A test of constancy scaling theory in a modified Mueller-Lyer illusion

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The center line of each of the two Mueller-Lyer figures was replaced by a rectangle whose length and width were both judged. The rectangle, bounded by wings positioned outward, was judged both longer and narrower than a standard rectangle of equal size, while the rectangle bounded by wings oriented inward was judged to be both shorter and wider than the standard rectangle. These results were considered to provide evidence against a constancy scaling explanation of geometric illusions. Other theories to account for the results were considered and found inadequate.

Gregory (1966) has proposed that the constancy scaling mechanism that underlies size constancy is inappropriately activated by perspective depth cues suggested by the wings in the Mueller-Lyer figure and leads, consequently, to the well-known illusion seen in Fig. 1.

According to this theory, Lines a and b in Fig. 1 appear to differ in length when, in fact, they are of equal length, because of the perspective depth cues inherent in the wings of the figure. The wings suggest that Line a is further from the viewer than is Line b, and, since both subtend equal visual angles, Line a is perceived as longer.

Tests of the constancy scaling theory have not uniformly supported it (Zanforlin, 1967; Over, 1968; Fisher, 1970; Massaro & Anderson, 1970). Nonetheless, Gregory's theory and other perspective explanations of the Mueller-Lyer illusion (for example, Gibson, 1966) remain important theories whose ranges of applicability extend to cover many geometric illusions.

The relationship between perceived size and perceived distance is often referred to as Emmert's law, which states that perceived area is proportional to the square of perceived distance. One can deduce from this law that the inappropriate constancy scaling that, according to Gregory, produces the distorted line lengths in the Mueller-Lyer figure would also produce distortions in line width if such judgments were made. That is, an object judged to be farther away than a reference object, when both objects subtend equal visual

angles, should be judged to be a larger object in both length and width than the reference. An object judged to be nearer than a reference object, when both objects subtend equal visual angles, should be judged to be a smaller object in both length and width than the reference.

The present experiment was designed to test the above predictions by replacing the center line in the Mueller-Lyer illusion with a rectangle whose length and width were both judged when it was bounded by wings oriented either inward or outward. Length and width judgments of horizontal and vertical rectangles without wings were also made.

METHOD

Subjects

Twenty undergraduate students from Luther College served voluntarily as Ss.

Apparatus

The length and width of an adjustable rectangle were changed by E, as instructed by S, to match the length and width of a standard figure. The adjustable rectangle was constructed of heavy white cardboard and was mounted so that it could be

moved horizontally on a vertical wooden board that was covered with mat black paper. The rectangle was partially covered by a stationary vertical black panel that defined one of the long sides of the rectangle. Horizontal adjustments of the rectangle changed its width. A sliding mat black panel on top of the rectangle could be adjusted vertically to change its length. In the frontal plane, as regarded by S, the figure appeared as a white rectangle on a flat, mat black background.

There were four standard figures, each made in two different sizes. The rectangles in the larger set were 8 x 2.5 cm in size, while the rectangles in the smaller set were 7 x 2 cm in size. All figures were constructed of white paper centered on a 21 x 27 cm mat black background.

The four standard figures can be seen in Fig. 2. The wings in Figs. b and c were 4.5 cm in length and tilted inward or outward from the rectangle at 45 deg from vertical.

Procedure

An S was seated approximately 1.6 m in front of the adjustable rectangle, while E sat behind the board on which it was mounted and made adjustments, as instructed by S, to match the length and width of the rectangle in the standard figure being presented. The length of the adjustable rectangle was always vertically positioned, as was the length of the standard figures except for Fig. d, which was horizontally positioned.

The standard figures were presented for judgment in a random order and were placed, for half the Ss, 17 cm to the right and slightly lower than the adjustable rectangle. For the remaining Ss, the standard was placed 17 cm to the left and slightly lower than the adjustable rectangle.

Ss were asked to instruct E to change the length and width of the adjustable rectangle until it appeared

Fig. 1. The Mueller-Lyer illusion.

Fig. 2. Shape and orientation of the figures judged for length and width. The rectangles in each of the four figures were of two sizes, 8 x 2.5 cm and 7 x 2 cm. All figures were white, centered on a black background.

Table 1
Mean Percent of Errors in Length and Width Judgments to the Four Standard Formst

	Figure a	Figure b	Figure c	Figure d
Errors in Length	0.91	-3.03*	4.73*	-3.46*
Errors in Width	0.47	3.69*	-2.04*	0.49

†Minus percentages indicate the judged value to be less than the actual value. Asterisks show judgment means significantly different ($p < .01$) from the judgment means for the standard vertical rectangle, a.

to be the same size as the standard being judged. The E made adjustments in the direction instructed by S until S said "Stop." When S was satisfied that the two rectangles appeared to be the same size, he informed E, who then recorded the dimensions of the adjustable rectangle to the nearest millimeter.

Four separate length and width judgments of both the large and small members of each of the four standard figures were made. The adjustable rectangle was adjusted from a setting where it was, for each of the judgments, longer and narrower, longer and wider, shorter and wider, and shorter and narrower than the standard.

RESULTS AND DISCUSSION

The percentage of error in the length and width judgments for each of the four figures, for each S, was calculated by the equation:

$$\frac{A - J}{A} \times 100 = \text{Percent of error score}$$

The mean actual length (7.5 cm) or the mean actual width (2.25 cm) is given by A. The mean judged length or the mean judged width is given by J. The percentage of error in judgments of the larger and smaller figures was averaged after determining that the pattern and magnitude of errors were similar between the two figure sizes.

Table 1 gives the mean percentage of error in judgments of length and of width to the four standard figures. An analysis of variance test shows the differences in the means of the errors in the judgment of length to be significant, $F(3,57) = 55.69$, $p < .01$. The same test shows the differences in the means of the errors in the judgment of width also to be significant, $F(3,57) = 16.34$, $p < .01$.

The means of the errors in the judgment of length to Figs. b, c, and d were significantly different beyond the .01 level from like judgments to the standard vertical rectangle, a, as determined by a two-tailed Dunnett test. The means of the errors in the judgment of width to Figs. b and c also were significantly different beyond the .01 level from like judgments of Fig. a, based on a two-tailed Dunnett test. The width judgments of Fig. d were not

significantly different from the width judgments of Fig. a.

The results show that the rectangle with outwardly positioned wings was judged to be longer and narrower than a rectangle that had no wings, while the rectangle with wings positioned inward was judged to be both shorter and wider than the reference rectangle.¹ These results are in disagreement with constancy scaling theory, from which it was predicted that the size, or area, of the rectangles should change with perspective distance cues and that the rectangle judged "long" should also be judged "wide," while the rectangle judged "short" also should be judged "narrow."

The results also show that a rectangle in a vertical position was judged to be longer than a rectangle of equal length oriented horizontally. The orientation, however, did not affect judgments of width. Thus, the horizontal-vertical illusion was confirmed in the judgment of length but not in the judgment of width. This finding suggests that different mechanisms underlie the forms of the Mueller-Lyer and horizontal-vertical illusions tested by this experiment.

No theory readily suggests itself to account for the experimental findings. The fact that the length and width judgments of figures of Figs. b and c were such that figure area was conserved may be an example, in the area of perception, of the intellectual process of conservation of area, which

has been extensively investigated by Piaget. Piaget's theory of illusions (Piaget, 1969), however, appears inadequate to account for the present results. The illusions of length in Figs. b and c may be the outcome of the "trapezium effect," which is the finding that the long side of a trapezoid is underestimated, while the parallel short side is overestimated, and this finding is employed by Piaget to explain the Mueller-Lyer illusion. The "trapezium effect" itself is accounted for in the more general terms of Piaget's theory of relative concentrations, but the theory does not apply in a straightforward manner to account for the illusions of width in the present experiment. For example, in Fig. c, each side of the rectangle might be regarded as the short side of a trapezoid, each trapezoid completed by virtual lines extending between the tips of the wings, as shown in Fig. 3. Since the short side of a trapezoid is overestimated, relative to the parallel long side, Fig. c should appear to be longer and wider than a like rectangle without wings. This, of course, is not the case. It is not clear how Fig. b needs to be analyzed in terms of Piaget's theory to explain the illusion of width that it produces.

Other current theories of illusions, as well, appear to be challenged by the results of the modified Mueller-Lyer illusion studied here. Pressey's (1970) assimilation theory, for example, seems difficult to apply to Fig. c, since, if assimilation accounts for the illusion of length, it appears that contrast most naturally accounts for the illusion of width.

A structural analysis of the figures producing the illusions in this experiment may, in fact, be the wrong approach to understanding them. Perhaps a satisfactory explanation can be developed from the notion that we

Fig. 3. The dashed lines represent virtual lines that complete trapezia in which the wings of the figures form the nonparallel sides.

have learned that something "stretched" becomes thinner and something "compressed" becomes wider and that the wings serve to either stretch or compress Figs. b and c.

REFERENCES

- FISHER, G. H. An experimental and theoretical appraisal of the perspective and size-constancy theories of illusions. *Quarterly Journal of Experimental Psychology*, 1970, 22, 631-652.
- GIBSON, J. J. *The senses considered as perceptual systems*. Boston: Houghton Mifflin, 1966.
- GREGORY, R. L. *Eye and brain*. New York: World University Press, 1966.
- MASSARO, D., & ANDERSON, N. H. A test of a perspective theory of geometric illusions. *American Journal of Psychology*, 1970, 83, 567-575.

- OVER, R. Explanations of geometrical illusions. *Psychological Bulletin*, 1968, 70, 545-562.
- PIAGET, J. *The mechanisms of perception*. New York: Basic Books, 1969.
- PRESSEY, A. W. The assimilation theory applied to a modification of the Müller-Lyer illusion. *Perception & Psychophysics*, 1970, 8, 411-412.
- WAITE, H., & MASSARO, D. W. Test of Gregory's constancy scaling explanation of the Müller-Lyer illusion. *Nature*, 1970, 227, 733-734.
- ZANFORLIN, M. Some observations on Gregory's theory of perceptual illusions. *Quarterly Journal of Experimental Psychology*, 1967, 19, 193-197.

NOTE

These results also replicate those of Waite and Massaro (1970), who found that a

rectangle bounded by outward positioned wings was judged longer and narrower than a like rectangle bounded by inward positioned wings. Unlike the results of the present study, all length and width judgments were underestimated in Waite and Massaro's study. This result appears to be a consequence of the method of judgment employed. Their Ss marked off on a sheet of paper the length of horizontal and vertical lines to match the width and length, respectively, of projected figures. The judgments, then, do not reflect the degree of illusion induced by the wing orientation alone since the standard and variable stimuli were perceptually dissimilar and were presented at different distances as well.

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