The apparent size of "projected" afterimages under conditions where size-constancy holds¹

JOHN J. FUREDY,² UNIVERSITY OF TORONTO
AND GORDON STANLEY, UNIVERSITY OF MELBOURNE

Stanley and Furedy (1966), using the paired-comparisons technique, reported that under conditions where size constancy held, Emmert's law failed as distance increased beyond 90 in. Experiment 1, designed to check this report with a shorter-duration induction flash, did not yield 90 in. as the point of failure. However, although complete size constancy for direct images was again obtained, the results did not unambiguously suggest strict proportionality between afterimage size and distance. To allow a less ambiguous assessment of proportionality, Experiment 2 used magnitude-estimation procedures. Distance estimates were completely veridical, but afterimage size varied only linearly, and not proportionally, with apparent distance. It was concluded the Boring (1940) was mistaken in his attempt to reduce size constancy and Emmert's law to the same principle.

Séguin (1858) noted that the apparent size of an afterimage varied as a function of the distance of the field of projection. Emmert (1881) formalized this relationship in what has subsequently become known as *Emmert's law*: The size of an afterimage (Nachbild) is directly proportional to the distance of the ground of projection from the O. There has been debate about whether the size and distance to which Emmert referred was physical (Young, 1948, 1950, 1951) or apparent (Boring, 1940; Edwards, 1950, 1953; Edwards & Boring, 1951), with the proponents of the latter view claiming that a physical interpretation of the law would reduce it to a trivial example of Euclidean ocular geometry.

An earlier version of the apparent interpretation of the law was put forward by Koffka (1935), who maintained that "the distance of the ground upon which the size of the after-image depends is not the objective or geographical, but the phenomenal or behavioral distance [p. 212]." Boring (1940), in supporting this view that apparent estimates were involved, further suggested that the law was an example of the principle of size constancy. One implication of Boring's position is that the law should hold only

under conditions where size constancy holds, an implication that was supported by Edwards (1953), who found that under reduction conditions (where size constancy would not obtain), the apparent sizes of the afterimages did not conform to the law. Similarly, Helson (1936) had reported that when the afterimage was viewed through a tube having a diameter only slightly larger than the image, most reports of perceived size were either equal to or only slightly larger than those for when projection distances were 2, 5, and 6 times the original distance of fixations of the stimulus. He concluded that for Emmert's law to hold, the image must be perceived in normal perspective relations.

Another implication of Boring's view that Emmert's law is a case of size constancy is that the law should hold when there is size constancy. Price (1961) reported evidence to support this, but Stanley and Furedy (1966) criticized his experiment on the grounds that he had always presented his Ss with the projection screen at the close distance first. This procedure may have led to the development of a response tendency to see the later-presented and apparently further afterimages as *always* increasing in size, independently of the range of distances of the projection field. In line with this possibility, Stanley and Furedy's results, which were based on randomly ordered presentations of distances, indicated that although size constancy obtained with comparable direct images over the whole range of distances from 18 to 126 in., the paired-comparisons scale for apparent afterimage size showed Emmert's law to fail as distance increased over 90 in. However, the afterimage was induced for 30 sec, a duration long enough for Ss to make eye movements, despite the instructions to fixate. Eye movements could have increased the area of the retina being stimulated and could, hence, have vitiated the comparison with the direct images in the size-constancy phase of the experiment.

The first experiment to be reported was designed to deal with this eye-movement problem. The second experiment employed a different psychophysical method from that of paired comparisons in order both to eliminate a possible confounding and to

allow a more precise test of whether or not the relationship between apparent size and distance was, indeed, one of strict proportionality.

EXPERIMENT 1

The aim was to replicate the previous study, with two changes. First, a 3-msec induction flash was used to eliminate the possibility of eye movements. Second, since the most interesting feature of the previous study was the breakdown at 90 in., only the five longest distances of that study were examined in the present experiment. These distances ranged, in 18-in. steps, from 54 to 126 in.

Subjects

Fifty students in an introductory course at Indiana University served as Ss.

Apparatus

The afterimage induction flash was a light circle subtending a visual angle of 2 deg 52 min, illuminated by a 3-msec flash from a photographic flash gun. A green Kodak Wratten filter (58) was placed in front of the gun. The remainder of the apparatus has been described previously (Stanley & Furedy, 1966). Briefly, the room illumination was feeble (0.035 apparent ft-c), the projection field was a moveable 3 x 5 ft white board, and the grey direct-image discs for the size-constancy phase of the experiment were attachable to the center of the board.

Procedure

The design of the experiment was as previously described (Stanley & Furedy, 1966), except that only five distances were used. Thus, in Phase 1 (Emmert's law), 30 Ss made paired-comparison judgments of the afterimage size and then of the distance of the projection field, at five distances ranging from 54 to 126 in. In Phase 2 (size constancy), 20 Ss made size and distance estimates using direct images that subtended the same retinal angle as that subtended by the afterimage-inducing stimulus. The general procedure and instructions in both phases were as reported by Stanley and Furedy (1966).

Results

From the 300 comparisons of apparent

Fig. 1. Paired-comparisons scales of the judged size of an afterimage as a function of the physical distance of the projection field.

distance made by the 30 Ss in Phase 1, the physically further distance was judged to be further 296 (98.7%) times, a result that replicates the previous study in clearly ordering the judged distances of the screen according to its physical distance from S. From the analogous 300 comparisons of the apparent sizes of the afterimage, the image "projected" onto a physically more distant field was judged to be larger 214 (71.3%) times. The proportions of times that the afterimage projected at a given distance was judged larger than the afterimage at another distance were .350, .358, .475, .633, and .683 for the 54-, 72-, 90-, 108-, and 126-in. distances, respectively. The results of computing the scale values for these size judgments in the five positions, where the scaling method assumes constant variance of discriminial differences (Torgerson, 1958, p. 161), are shown in Fig. 1, which also shows the values from the previous experiment. It will be noted that while the locus of the previous breakdown at 90 in. was clearly not replicated in the present results, there are suggestions of breakdowns at both the first and second, and fourth and fifth, abscissal points, pairs of points between which the paired-comparisons scale distances seem to diminish markedly. However, these breakdowns were not statistically reliable in terms of a test for departures from linearity applied over all five abscissal points, the least-squares fit yielding a chi square of 2.8, $df = 3$, $p > .2$. Indeed, application of the same test over the seven abscissal points of the earlier study yielded only a near-significant chi square of 9.2, $df = 5$, $p < .1$.

From the 200 comparisons of apparent distance made by the 20 Ss in Phase 2, the physically further distance was judged to be further 191 (95.5%) times, while the

corresponding 200 comparisons of apparent size of the discs produced 197 occasions (98.5%) when the physically larger disc was judged as larger. These results, like those of the previous study, indicate veridical distance judgments as well as size-constancy judgments under the low-illumination conditions.

As in the previous study (Stanley & Furedy, 1966), the hypothesis was entertained that Emmert's law did hold clearly, but only for some Ss in the population. As one test of this hypothesis, the rank correlations for each Phase 1 S were computed for size and distance judgments over the five positions. Although the 20 correlations ranged from +.95 to -.25, there was no evidence for a bimodal distribution and, hence, no support for the hypothesis. Another test can be obtained by determining the Emmert Score (ES) for each Phase 1 S, where ES is given by the number of occasions on which the further-projected afterimage is judged to be larger, and then examining the frequency distribution of these ES values. The obtained frequencies from the 20 Phase 1 Ss were 3, 6, 2, 5, 7, 2, 4, and 1 for ES values of 10, 9, 8, 7, 6, 5, 4, and 3, respectively. As in the case of the rank correlations, however, the departure from normality of this distribution was not significant ($p = .2$), as tested by the Kolmogorov-Smirnov one-sample test (Siegel, 1956).

Discussion

In both this and the previous experiment (Stanley & Furedy, 1966), the results clearly indicate both that size constancy held and that apparent distance was unequivocally and directly related to physical distance. However, the relationship between apparent size and

(both physical and) apparent distance remains in question. On the one hand, the breakdowns in linearity in the two experiments, as represented in Fig. 1, were neither consistent between experiments in locus nor statistically reliable by the chi-square, goodness-of-fit tests. On the other hand, the chi-square tests in these applications lack power because of the relatively few degrees of freedom, so that very gross departures from linearity would be required for the rejection of the null hypothesis. Nevertheless, in contrast to our previous claim (Stanley & Furedy, 1966), the data at most provide only an ambiguous case against Emmert's law, and this ambiguity suggested the need for a change in experimental tactics for examining the law.

EXPERIMENT 2

The previously used psychophysical method of paired comparisons has at least two disadvantages that it does not share with the method of magnitude estimation. First, since S had to close his eyes between the two observations necessary for each paired comparison, the relative estimates of the two sizes could have been influenced by the entoptic afterimage (Stanley, 1966) that is present under such conditions. While the entoptic afterimage could be confounding in paired-comparisons judgments, its presence as a standard should be an aid in the case of magnitude estimation. The second disadvantage of the paired-comparisons method concerns the limited information that it yields, a shortcoming that emerges from considering the abscissal and ordinal values in Fig. 1. As the two scales are not comparable, it is clear that the question of whether or not size increases strictly *proportionally* with distance cannot be determined. That is, only the *linearity*, not the *slope*, of the function can be assessed. On the other hand, the magnitude-estimation method used in the following experiment allowed assessment of both characteristics of the function.

Subjects

Forty students in an introductory course at the University of New England served as Ss.

Apparatus

The apparatus was identical to that used in Experiment 1, except that: (a) no direct-image discs were used, and (b) the

Fig. 2. Mean apparent projection-field distances and afterimage sizes as functions of physical projection-field distance.

be influenced by information other than that based on visual distance (e.g., Urist, 1959; Gregory, Wallace, & Campbell, 1959). In this connection, it will be noted that the present failure to obtain proportional increases in afterimage size with increasing projection distances is similar to Helson's (1936) results mentioned at the outset. Such similarity in results would not be expected from Boring's reductionist position, since in the present experiments, in contrast to Helson's conditions, distance cues were both readily available to Ss and were obviously used by them in their clearly veridical judgments of distance.

room illumination was 0.03 apparent ft-c.

Procedure

All seven distances of Stanley and Furedy's study (18-in. steps from 18 to 126 in.) were used. Each S first made estimates of afterimage size at each distance and then made estimates of distance. The order of distances for the two conditions was randomized for each S. The procedure and instructions regarding size and distance estimates followed those detailed previously (Stanley & Furedy, 1966), except that: (a) S was presented with a single rather than pairs of afterimages and distances, and (b) restimulation of the afterimage (when necessary) was given in the eye opposite to that in which S had reported fading of the afterimage.

Results

Figure 2 shows the mean estimates of both apparent afterimage size (open circles) and projection-field distance (closed circles) as functions of physical projection-field distance. The axes are scaled to yield a 45-deg slope for the locus of theoretical points predicted from Emmert's law: strict proportionality between apparent afterimage size and apparent projection-field distance. As in the previous experiments, apparent size did increase as a function of physical projection-field distance, and a one-way analysis of variance showed this increase to be both reliable [$F(6,234) = 4.88$, $p < .001$] and linear, with the quadratic component failing to approach significance ($F < 1$). Similarly, as in the previous experiments, apparent distance was both a reliable [$F(6,234) = 150.54$, $p < .001$] and

a linearly increasing function of physical distance, with the quadratic component again failing to approach significance ($F < 1$). In addition, apparent distance increased proportionately with physical distance, with the slope of the line of best fit being 42 deg 50 min, which does not differ significantly from the 45-deg slope of the theoretical function [$t(234) = 0.15$]. In contrast, the slope of the line of best fit for the apparent-size function was 6 deg 10 min, which is significantly different from the theoretical function predicted on the basis of strict proportionality between size and physical distance [$t(234) = 3.89$, $p < .001$].

Discussion

Emmert's law was confirmed by the present results in the weak sense that, since both apparent size and apparent distance varied reliably and linearly with physical distance, the former two dependent variables varied directly and linearly with each other. However, since only apparent distance, and not apparent size, varied proportionally with physical distance, the present use of the magnitude-estimation method does not support the strict version of Emmert's law: The apparent size of an afterimage does *not* seem to increase proportionally to the apparent distance of the field of projection.

That this strict proportionality fails to hold under conditions where both complete size constancy obtains and distance estimates are veridical suggests that Boring (1940) was mistaken in his attempt to reduce size constancy and Emmert's law to the same principle. One reason why such a reduction may be unsound is that the size of afterimages can

REFERENCES

- BORING, E. G. Size constancy and Emmert's law. *American Journal of Psychology*, 1940, 53, 293-295.
- EDWARDS, W. Emmert's law and Euclid's optics. *American Journal of Psychology*, 1950, 63, 607-612.
- EDWARDS, W. Apparent size of after-images under conditions of reduction. *American Journal of Psychology*, 1953, 66, 449-455.
- EDWARDS, W., & BORING, E. G. What is Emmert's law? *American Journal of Psychology*, 1951, 64, 416-422.
- EMMERT, E. Grossenverhältnisse der Nachbilder. *Klinisches Mitteilungsblatt für Augenheilkunde*, 1881, 19, 443-450.
- GREGORY, R. L., WALLACE, J. G., & CAMPBELL, F. W. Changes in the size and shape of visual after-images observed in complete darkness during changes of position in space. *Quarterly Journal of Experimental Psychology*, 1959, 11, 54-55.
- HELSON, H. Size-constancy of the projected after-image. *American Journal of Psychology*, 1936, 48, 638-642.
- KOFFKA, K. *Principles of Gestalt psychology*. New York: Harcourt, Brace, 1935.
- PRICE, G. R. On Emmert's law of apparent sizes. *Psychological Record*, 1961, 11, 145-151.
- SÉGUIN, M. J. M. Recherches sur les couleurs accidentelles. *Annales de Chimie et de Physique*, 1858, 41, 423.
- SIEGEL, S. *Nonparametric statistics*. New York: McGraw-Hill, 1956.
- STANLEY, G. The apparent size of entoptic after-images. *Psychonomic Science*, 1966, 4, 289-290.
- STANLEY, G., & FUREDY, J. J. Size constancy and Emmert's law of apparent sizes. *Australian Journal of Psychology*, 1966, 18, 266-270.
- TORGERSON, W. S. *Theory and methods of scaling*. New York: Wiley, 1958.
- URIST, M. J. After-images and ocular muscle proprioception. *American Medical Association Archives of Ophthalmology*, 1959, 61, 230-232.
- YOUNG, F. A. The projection of after-images and Emmert's law. *Journal of Genetic Psychology*, 1948, 39, 161-166.

YOUNG, F. A. Boring's interpretation of Emmert's law. *American Journal of Psychology*, 1950, 63, 277-280.

YOUNG, F. A. Concerning Emmert's law. *American Journal of Psychology*, 1951, 64, 124-128.

NOTES

1. The preparation of this report was aided by

Grant APA 303-118-80 to the senior author from the National Research Council of Canada and by critical advice from G. B. Thornton and J. C. Ogilvie. A brief version of this report was presented at the Annual Conference of the Australian Psychological Society, August 1968.

2. Address: Department of Psychology, University of Toronto, Toronto, Ont., Canada.

3. The term, "projected," is not meant in its

literal sense. The term is an unfortunately widespread remnant from the days of the projection theory of vision, but none of those associations are implied by its use in the present article.

(Accepted for publication May 19, 1969.)