An alternative view of the "Gibson normalization effect"

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Two experiments are reported which show that (1) a curve tends to be perceived as more curved than its physical dimensions warrant, (2) after a period of inspection there is a decrease in the magnitude of this illusion, and (3) in a minimal cue, monocular viewing, situation a curve is perceived as rotated in space. These findings are used to present a different interpretation of the "Gibson normalization effect".

In 1933 Gibson observed that with prolonged inspection a curved line comes to appear to be less curved. He also noted that subsequently a straight line appears to be curved in the direction opposite to that of the inspected curve. This finding has been repeatedly confirmed (Bales & Follansbee, 1935; Carlson, 1963; Pick, Hetherington, & Belknap, 1962). Gibson attributed this apparent straightening of the curve to a process of "normalization." This process of normalization is essentially a movement toward a perceptual norm—in this case the norm being "straightness" (Gibson, 1933, 1959). This has never seemed satisfactory, since it resembles a mere restatement of the empirical result and, hence, others have sought different explanations.

Köhler and Wallach (1944) attempted to explain the phenomenon in terms of cortical satiation processes, the same processes which they used to account for figural aftereffects. There are several difficulties with this explanation. For instance, the Gibson effect for curvature occurs even when the eye is free to move over the curve during the inspection period, whereas steady fixation seems to be necessary for the other phenomena classified as figural aftereffects. Another problem for this approach was posed by Carlson (1963) who found that the apparent straightening effect occurred even when the test curve was more curved than the inspection figure. This is in the opposite direction from that predicted from satiation theory. Similar results were found by Nozawa (1953, reviewed in Sagara & Oyama, 1957). In addition, Pick et al (1962) report that the Gibson effect and figural aftereffects decay differently as a function of the nature of the post-inspection visual field. These data challenge the adequacy of a figural aftereffects explanation.

The apparent straightening of an inspected curve has, to date, been viewed as a decrease in perceptual accuracy, that is to say, that after inspection the perception is distorted. Perhaps this viewpoint is incorrect. Most reports in the literature indicate that prolonged free inspection of figures, rather

than resulting in distortion, leads to an increase in the accuracy or veridicality of perception (i.e., Piaget & Morf, 1953-1954). Perhaps the most striking instances of such increase in accuracy with inspection are the decrements in the magnitude of the classical geometric illusions. Such decrement has been reported for the Müller-Lyer illusion (Judd, 1905; Köhler & Fishback, 1950; Lewis, 1908; Selkin & Wertheimer, 1957), for the horizontal-vertical illusion (Seashore, Carter, Farnum, & Seis, 1908), the Poggendorf illusion (Cameron & Steele, 1905), and the Zöllner illusion (Judd & Courten, 1905).

Perhaps the Gibson curvature effect could result from a similar increase in perceptual accuracy. If such a view were correct, one would expect to find that there is some distortion or illusion in the initial perception of a curve, an illusion that decreases with inspection. If a curve is initially perceived as more curved than it actually is, a decrement in this illusion would produce the observed Gibson effect. To determine whether or not the perception of a curve involves such an illusion which decreases with inspection, Experiment 1 was conducted.

EXPERIMENT 1

Some method had to be devised to assess the veridicality of the initial perception of curvature. It was decided to have Ss estimate the height of a curve (the distance between the wing tips) and the width of the curve (the displacement of the center of the curve). These two measures gave us an indication of perceived curvature which can be compared to the actual physical dimensions.

Subjects

Twenty students enrolled in the elementary psychology course at Stanford University participated in this experiment.

Apparatus

The stimuli employed were a rectangle 50 mm high and 7 mm wide, which served as the control figure, and a curve of the same height and width, which was the experimental figure. The curve was an arc of a circle with a radius of curvature of 48 mm. Both stimuli were drawn in black ink on 5 x 8 in. white cardboard cards. The stimuli were presented on a white display board approximately 18 in. from S, and could be oriented with the long dimension either horizontal or vertical.

Measurement of the apparent size of the parts of the figures were made by use of an adjustable line length. This adjustable line length was a slide and groove arrangement, with a black line drawn on a 2.7 cm wide pasteboard slide. The inked line extended out to within 5 cm of the end of the slide. S pulled or pushed the slide manually to change the amount of line visible. Readings were taken from a millimeter scale affixed to the back of the apparatus.

The adjustable line length was placed 20 cm below and 14 cm to the left of the stimulus card. Both the stimulus and measuring device were simultaneously in view. The adjustable line was always placed in the same orientation as the dimension to be estimated.

Procedure

The Ss were randomly assigned to one of two conditions; half viewed both the rectangle and the curve with the long dimension vertical, while the other half viewed them with the long dimension oriented horizontally.

S was required to estimate the height and the width of the stimulus figures by setting the adjustable line length equal to the required dimension. S made two settings of the height and width of the rectangle and then of the curve. Each dimension was measured once starting with the line pushed in and once with it pushed out. Order of height and width measurements was counterbalanced.

Following these measures S was told, "Now I want you to look at the curve. You may run your eyes up and down it, but I want you to pay attention only to the curve." S then inspected the curve for 5 min. The instruction was repeated about half way through the inspection period. Five minutes of inspection of a curve has been shown to be an adequate amount of time for the Gibson curvature effect to develop (Bales & Follansbee, 1935; Pick et al, 1962).

Following this inspection, S was once again required to estimate the height and width of the curve, as in the premeasure.

Results

Table 1 presents the results of this experiment. We may first look at the data for the rectangle and the curve on the initial measurements. The difference between the width estimate of the curve and the width estimate of the rectangle was 3.2 mm for vertical orientation and 2.7 mm for horizontal orientation. This overestimation of the curve width relative to the rectangle width is significant with $p < 0.001$ ($t = 6.94$ for vertical orientation and $t = 4.80$ for horizontal orientation). The height differences were 0.05 mm for vertical and -2.4 mm for horizontal orientation, neither of which are significant ($t = 0.39$ for vertical orientation and $t = 0.87$ for horizontal).

Table 1. Perceived Height, Width and Radius of Curvature for Curve and Rectangle in Experiment 1.*

Dimension	Physical Measure	Orientation of Stimuli			
		Vertical		Horizontal	
		Curve	Rectangle	Curve	Rectangle
Initial Measure					
Height	50.0	51.2 (3.9)	51.7 (2.2)	48.2 (5.2)	50.6 (5.3)
Width	7.0	9.6 (1.4)	6.4 (0.7)	8.8 (1.6)	6.1 (0.7)
Radius of Curvature	48.0	39.0 (6.1)	--	38.0 (7.8)	--
After Inspection					
Height	50.0	52.2 (3.0)	--	49.8 (6.4)	--
Width	7.0	8.7 (1.7)	--	7.4 (1.3)	--
Radius of Curvature	48.0	44.1 (4.9)	--	47.0 (13.4)	--

*All numbers in mm. Standard Deviations given in parentheses.

One may also compare the estimates to the actual physical dimensions. None of the height estimates are significantly different from the actual physical height. For the curve, the width estimates were 9.6 mm for the vertical orientation and 8.8 mm for the horizontal. Both of these estimates are significantly greater than the actual physical width of 7 mm at $p < 0.001$ ($t = 7.02$) for the vertical orientation and $p < 0.02$ ($t = 3.05$) for horizontal. For the rectangle the width estimate of 6.4 mm in the vertical orientation is almost significantly different from the physical dimension at $p < 0.10$ ($t = 2.10$), and the estimate of 6.1 mm in the horizontal orientation is a significant underestimation at $p < 0.05$ ($t = 2.44$). It is clear that overestimation of the curve width, without overestimation of curve height, reflects a perception of greater curvature than is physically present in the figure. This may also be seen by computing the perceived radii of curvature. For the vertical orientation the perceived radius of curvature is 39 mm and for the horizontal it is 38 mm. Both of these are significantly less than the physical radius of curvature which is 48 mm ($p < 0.001$, $t = 4.46$, and $p < 0.01$, $t = 3.80$, respectively). The curve is indeed perceived as more curved than it physically is and this perception of increased curvature is due to an overestimation of the width dimension.

Let us now turn to the height and width estimates following the 5 min inspection of the curve. The mean change in the height estimate was 1.0 mm for the vertical orientation and 0.6 mm for horizontal. Neither of these changes is significant ($t = 1.07$ for vertical and 1.49 for horizontal). For the width, the changes were -0.9 mm for vertical and -1.4 mm for horizontal orientation. Both changes are

Fig. 1. (a) Ponzo Illusion; (b) Possible perceptual effect of perspective lines.

significant, at $p < 0.05$ for vertical ($t=2.36$) and $p < 0.001$ ($t=6.71$) for horizontal. The computed radius of curvature also, of course, changes. There is an increase of 5.1 mm for the vertical orientation and 9.0 mm for the horizontal, both of which are significant, at $p < 0.02$ ($t=2.97$) for vertical and $p < 0.01$ ($t=3.79$) for horizontal orientation.

Discussion

The data support the idea that the Gibson curvature effect should be viewed as similar in nature to the well known decrements in magnitude of geometric illusions. We have shown that the initial perception of a curve is more curved than actuality and that this illusion decreases with inspection. The illusion and the decrement are entirely confined to the width dimension.

It might be argued that the width estimation of the curve cannot be adequately compared to the width estimation of the rectangle since the former is an open figure and the latter a closed figure. Indeed, Sanford (1898) demonstrated that the width of an open figure does tend to be overestimated. Although this would not explain the decrement in overesti-

mation following inspection, it is serious enough to warrant repeating the experiment with a more adequate control figure.

In addition to questions as to the adequacy of the rectangle as a control figure, questions may be raised as to why such an illusion should exist, that is, why should excessive curvature be perceived. In the next experiment we also investigated one possible basis for this illusion.

EXPERIMENT 2

One of the most interesting attempts to elaborate the basis of visual geometric illusions has been presented by Gregory (1963, 1966). He maintains that certain lines in some illusion figures serve as perspective cues. These perspective cues evoke constancy scaling mechanisms appropriate to figures actually viewed in depth. This constancy scaling is misapplied since the illusion figures are really flat. This misapplication of the constancy scaling results in these illusions, as can be illustrated by the Ponzo illusion (Fig. 1a). Line 1 is seen as longer than line 2, according to this perspective notion, because the converging lines surrounding line 1 and line 2 evoke constancy scaling as if they were receding back into space. Lines 1 and 2 subtend the same retinal angle, but, since the misapplied perspective cues indicate that line 1 is farther away than line 2, the constancy scaling comes into play and indicates that line 1 is larger than line 2. Gregory feels this explanation applies to the Müller-Lyer illusion and others in addition to the Ponzo illusion. Gregory (1966) shows in support of his idea that the magnitude of the Müller-Lyer illusion correlates very well with the perceived depth of the same figures when they are viewed monocularly in a minimal cue situation.

These ideas led us to wonder whether the relatively flat wings of a curve could also serve as perspective cues as illustrated in Fig. 1b. If so, constancy scaling might be evoked as if the curve were actually rotated in space. It is clear that if such rotational cues do exist, then by application of misplaced constancy scaling one would obtain an overestimation of the width of the curve. The height would not be affected. If this is the proper explanation of the curvature illusion, then one should find a correlation between the magnitude of the perceived rotation of the curve in a monocular minimal cue situation and the magnitude of overestimation of the width in a normal viewing condition.

We earlier discussed some difficulties in interpretation when a rectangle was used as a control figure. For this experiment, therefore, the form in Fig. 2 was used.

The operations necessary to judge the height and the width in this control figure more closely resem-

Fig. 2. Control figure used in Experiment 2.

ble those necessary for the estimations of the curve. Both are open figures and none of the lengths estimated are actual lines in either figure.

Subjects

Thirty-six Stanford students were used in this study. Twelve were graduate student volunteers and 24 were undergraduates enrolled in the elementary psychology course.

Illusion measurement

Two stimuli were drawn on white paper with black ink. One was a curve with height 20.25 cm and width 5.1 cm. The control figure (see Fig. 2) had the same height and width.

A larger version of the adjustable line length used in Experiment 1 was employed. A black line of 2.0 mm width was placed on a white Formica slide. The slide was 1.3 cm wide. The readings of length settings were taken from a centimeter scale abutted against the slide.

The stimulus to be judged was mounted on a black display board 40 cm from S. The adjustable line was placed with its base 15 cm to the left and 8 cm below the figure. Both the adjustable line and the test stimulus were simultaneously in view.

Measurements of height and width were made exactly as in Experiment 1, except that here the order of the curve and control figure measurements were balanced across Ss.

Depth measurement

A modification of Gregory's apparatus was prepared (Gregory, 1966). Two stimulus masks were made from heavy construction paper. One contained a cut-out curve of the same dimensions as that used in estimating height and width. The other contained a cut-out straight line of the same height. These stimulus masks could be mounted in front of a polarized light source. The eye piece through which

S viewed the figures contained polaroid filters that caused the figure to be seen monocularly as a luminous line or curve.

Mounted on a track extending out laterally was a frame containing three neon light bulbs. These could be individually lit and were screened from shedding ambient light by electrical tape and frosted paper. The images of these lights were reflected from a half silvered mirror and were seen binocularly by S. As S moved a handle laterally, the point of light seemed to approach or recede in distance from him. One light was set to be at the height, and slightly to the right, of the bottom of the curve or of the line, another to the height, and slightly to the right, of the middle of the curve, and the third at the height, and slightly to the right, of the middle of the line. At any one time only one of the adjustable lights was turned on. Nothing but the luminous figure and the movable point of light was visible to S.

S was required to set the light so that it was the same distance away from him as various parts of the figure that he was viewing. He made two settings of the apparent distance of the bottom and of the middle of each figure. Order of measurements and of figures was counterbalanced.

Results

The data on estimates of height and width with normal viewing are shown in Table 2. The estimated width of the control figure was 5.47 cm, for the curve it was 6.24 cm. Both widths are overestimated relative to the actual physical width of the figure, a finding consistent with Sanford's report (Sanford, 1898) that the width of open figures tends to be overestimated. The overestimations are significant for both with $p < 0.001$ ($t = 5.84$) for the curve and $p < 0.01$ ($t = 3.49$) for the control. The width of the curve, however, is significantly overestimated compared to the width of the control figure ($p < 0.001$, $t = 5.35$).

Ss significantly overestimated the height of the control figure ($t = 4.37$) and the difference between the height estimates for the curve and the control figure is significant ($p < 0.05$, $t = 2.38$). The reason for this difference is unclear to us.

Some measure which takes both estimates of height

Table 2. Perceived Height, Width and Radius of Curvature for Curve and Control Figure in Experiment 2.*

Dimension	Physical Measure	Curve	Control
Height	20.25	20.59	21.22
		(1.46)	(1.33)
Width	5.10	6.24	5.47
		(1.17)	(0.64)
Radius of Curvature	12.60	11.92	13.19
		(1.57)	(1.77)

*All numbers in cm. Standard deviations given in parentheses.

Table 3. Perceived Distance of Middle and Bottom of Curve and Line in Experiment 2.*

	Curve	Line
Bottom	41.39 (7.99)	47.10 (12.84)
Middle	45.70 (9.03)	47.29 (13.22)

*All numbers in cm. Standard Deviations given in parentheses.

and width into account is also desirable. One such measure is the radius of curvature. The actual physical radius of curvature is 12.60 cm. The estimated radius of curvature is 11.92 cm for the curve and 13.19 cm for the control figure. This difference is significant with $p < 0.001$ ($t = 5.38$). The estimated radius of curvature for the curve is significantly smaller than the physical radius of curvature with $p < 0.02$ ($t = 2.61$). The radius of curvature of the control figure is significantly larger than the physical measure with $p = .05$ ($t = 2.00$).

These data, obtained using a more adequate control figure, are consistent with the data from Experiment 1. A curve is perceived as more curved than it physically is and this curvature illusion is attributable to an overestimation of the width dimension.

Let us now turn to the monocular depth estimates. The data are presented in Table 3. If the curve is seen as rotated in space, we would expect a difference between the perceived distance of the middle of the curve and the perceived distance of the bottom. This difference is 4.31 cm for the curve, that is, the middle of the curve is seen as 4.31 cm farther away than the bottom. This difference is significant with $p < 0.001$ ($t = 4.02$). The comparable measure for the line is a nonsignificant 0.19 cm. The difference of 4.12 cm between these measures for the curve and the line is significant in the predicted direction ($p < 0.01$, $t = 3.38$). As may be seen in Table 3, the absolute distance settings are quite variable. This is due to the fact that some of the Ss tend to see the figures as quite close and some as quite far away. However, each S is usually consistent within his frame of reference.

These data make it clear that in the minimal cue, monocular circumstance, the curve is indeed seen as rotated in space, with the middle being perceived as farther away than the wing tips. The data in Table 2 also make it clear that the width of a curve seen under normal viewing conditions is overestimated. If both of these perceptions are due to the same process, then one would expect a positive correlation between the magnitude of the perceived rotation and the magnitude of the width overestimation. This product moment correlation is +0.35, which for $N = 36$ is significant ($p < 0.05$). This positive correlation strengthens the contention that the perspective cues provided by the wings of the curve produce the overestimation of width through the misapplication of constancy scaling.

It is interesting in this connection that the magnitude of the two effects are roughly comparable. One may calculate the magnitude of the width estimation that might be expected from the magnitude of rotation obtained in the monocular situation. The expected perceived width, if shape constancy were perfect, is 6.67 cm. If shape constancy were less than 100 per cent then the obtained width estimate of 6.24 cm would not be too far off.

DISCUSSION AND CONCLUSIONS

The results of both experiments demonstrate that a curved line is initially seen as more curved than is warranted by its physical dimensions. The first experiment also shows that the curvature illusion decreased after 5 min of inspection under conditions which normally produce the "Gibson normalization effect." There is a similarity here to results obtained in studies of decrement in the magnitude of the classical geometric illusions such as the Müller-Lyer illusion. In each of these situations one starts with a figure which is seen as distorted in some dimension. With inspection, the magnitude of the illusion decreases for both. These similarities seem to suggest that both the decrement in the geometric illusions and the apparent straightening of an inspected curve (the "Gibson effect") may be due to the same underlying psychological process.

Both the normalization hypothesis and the figural aftereffect explanation for the Gibson effect, in addition to their shortcomings discussed earlier, start with the assumption that the apparent straightening of a curve following inspection represents a distortion of the figure. The data we have presented indicate that the Gibson effect is simply the decrease of an already existing distortion. If we are correct, these other attempted explanations seem irrelevant.

Given the existence of the curvature illusion, one would like to know why it occurs and the mechanism by which it decreases with inspection. The basis of this distortion, or illusion, seems to be interpretable in terms of Gregory's hypothesis of misapplied constancy (Gregory, 1963, 1966), the wings of the curve serving as perspective cues. Such an interpretation would imply that when viewed monocularly in a minimal cue situation, a curve would appear to be rotated with the middle seen as farther away than the wing tips. It would also imply that the illusion would be confined to the width dimension. In addition, the magnitude of the width overestimation and the degree of perceived rotation of the curve should be positively correlated. Data from the second experiment confirm all of these expectations.

Although we did not deal with the matter experimentally, it is important to understand the mechanism by which the illusion decreases with inspection. Some recent data seem to indicate one possible basis for such an illusion decrement. Festinger, White and Allyn (1967, in press) have found that saccadic eye movements

during an inspection period produce more decrement of the Müller-Lyer illusion than does fixation. Burnham (1967, in press) has also shown that saccadic eye movements produce more decrement in the Müller-Lyer illusion than do smooth tracking eye movements. The explanation offered for these results is that information is obtained from erroneous eye movements that is used to correct the eye movements. This leads to a decrement in the illusion magnitude. The same mechanism may be responsible for the reduction of the curvature illusion.

We have come to the conclusion that the process which is responsible for the Gibson effect is the same process which is responsible for the decrement in geometric illusions. It is easy, however, to see why other investigators regarded the Gibson effect as a distortion of perception. The fact that, after inspecting a curve, a straight line appears distortedly curved, would lead easily to this view. It is, however, not a necessary view to take. Whatever correction process is responsible for the decrement of the curvature illusion undoubtedly generalizes to other figures viewed immediately after the inspection period. Thus, through such generalization, a decrement in an illusion can result in a distortion of some other figure.

References

- Bales, J. F., & Follansbee, G. L. The aftereffect of the perception of curved lines. *J. exp. Psychol.*, 1935, 18, 499-503.
- Burnham, C. A. Decrement of the Müller-Lyer Illusion with saccadic and tracking eye movements. Manuscript in preparation, Univ. of Texas, 1967.
- Cameron, E. H., & Steele, W. M. The Poggendorf Illusion. *Psychol. Rev. Monogr. Suppl.* 1905, 7 (#29), 83-111.
- Carlson, V. R. Generality of negative aftereffect following adaptation to curvature. *Scand. J. Psychol.*, 1963, 4, 129-133.
- Festinger, L., White, C. W., & Allyn, M. Eye movements and the Müller-Lyer Illusion. Manuscript in preparation, Stanford Univ., 1967.
- Gibson, J. J. Adaptation, after-effect and contrast in the perception of curved lines. *J. exp. Psychol.*, 1933, 16, 1-31.
- Gibson, J. J. Perception as a function of stimulation. In S. Koch (Ed.), *Psychology: A study of a science*. New York: McGraw Hill, 1959. Pp. 456-501.
- Gibson, J. J., & Radner, M. Adaptation, after-effect and contrast in the perception of tilted lines: I Quantitative studies. *J. exp. Psychol.*, 1937, 20, 453-467.
- Gregory, R. Distortion of visual space as inappropriate constancy scaling. *Nature* (London), 1963, 199, 678-680.
- Gregory, R. L. Visual illusions. In B. M. Foss (Ed.), *New horizons in psychology*. Baltimore: Penguin Press, 1966. Pp. 68-96.
- Judd, C. H. The Müller-Lyer Illusion. *Psychol. Rev. Monogr. Suppl.*, 1905, 7 (#29), 55-81.
- Judd, C. H., & Courten, H. C. The Zöllner Illusion. *Psychol. Rev. Monogr. Suppl.*, 1905, 7 (#29), 112-139.
- Köhler, W., & Fishback, Julia. The destruction of the Müller-Lyer Illusion in repeated trials: I. An examination of two theories. *J. exp. Psychol.*, 1950, 40, 267-281.
- Köhler, W., & Wallach, H. Figural after-effects. *Proc. Amer. Phil. Soc.*, 1944, 88, 269-357.
- Lewis, E. O. The effect of practice on the perception of the Müller-Lyer Illusion. *Brit. J. Psychol.*, 1908, 2, 294-306.
- Nozawa, S. Prolonged inspection of a figure and the after-effect thereof. *Jap. J. Psychol.*, 1953, 23, 217-234; 24, 47-58.
- Piaget, J., & Morf, A. Recherches sur le développement des perceptions. XX. L'action des facteurs spatiaux et temporels de centration dans l'estimation visuelle des longueurs. *Arch. Psychol. Geneve*, 1953-54, 34, 243-288.
- Pick, H. L., Jr., Hetherington, M., & Belknap, R. Effects of differential visual stimulation after induction of visual after-effects. *J. exp. Psychol.*, 1962, 64, 425-429.
- Sagora, M., & Oyama, T. Experimental studies on figural after-effects in Japan. *Psychol. Bull.*, 1957, 54, 327-338.
- Sanford, E. C. *A course in experimental psychology. Part I: Sensation and perception*. Boston: Heath, 1898.
- Seashore, E. C., Carter, E. A., Famum, E. C., & Seis, R. W. The effect of practice on normal illusions. *Psychol. Rev. Monogr. Suppl.*, 1908, 9 (#38), 103-104.
- Selkin, J., & Wertheimer, M. Disappearance of the Müller-Lyer Illusion under prolonged inspection. *Percept. mot. Skills*, 1957, 7, 265-266.

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