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Last but not least

A new optical-geometrical illusion

Abstract. We describe and attempt to explain a new and unusual optical-geometrical illusion with three levels of distortion. The illusory figure is made up of three juxtaposed bands of the same width, which, when appropriately juxtaposed, appear to be of different widths. We hypothesised that the effect would depend on the combined action of various factors: (i) the band shapes and their reciprocal spatial position; (ii) the degree of coincidence of the sides of the juxtaposed bands; and (iii) the inability of the perceptual system to account for all the projective transformations. An experiment was conducted in which the shape of three stimuli was manipulated through affine transformation as well as variation of side lengths. The participants' task was to evaluate the width of the bands. The results revealed a robust and stable illusory effect; the factors that seem to influence the illusion most are band shape and conjoining side lengths.

In psychological research, the term 'optical-geometrical illusion' usually refers to a discrepancy between perceived reality and physical reality (Gillam 1998). The illusory figure presented here (figure 1a) is made up of three juxtaposed bands of the same width—a parallelogram and two rectangular trapezoids—which appear, however, to be of different widths when suitably juxtaposed (see figure 1b). Specifically, the band appearing at the top (the 'upper' band) looks wider than the band immediately below it (the 'central' band), which in turn looks wider than the third band below it (the 'lower' band).

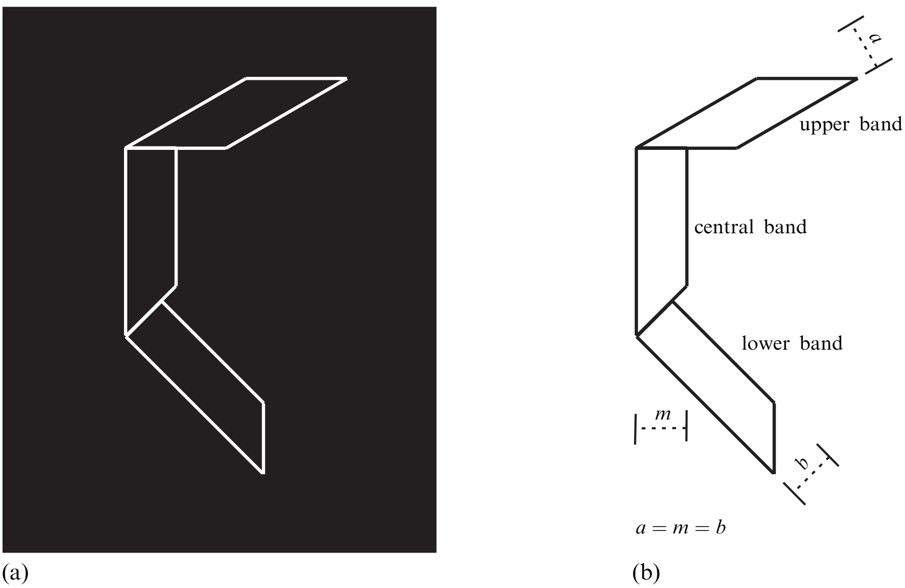


Figure 1. (a) The optical-geometrical illusion. (b) The illusion is characterised by three bands of geometrical, but not phenomenal, equal widths.

The illusion seems to have some aspects in common with other well-known illusions, such as Shepard's (1981, 1990), Jastrow's (1891), and Sander's (1926). The illusory effect in Shepard's illusion originates in a lack of the shape-constancy mechanism (Coren and Girgus 1978; Shepard 1981, 1990; Da Pos and Zambianchi 1996; Gillam 1998). In Jastrow's illusion (see figure 2b) the contrast effect seems to explain the illusory effect. In fact, when evaluating the size of an area, the perceptual system seems to be influenced by the length of the lines (sides) delimiting the area (Jastrow 1891; Luckiesh 1922/1965; Robinson 1972; Coren and Girgus 1978; Da Pos and Zambianchi 1996; Gillam 1996). In Sander's illusion (see figure 2c), two equally long diagonals (Luckiesh 1922/1965; Sander 1926; Kennedy et al 1992) appear, however, to be of very different lengths when included in two nearer but different-in-size figures.

There is a general consensus that optical illusions represent a perceptual phenomenon stemming from the action of many converging factors, and it is thought that most known illusions are the result of the activation of one or more perceptual-cognitive, physiological, and/or structural processes (Coren 1999). We also believe that the illusion presented here depends on different factors that operate either alone or in synergy with each other to result in three different levels of perceived illusory width within the same pattern. Whereas this illusion presents aspects in common with other well-known illusions (Shepard's, Jastrow's, and Sander's) it shows, as it will be explained later, some original features.

In order to learn more about the mechanisms underlying this illusion and to identify what properties of local and global stimuli are combined by the visual system to yield the illusory effect we conducted an experiment. Participants were presented with the three different stimuli shown in figure 2, which were produced by imposing two affine transformations (figures 2b and 2c) on the upper band shown in figure 2a and by maintaining the KLM angle (120°) and physical band widths (2.2 cm) constant (see figure 3). The upper-band modifications impinged on both the central-band shape and the conjoining side-length differences. The internal central-band angle (the KLM angle)

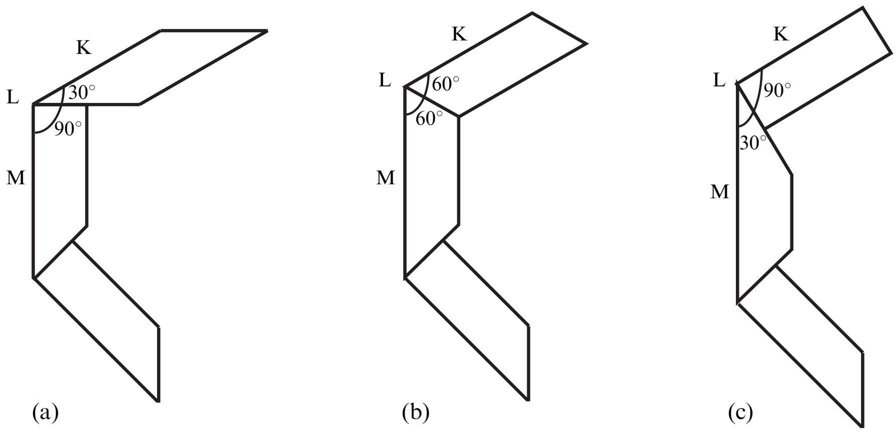


Figure 2. The three experimental stimuli obtained by changing the angle between the 'upper' and 'central' bands. (a) Stimulus 'A'; (b) stimulus 'B'; (c) stimulus 'C'.

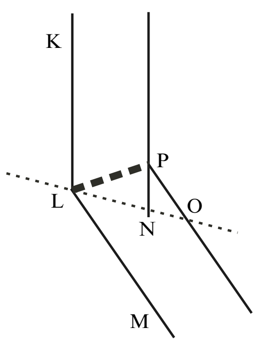


Figure 3. Geometrical analysis of the KLM angle (see explanation in the text).

thus took on the following values: 90° in stimulus ('A'), 60° in stimulus ('B'), and 30° in stimulus ('C') (see figure 3).

It should be noted that in stimulus ('B') the conjoining sides of the upper and central bands coincided perfectly, given that this conjunction was the bisector of the KLM angle. Hence, the transformations turned the central band in stimulus ('A') from a rectangular trapezoid perceived in frontal space into a highly asymmetrical scalene trapezoid in stimulus ('C'), which can also be perceived as a rectangle tilted in depth.

The participants' task was to estimate the widths of the three bands by using four different measurement methods, based on Coren and Girgus's (1972) suggestions concerning the reliability of methods for measuring illusory effects.[1]

Figure 4 shows the distribution of the data for the upper, central, and lower bands, for each stimulus, revealing how the phenomenological band width differed as a function of the three different stimuli and in agreement with our hypothesis on the role of different converging local and global factors, which works alone or in synergy. Data analyses revealed that the band width differences perceived by participants were due to different band shapes (global factors), different band combinations (global factors), and different conjoining side lengths (a local factor).

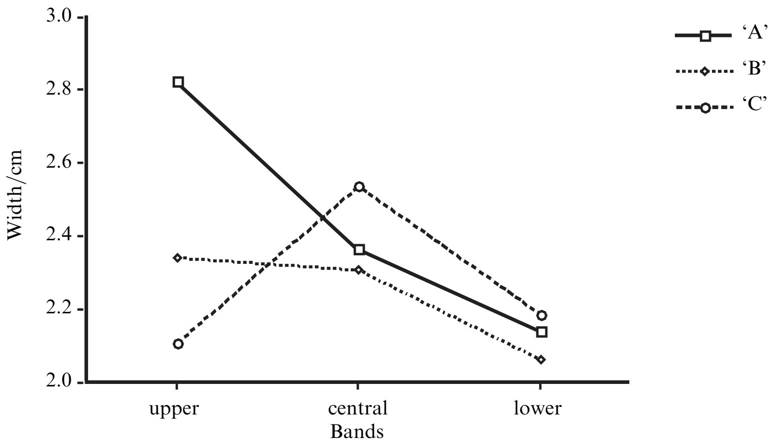


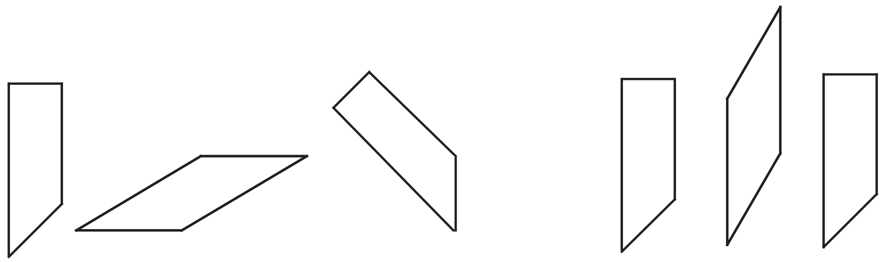
Figure 4. Width of the three bands indicated on the axis of the abscissa applying to the three experimental stimuli 'A', 'B', and 'C'.

In fact, there was an inversion in subjective upper and central band width estimates for stimuli ('A') and ('C'), but no significant estimate difference for the upper and central bands in stimulus ('B'), where the contrast effect (local factor) is eliminated because the conjoining upper and central band margin is the bisector of the KLM angle.

In agreement with the literature on the perception of optical illusions, which maintains that optical-geometrical illusions result from the interaction of different factors and on the basis of the results of our own experiment we believe that the illusory effect described here can be attributed to the following aspects: (i) global factors—the reciprocal spatial position of the figures (constancy mechanism), their relative shapes, and possible 3-D perceptual solutions for some figures; (ii) local factors—different conjoining side lengths (contrast effect); and (iii) the inability of the perceptual system to account for all the projective transformations implemented.

[1] Following the suggestions of Coren and Girgus (1972) concerning reliability of measurement methods of illusion effects, four different psychophysical estimates were carried out: two comparative tasks with the constant-stimuli method (ascending and descending), a reproduction task, and an adjustment task.

For example, figure 5 shows the role of the reciprocal spatial positions of the bands. When the quadrilateral and the two trapezoids are separated and located in different reciprocal positions (see figure 5a), only the quadrilateral (upper band) is still seen as being wider than the other bands, and the illusion therefore occurs only for this figure. Moreover, when the three figures are aligned vertically, the illusory effect disappears, both removing the constancy mechanism effect due to the different orientations of equal shapes and reducing the 3-D cues (see figure 5b).



(a) (b)

Figure 5. The role of the reciprocal spatial positions of the bands.

It is known that our perceptual system has a hard time precisely evaluating the length of lines that are tilted in various directions in space but are also incorporated in different figures. In agreement with Coren's (1999) observations, our participants were influenced not only by the segment lengths they were asked to estimate, but also by other pattern aspects, which then interfered with width estimates. In fact, figure 6 shows how the equal orthogonal length between the long sides appears to differ even if it is depicted in both bands (see figure 6). Once more, the length at the top is perceived as being greater than the central one.

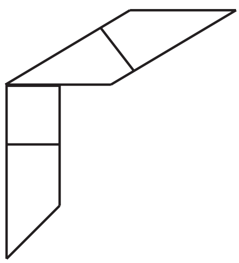


Figure 6. Inability of the perceptual system to account for all the implemented projective transformations.

Moreover, if we remove all illusion-inducing elements one by one, ie side length differences (see figure 7b), 3-D cues, and shape cues, ending with coupled parallels (see figure7c), the illusory distortion decreases in the same direction (see figure 7).

We observed the strongest illusory effects when the above-cited factors were simultaneously present, as in stimuli ('A') and ('C'). Further verification can be inferred from our participants' evaluations of the width of the lower bands in all three stimuli: the three lower trapezoids are equal figures, yet width evaluations differed in all three instances, depending on the variation of the shapes of the central band and the lengths of different conjoining sides (contrast effect).

In conclusion, we observed a clear illusory effect of stable intensity, which seems to depend on the combined action of the following factors:

(1) Participants were unable to evaluate the width of each band as the orthogonal distance between the long sides, as requested, and apparently made their judgments on the basis of the portrayed sides. Figure 6 is a clear demonstration of this phenomenon.

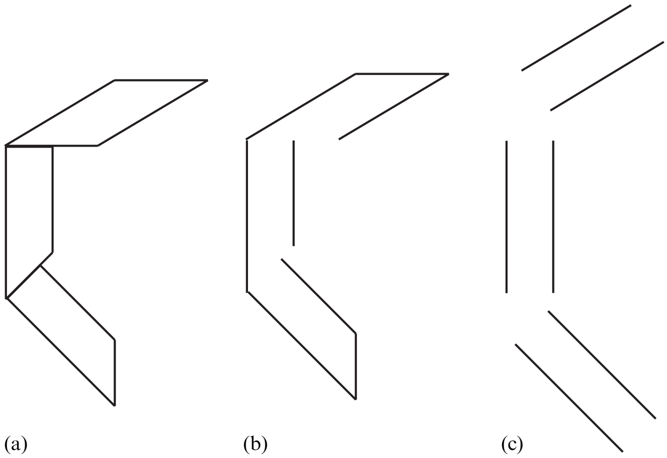


Figure 7. When all illusion inducing elements are removed one by one, the illusory distortion decreases in the same direction.

(2) The global factors of mutual position of equal shapes in size evaluations (constancy mechanism) and 3-D effects for the upper and central bands (stimulus 'B').
(3) The local factors of differences in conjoining side lengths of two congruent figures (contrast effect), as occur in Jastrow's and Sander's illusions.

We stress that the singularity of this illusion—the perception of three different levels of width within the same illusory pattern—depends on the influence of different factors operating simultaneously, alone or in synergy, on different parts of the figure.

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