A binocular parallax theory of the geometric illusions

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A new theory of the geometric illusions is presented. Three perceptual processes are described, tending to reduce binocular parallax anomalies for environments containing overlaid objects. Inappropriate operation of these processes gives rise to the illusions. The effects of environmental training on the illusions are considered. Results from cross-cultural studies are cited and used to test a prediction from the theory concerning the magnitudes of cross-cultural differences for two forms of the vertical-horizontal illusion.

Recently there has been a revival of interest in the geometric illusions. Gregory (1966) list six theories which he rejects: (1) the eye movement theory, (2) the limited acuity theory, (3) the confusion theory, (4) the empathy theory, (5) the pregnance theory, (6) the perspective theory, together with an account of his inappropriate constancy scaling theory. The purpose of this report is to suggest another possible explanation of the geometric illusions, namely that they arise from perceptual processes which tend to reduce anomalies resulting from the combination of two monocular visual fields into one binocular field.

The binocular parallax theory

Consider an object A interposed between an observer O and a background B, as shown in Fig. 1. The observer's left and right eye fields of view will be as shown in Fig. 2. In each of these there are parts of the background, shown shaded, which appear in only one of the fields and are known as monocular areas. Julesz (1960) has demonstrated that the monocular areas are preserved in the binocular field. If the background contains a contour XY inclined to the object A the resulting fields of view will be as shown in Fig. 3, the monocular elements of the contour being shown as broken lines. Figure 4 represents the recombination in the binocular visual field. In this case the contour XY is not geometrically a continuous line, although it is generally perceived as such. It is suggested that this occurs because a perceptual transformation acting on

Fig. 1. A binocular observer O viewing a background B and an interposed object A.

Fig. 2. Left (a) and right (b) eye views of observer in Fig. 1. Monocular areas are shown shaded.

this binocular field shifts *all* contours intersecting at acute angles in the direction of the arrows shown in Fig. 4. This process would account for illusions of the Müller-Lyer, Poggendorff, Orbison, Hering and Zöllner variety.

A further point of interest is that contours in the binocular field may be longer than in either of the monocular fields. For simplicity consider the case of a horizontal contour EH and an interposed object A. The binocular field is represented in Fig. 5, EF and G'H being contributed by the left monocular field and EF' and GH by the right monocular field. The length of contour in the binocular field is greater by an amount $F'F = GG'$ than in either of the monocular fields, and thus the distance EH in the binocular field is greater than it would be if the object A were absent. This suggests a second perceptual transformation of the binocular field in which the length of *all* divided lines is reduced, thus giving illusions of the type shown in Fig. 6 (Künnapas, 1955) and the common observation that horizontal stripes make objects appear fatter and vertical stripes make them appear thinner than similar unstriped objects.

Because the total distance EH in the binocular field is greater than it would be if the object A were absent, an element of the contour will be represented by a similar proportion of EH when A is present. Hence a third perceptual process is postulated, the effect of which is to expand the length of elements of *all* contours in

Fig. 3. Left (a) and right (b) eye views of oblique contour XY with object A interposed between observer and contour.

Fig. 4. Binocular field representation of Fig. 3. The monocular portions of the contour are shown as broken lines. The arrows indicate the effect of the shift resulting from process (1).

inverse proportion to the length of contour of which they form part. This would give a contrast illusion and the Ponzo illusion as shown in Fig. 7.

The geometric illusions result from the operation of these three processes in situations in which they are inappropriate. This is possible because, although they act in a manner which tends to reduce binocular parallax anomalies, they are initiated not by binocular parallax but by specific contour configurations. It may be that this method of operation has a biological parsimony in that no information is required on the monocular origins of contours in the binocular field. This theory predicts that the illusions will be destroyed if the figures are presented so as to contain the appropriate amount of binocular parallax. This can be done for the Poggendorff illusion by viewing Fig. 3 stereoscopically. Gregory (1964) has reported that destruction by this method of presentation seems to be general for all the illusions. The illusions may also be destroyed by viewing a three dimensional model having the appropriate separation between the overlaid object and the background contours.

Cultural differences

The magnitude of the illusions is subject to cultural differences (Segall, Campbell, & Herskovits, 1963) which have been thought to follow from differing degrees of "carpenterization" of the perceptual environment (see also Gregor & McPherson, 1965). The binocular parallax theory would account for these differences by the parameters of the three perceptual correcting processes becoming matched to the general level of binocular parallax encountered by the S. This would be least for Ss living in an open vista environment, greater for Ss

Fig. 5. Binocular field representation for an observer viewing a horizontal contour EH and an interposed vertical object A. Due to the inclusion of both monocular contours, shown as broken lines, the distance EH is greater by $F'F = GG'$ than it would be if A were absent.

Fig. 6. This diagram from Künnapas (1955) separates the vertical-horizontal illusion, a perceived as longer than c , from the divided line illusion, c perceived as shorter than b .

living in forests and greatest for Ss living under the conditions of European civilization.

The binocular parallax theory does not cover the vertical-horizontal illusion, but it does partly cover the inverted T illusion which contains a divided line illusion component as well as a vertical-horizontal illusion component (Künnapas, 1955). The effect of environmental differences on the vertical-horizontal illusion is expected to act in the opposite direction to that just described for the geometric illusions, Ss living in open flat terrain being more susceptible to the vertical-horizontal illusion than those living in a European environment. We would therefore expect reduced cross-cultural differences for the inverted T illusion as compared with the pure vertical-horizontal illusion in the form of an inverted L. Data from Segall, Campbell, & Herskovits (1963) and from Gregor & McPherson (1965) on 19 cultural groups were used to test this prediction. A significant F-ratio ($p < .05$) was found between the variance of PSEs for the pure and mixed forms of the illusions in the predicted direction.

Fig. 7. The Ponzo illusion (c) may be considered to derive from the contrast illusion (a) through the common form (b).

References

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