & VENDRIK, A. J. H. Simultaneous contrast, filling in process and information processing in man's visual system. *Brain Research*, 1970, **11**, 411-430.
- GREGORY, R. L. Cognitive contour. *Nature (London)*, 1972, **238**, 51-52.
- JORY, M. K., & DAY, R. H. The relationship between brightness contrast and illusory contours. *Perception*, 1979, **8**, 3-9.
- KENNEDY, J. M. Attention, brightness, and the constructive eye. In M. Henle (Ed.), *Vision and artifact*. New York: Springer, 1976.
- KOFFKA, K. *Principles of Gestalt psychology*. New York: Harcourt Brace, 1935.
- LANDAUER, A. A. Subjective states and the perception of subjective contours. In J. P. Sutcliffe (Ed.), *Conceptual analysis and method in psychology: Essays in honour of W. M. O'Neil*. Sydney, Australia: Sydney University Press, 1978.
- O'BRIEN, V. Contour perception, illusion and reality. *Journal of Optical Society of America*, 1958, **48**, 7-30.
- SPILLMAN, L., FULD, K., & GERRITS, H. J. M. Brightness contrast in the Ehrenstein illusion. *Vision Research*, 1976, **16**, 713-719.
- WALLS, G. L. The filling in process. *American Journal of Optometry*, 1954, **31**, 329-341.

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