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THE EFFECT OF ATTITUDE UPON THE PERCEPTION OF SIZE

By ALBERTA S. GILINSKY, Columbia University

In the absence of other indicants to distance, the size of the retinal image necessarily determines our perceptions of two dimensions, width and height.[1] Holway and Boring have shown that as increasing sensory data are made available, perceived size comes to depend less on retinal size and more on object-size as distance is varied.[2] For free binocular regard, functions relating the adjusted size of a comparison-object to the distance of a standard object were close to or exceeded the function for size-constancy, at least up to 120 ft., the maximal distance used in their experiment. What happens at greater distances? Two experiments have been reported which match a relatively near-by object to a distant object: one, a stake, half-a-mile away; the other, the moon, 239,000 miles away.

Under open-air conditions favorable for viewing distance, Gibson required his *Ss* to estimate the real, correct height of wooden stakes, from 14 to 784 yd. (nearly half-a-mile), in terms of a numbered series of comparison stakes, 14 yd. away.[3] Five practice trials were given with the test-objects at the same distance as the comparison objects, 14 yd., followed by 25 trials at each of 6 distances, beginning with

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[1] William Lichten and Susan Lurie, A new technique for the study of perceived size, this JOURNAL, 63, 1950, 280-282; A. H. Hastorf and K. S. Way, Apparent size with and without distance cues, *J. Gen. Psychol.,* 47, 1952, 181-188.

[2] A. H. Holway and E. G. Boring, Determinants of apparent visual size with distance variant, this JOURNAL, 54, 1941, 21-37.

[3] J. J. Gibson, Motion picture testing and research report No. 7, *Army Air Force Aviation and Research Reports,* 1947, 200-211.

the farthest distance and progressing toward the nearest. The results for the 71-in. stake were typical. The mean estimate at 14 yd. was 71.9 in. ($SD = 1.8$). At 784 yd., with the intervening ground continuously visible, the 71-in. stake gave a mean estimate of 74.9 in. ($SD = 9.8$). Although variability increased with distance, Gibson concluded that "an object can apparently be seen with approximately its true size *as long as it can be seen at all.*"[4]

Boring, on the contrary, found that the apparent size of the full moon on the horizon was equalled by an 8.5-in. disk 12 ft. away—that is, the moon on the horizon was matched by a disk subtending an angle of 3° although the moon itself subtended an angle of only 0.5°.[5] Boring summarizes his observations as follows: "It is impossible to perceive the moon as big as it really is (2160 miles across) or as small as its retinal image is (0.5° across). You see something in between, nearer retinal size than object size."[6]

These experiments leave us an unexplored range (between a half-a-mile and astronomical distances) and some very perplexing problems. Their results are contradictory: one indicates that size-constancy fails at great distances; the other that it does not. Boring accepts both conclusions and compares the paradox to the dilemma of the railroad tracks, now seen to converge, now seen not to converge.[7] He suggests that we may be dealing with two systems of perception, two observational attitudes corresponding perhaps to Gibson's distinction between the visual field and the visual world.[8] The problem, then, is to specify these two types of perception, this field and this world, in operational terms. How can this difference in observation be induced? If it depends upon different conditions of the organism and not upon different conditions of stimulation, then what are the alternative modes of response to the same stimulation, and how are they related to distance?

The present study attempts to answer these questions by investigating the perception of size of objects under two contrasting observational sets: one for matching 'objective' size; and the other for matching 'retinal' or 'projected' size.

Apparatus and Procedure

To provide a sufficient range and maximal opportunity for the object-directed set to exert an influence, the experiment was conducted out of doors in daylight with all the usual cues of distance available. The experimental site consisted of a fairly level stretch of grassy terrain parallel to an inactive airport runway, 5,000 ft. long.

The general plan of the experiment required that S match the size of a standard

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[4] Gibson, *The Perception of the Visual World,* 1950, 186.
[5] Boring, The moon illusion, *Amer. J. Physics,* 11, 1943, 55-60.
[6] Boring, Visual perception as invariance, *Psychol. Rev.,* 59, 1952, 146.
[7] *Ibid.,* 142 ff.
[8] Gibson, *The Perception of the Visual World,* 26-43.

stimulus-object placed at various distances directly ahead of him, by altering the size of a variable stimulus-object, 100 ft. away and 36° 26′ to the right of the direct line of regard.[9]

Stimulus-objects. The stimulus-objects were plane white isosceles triangles, constructed of sheet aluminum and placed perpendicularly. They were seen against a background of grassy terrain and remote trees and buildings at the far end of the

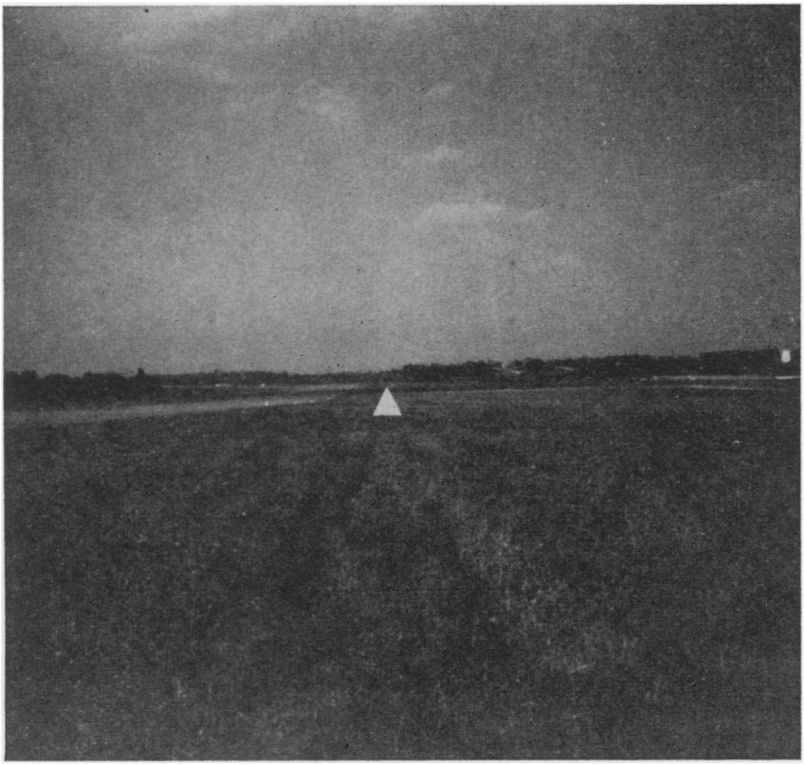

FIG. 1. SCENE AS VIEWED BY *S*
The 66-in. standard triangle at 200 ft.

field. Fig. 1, a photograph taken from *S*'s station, shows one of the standard triangles at 200 ft. The surface of the ground, as may be noted, is clearly visible and provides cues of perspective and texture. Other monocular cues were provided by aerial perspective, light and shade, and head-movement parallax. Binocular vision was employed throughout the study, thus stereoscopic vision may have supplied cues at the shorter if not at larger distances.

(*a*) *Standard.* Four standard triangles were used, which ranged in 12-in. steps

[9] R. B. Joynson (The problem of size and distance, *Quart. J. Exper. Psychol.*, 1, 1949, 119-135) found that the effect of size-constancy was maximal at approximately this degree of separation.

in base and altitude (which were equal) from 42 to 78 in., and in area from 882 to 3042 sq. in. In these triangles, a leg is 1.12 times the altitude or the base. The standard triangles were placed, one at a time, at 6 distances: 100, 200, 400, 800, 1600, and 4000 ft. from *S*.

(*b*) *Variable*. The variable triangle was identical in shape and color with the standard triangles. It could be varied in size by raising or lowering it into a pit in the ground. An attempt was made to provide a range in size-variation which exceeded the range in altitude of the standard objects at both ends. When elevated to maximal height, its altitude measured from ground level was 7 ft. 2 in. (see Fig. 2). While this upper limit exceeded by 8 in. the altitude of the largest test-object, it proved to be insufficient, as will appear later. The variable triangle could be lowered

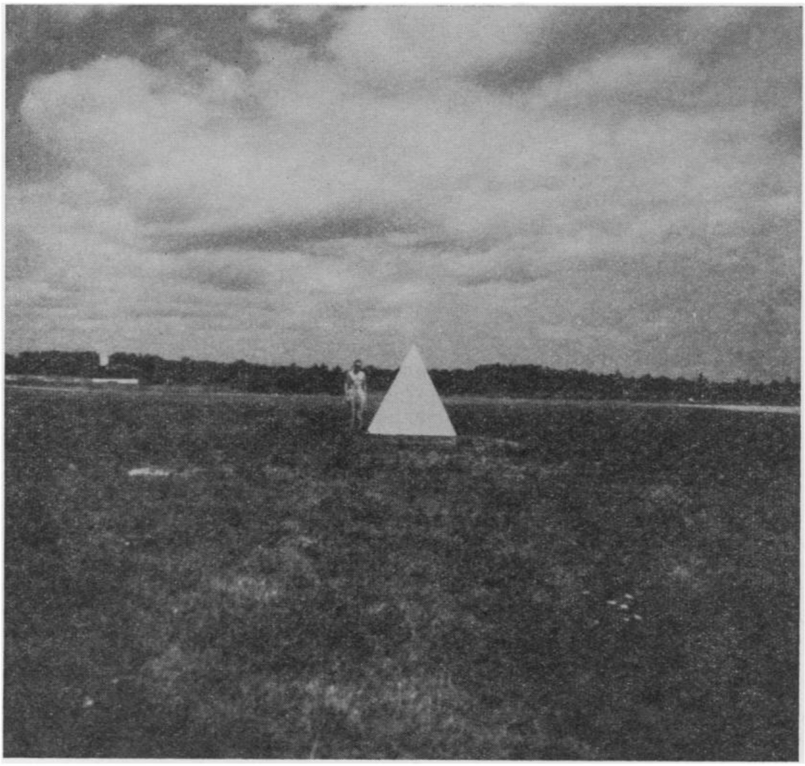

FIG. 2. VARIABLE TRIANGLE AT MAXIMAL SIZE
The man beside the triangle gives a cue, unavailable to *S*, of relative size.

below ground level to provide a zero value of the size-range. Since the nature of the mechanism was such that settings of the triangle at an altitude of only a few inches could not be accomplished as precisely as settings at greater altitudes, the variability of the settings at the lower end of the size-range was correspondingly greater.

The adjustment of the variable triangle was under the remote control of *S*. Compressed air was used to operate the lifting apparatus, as shown schematically in Fig. 3.[10] The apparatus was contained by a T-shaped pit, 8 ft. 5 in. deep, lined with cinder blocks. A side-view is shown at A. The triangle was supported by a double steel beam, 16 ft. in length, with a hinged coupling on the back of the triangle approximately 4 ft. from its top. The opposite end of the beam was connected to the end of the piston shaft of the air cylinder C by a hinged coupling at E. The beam supporting the triangle was itself supported by a second beam 8 ft. in length with a hinged coupling at B, exactly in the center of the longer beam. The 8-ft. beam was hinged to the base of the apparatus directly beneath the triangle.

This mechanical linkage resulted in the translation of horizontal motion of the shaft of the air cylinder into vertical motion of the triangle in a frontal plane.

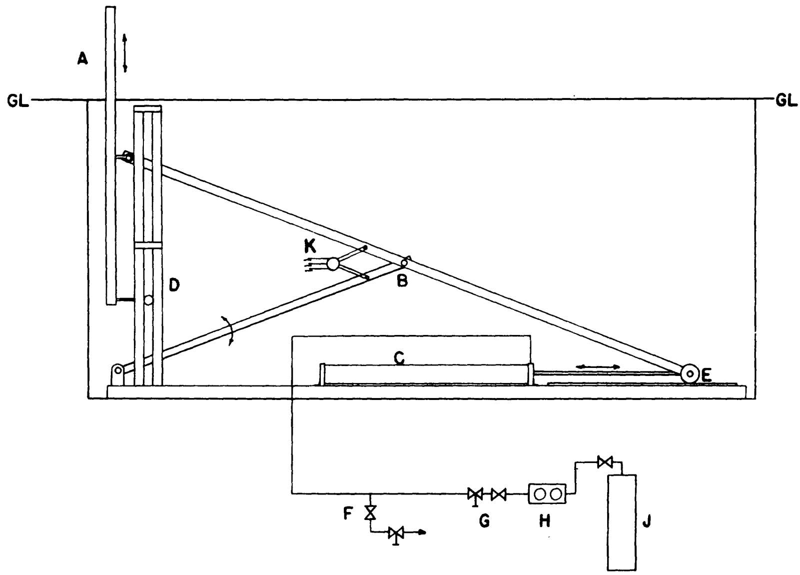

FIG. 3. DIAGRAM OF APPARATUS FOR VARIABLE TRIANGLE

By appropriate adjustment of the input valve G in the line from the high pressure storage tank J and the exhaust valve F, the triangle could be raised or lowered to any desired position and maintained at that position. Two small wheels supported by short metal extensions from the base of the triangle traveled in vertical guide rails D located directly behind the triangle, and eliminated wobbling.

The altitude of the variable triangle was recorded from a remote electrical indicator at *E*'s station.[11] A rotary potentiometer was attached at K to the supporting structure of the triangle. Any change in the angle of intersection of these two members resulted in a change in the position of the potentiometer shaft and a consequent variation in resistance between the variable terminal of the potentiometer and either end terminal. The altitude of the triangle was a sine function of half the voltage drop in the circuit, a drop that was indicated by a milliameter in series with a 1000-ohm resistor. Meter readings were converted to triangle alti-

[10] The apparatus was designed and built by Mr. Edward Palasthy, Department of Mechanical Engineering, Columbia University.

[11] The method was devised by Dr. John Lott Brown, Department of Psychology, Columbia University.

tude from a calibration curve that was determined empirically. The range of scale-readings representing the change from minimal to maximal altitude was adjusted by means of a variable resistor in series with the potentiometer. The method was rapid and convenient and it avoided cues which might have arisen from *E*'s approach and measurement of the variable stimulus-object.

Throughout the study an attempt was made to avoid giving *S* any adventitious cues of distance. Comparison of the stimulus-objects with familiar objects was prevented as far as possible. The standard triangles, for example, were not seen by *S* as they were moved to the different stimulus-points and neither their size nor number was made known to *S*.

Data were collected during the summer of 1953 and only on days that the Airport Control Tower reported visibility as 13 miles or better. For the majority of the experimental sessions, which were held between 10 A.M. and 5 P.M., visibility exceeded 15 miles.

Subjects. The *S*s were young men, chiefly high school students, from the surrounding area. All had or were corrected to normal vision. All the *S*s served under two sets of instructions which were randomly so counterbalanced that the same number of *S*s served first under each of them.

Instructions. A mimeographed sheet containing the 'objective' or the 'retinal' instructions was given *S* and he was asked to follow as they were read aloud by *E*.[12]

'Objective' instructions. Now we are going to give you very specific directions as to what you are to do. It is important that you do exactly as we tell you. Suppose we were to place the standard triangle beside the variable; how big would you have to make the variable triangle so that it would be exactly the same size as the standard? Now so adjust the variable triangle that it is equal to the standard in size—that if you measured both with a ruler they would measure exactly the same. Remember, we wish to know how big you think the standard triangle really is. Do you understand?

The aim of these instructions was to elicit the attitude presumably established in Gibson's *S*s by emphasizing the real, physical, tape-measured size of the standard and variable objects.[13] The task required *S* to look back and forth between the standard and variable stimulus-objects and so to adjust the variable that the two were judged objectively equal.

'Retinal' instructions. Now we are going to give you very specific directions as to what you are to do. It is important that you do exactly as we tell you. As you know, the further away an object is from you the smaller it appears. The moon and the stars, thousands of miles away, look very tiny but we know that they are actually very large. Now, if you were to see a triangle very far away, it would also look pretty small. The question is, how small does it look when it is far away out there in the field? Imagine that the field of view is a scene in a picture or photograph. Every image in the picture is fixed in size. If you were to cut out

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[12] The influence of instructions is well attested by the following studies: B. E. Holaday, Die Grőssenkonstanz der Sehdinge bei Variation der inneren und äusseren Wahrnehmungsbedingungen, *Arch. f. d. ges. Psychol.*, 88, 1933, 419-486; T. M. Martin and R. W. Pickford, The effect of veiling glare on apparent size relations, *Brit. J. Psychol.*, 29, 1938, 92-103; M. R. Sheehan, A study of individual consistency in phenomenal constancy, *Arch. Psychol.*, 31, 1938 (No. 222), 1-95.

[13] Gibson, Motion picture testing, *op. cit.*, 203.

the fixed image of the standard triangle and paste it on the image of the variable triangle, would the two images be just the same size? Now, so set the variable triangle that the cut-out image of the standard triangle would be exactly equal to it in size—that the two images would actually coincide.

These instructions were directed to generating the attitude presumably taken by Boring's *S*s in his experiments on the moon,[14] and by Boring himself in the Holway-Boring study.[15] Here the instructions demanded that *S* look at the standard triangle, fix its image in memory, look at the variable triangle, lay the memory trace of the standard over it, judge too large or too small and adjust. He could look back and forth and check until he could no longer notice a difference between them.

Procedure. After reading the instructions applicable to the day's task, *S* sat in a chair facing the standard triangle—previously placed at one of the six stimulus-distances—and was shown how to operate the apparatus which adjusted the size of the variable triangle. Several practice trials were given to familiarize him with the method.

The standards at different distances were presented in random order, except the nearest distance (100 ft.) was never used first. At every stimulus-distance, the standards to be used during that session were presented, one by one, in haphazard order.

S's adjustments of the variable triangle alternated between 'larger to equality' and 'smaller to equality.' In half of the trials he began with 'larger' and in half with 'smaller.' In both cases he was permitted to make fine adjustments up and down until he was satisfied with the match.

For every standard at every stimulus-distance, from 32 to 36 *S*s served. The results of our *S*s were discarded because these *S*s were unable, under 'objective' instructions, to make the variable triangle large enough, due to the limitations of the apparatus, to bring it to the judged size of the larger standards.

RESULTS

Since an analysis of the data of the individual *S*s revealed that they gave practically identical results under like conditions (instructions, object-size, and object-distance), the data for the *S*s were averaged. The means and *SD*s of their settings are shown in Table I. The upper half of the table contains the results under the 'objective' instruction; the lower half, the results under the 'retinal' instruction. The mean size-matches as a function of distance are plotted for the two instructions in Figs. 4 A-D. Fig. 4 A shows the functional relation when the 42-in. standard triangle was used; Fig. 4 B, when the 54-in. standard was used; Fig. 4 C, the 66-in. standard; and Fig. 4 D, the 78-in. standard.

Consider first the curve which represents 'objective' instructions. The variable shows a tendency to *increase* with distance with this observational attitude. For three of the four standards the data for this condition

[14] Boring, The moon illusion, *op. cit.;* personal correspondence.
[15] Holway and Boring, *op. cit.,* 25-26.

exceed the function for size-constancy. In the fourth case, that of the largest (78-in.) standard, the results are erroneously small because limited by the maximal size (86 in.) of the variable object. It will be recalled that data obtained from six *S*s were discarded because these

TABLE I

MEANS AND STANDARD DEVIATIONS (IN INCHES) OF MATCHES OF THE VARIABLE TO EACH STANDARD AT VARIOUS DISTANCES AND DIFFERENT INSTRUCTIONS

Instructions	Standard (in.)	No. of Ss	Distance of standard (ft.) 100	200	400	800	1600	4000
'Objective'	42	32	44.7	48.4	56.6	54.6	58.1	56.3
			3.4	6.9	13.1	12.8	11.8	14.3
	54	36	55.3	59.0	62.7	65.2	65.4	69.5
			3.8	8.3	9.8	12.4	12.0	11.6
	66	35	67.8	70.6	71.6	72.1	74.0	75.6
			4.8	8.4	9.5	10.8	9.9	7.3
	78	32	77.6	77.2	76.8	68.7	75.4	78.4
			4.3	6.2	8.2	13.8	9.8	7.7
'Retinal'	42	32	41.0	32.2	23.5	14.9	8.6	4.4
			4.1	4.4	5.6	6.2	5.5	2.8
	54	36	52.6	40.8	30.2	16.7	9.3	4.9
			3.3	6.3	8.1	6.8	5.5	3.1
	66	35	63.8	52.3	38.1	23.5	14.1	6.2
			4.3	7.2	10.5	9.2	7.7	4.3
	78	32	76.4	57.9	44.6	26.7	18.0	8.9
			5.1	7.3	12.7	10.3	9.7	6.0

*S*s reported that the variable triangle could not be made large enough to match the size of the 78-in. standard. Presumably, some of the remaining *S*s, while apparently satisfied with comparison settings at or near the upper limit of the variable triangle, might have produced larger size matches if these had been available to them.

The data for the 'retinal' instructions yield a function for perceived size *decreasing* with increasing distance. The curves drawn through the plotted points for this condition lie within the functions for size constancy and the visual angle, and are fitted by a theoretial equation for perceived size derived by the writer in a previous paper.[16]

[16] A. S. Gilinsky, Perceived size and distance in visual space, *Psychol. Rev.*, 58, 1951, 460-482.

The four curves for 'retinal' matching of Fig. 4 have been replotted in a single figure to facilitate their comparison. Fig. 5 exhibits these functions as a family of curves, with size of the standard as the parameter. The lines drawn through the four sets of data are given by the following single equation:

$$St_c/St = (A + \delta)/(A + D) = (300 + 90)/(300 + D) \quad \ldots [1]$$

where St_c is the adjusted size of the variable triangle, St is the size of the standard, and D is the distance of the standard from S. The meanings

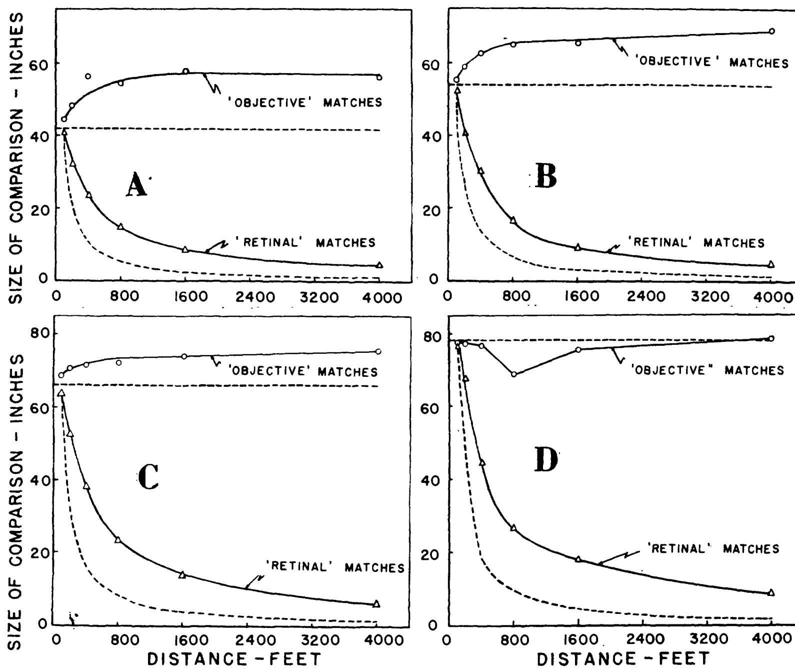

FIG. 4. SIZE OF VARIABLE EQUATED TO EACH OF THE FOUR STANDARDS AS A FUNCTION OF DISTANCE AND INSTRUCTION

A is the 42-in. standard; B, the 54-in.; C, the 66-in.; and D, the 78-in. standard. The horizontal broken line represents the object-size as constant and the bottom broken curve, the actual size of the retinal image or visual angle.

of A and δ are discussed at length in the reference cited. It is apparent that the parameter of size does not affect the form of the function since a single equation provides an adequate fit to all four of the curves.

It may be shown that the ratio of the adjusted size of the variable triangle to the size of the standard (St_c/St) is independent of the size of the standard. Fig. 6 shows the ratios obtained by dividing the average size of the variable triangle by the size of the standard to which the comparison was equated.

The lower solid curve is the curve of Equation [1] drawn through the data for all standards and all *S*s combined for the 'retinal' matching. Each

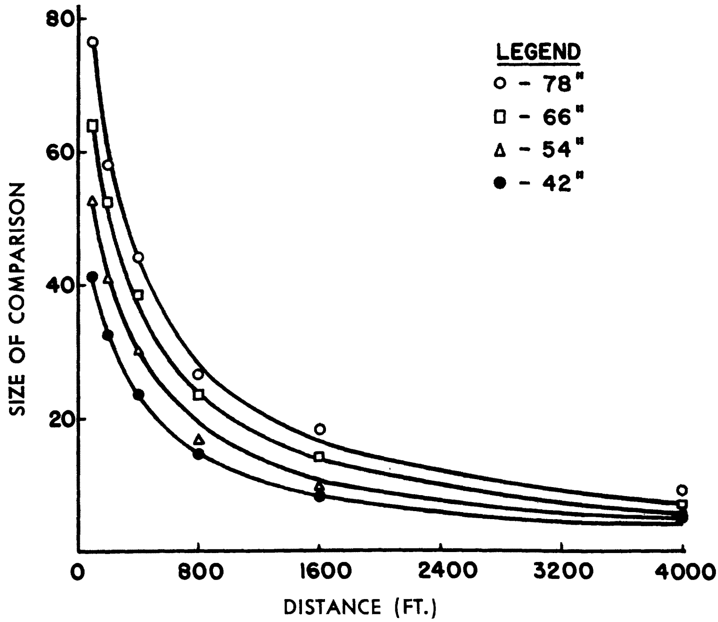

FIG. 5. 'RETINAL' MATCHES TO EACH STANDARD AS A FUNCTION OF DISTANCE
The curves drawn through the data are computed from Equation [1], using identical values of the constants in the four cases. From top to bottom the four curves are displaced in the order of the decreasing size of the standard objects to which they refer, 78, 66, 54, and 42 in. Data are the averages of all *S*s.

plotted point (triangle) thus represents the mean of 135 observations. The upper solid curve is drawn through the data for 'objective' matching for all except the largest standard and thus each point (circle) on this function is based on 103 determinations. The results for the largest (78-in.) standard were omitted from this composite because they deviate from the rest of the results obtained under the 'objective' instructions, and are believed to reflect an artificial 'cut-tail' error imposed by the upper limit of size of the variable triangle. To have included them in determining the average 'objective' matches would have led to a false general impression of greater objective accuracy than was actually achieved. The data summarized in Fig. 6 represent the typical findings of the present experiment.

While this is a simple arrangement of the data, the functions do not appear to resemble those obtained by other investigators. Fig. 7 is a different plot of the data in the form made familiar by Holway and Boring and facilitates comparison with their results.[17] Since in their experiment the standard was kept constant in angular size, the function for

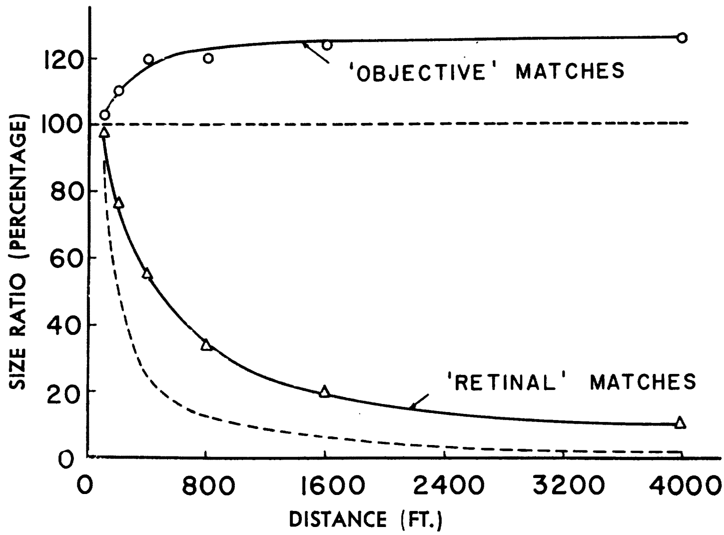

FIG. 6. 'OBJECTIVE' AND 'RETINAL' MATCHES PLOTTED AS RATIOS OF THE SIZE OF THE VARIABLE TO THE SIZE OF THE STANDARD TO WHICH COMPARISON WAS MADE

The points plotted are for all *S*s and all standards except the largest. Constant object-size and the size of the retinal image (visual angle) are shown by the upper and lower broken lines respectively.

constant object-size is a straight line which rises in proportion to the distance and the function for constant retinal size is a horizontal straight line.

Fig. 7 uses the data of Fig. 6 to show how the size of a triangle would appear to change if its angular size and not its linear size were kept constant as it receded 4000 ft. from *S*. Taking the value for 100 ft. as the base, the means of the size-matches were multiplied by the corresponding distances, by 2 for 200 ft., by 4 for 400 ft., . . . by 40 for 4000 ft. The

[17] Holway and Boring, *op. cit.*, 23 ff.

mean standard size, a theoretical test-object of 60 in. at 100 ft., was also multiplied by distance to illustrate the ideal function for a variable object increasing with the standard object and remaining equal to it. Such an object would subtend a constant visual angle of 2° 52′. Fig. 7 makes the assumption that the relations of Table I would hold for very much larger test-objects, that it is the ratio of sizes being compared and

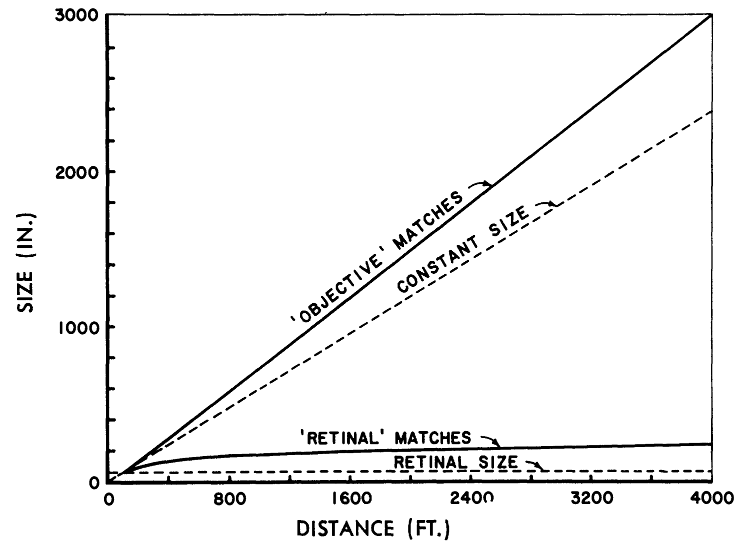

FIG. 7. 'OBJECTIVE' AND 'RETINAL' MATCHES AS A FUNCTION OF DISTANCE
These curves are derived from those of Fig. 6 by the use of certain simple asumptions. The data have been transformed to show how the size of a receding standard object, which subtended a constant visual angle of 2° 52′, would be matched by a variable object at a distance of 100 ft. under each condition of observation.

not the absolute magnitudes that are important in perception. Some evidence for the independence of the size-distance relations from the absolute magnitudes of the stimulus-objects has been given by the present data but the parameter has been varied only within a limited range.

Plotted in this form the functions of Fig. 7 appear to be similar to those of Holway and Boring's Figs. 3-22.[18] The function for the 'objective' attitude is now a straight line rising with distance and exceeding the slope of the line for size constancy. The function for the 'retinal' matches is slightly curvilinear and close to the horizontal slope for perceived size dependent only upon retinal image.

[18] *Ibid.*, 26-34.

At first glance the position of this curve resembles that of the extreme reduction condition of the Holway-Boring study. This is deceiving. Actually, the curve is given by Equation [1] for perceived size in which the value of the parameter A (300 ft.) is in reasonably good agreement with that found to apply to Boring's own binocular observations in the former study. Boring's data were fitted by the same equation with A taken as 243 ft.[19] The higher value of A in the present experiment may be attributed to the many more compelling distance cues given by the airfield in broad daylight as contrasted with the Harvard corridor at night. Neither experiment permitted the direct determination of δ in the formula, but in both cases it has been approximated as the distance of the variable object. Its precise value is immaterial since we assume equality of visual size when object and variable have equal physical size and are placed at identical viewing distance. Some error in both experiments prevented exact matches in size when standard and variable were equidistant. A slight adjustment in the assumed value of δ, from 100 ft. to 90 ft. in the present application of the equation, corrected the discrepancy.

If our binocular 'retinal' matches appear to show considerably more reduction to retinal image size than Boring's, the answer is that our distances are so much greater, 4000 divided by 120 equals 33.3 times as great. For small values of the distance D (relative to A), perceived size is close to actual size, but for very large distances D (relative to A), perceived size is greatly diminished and varies inversely with D, corresponding to the reduction in size of the retinal image.

Discussion

The results show a clear distinction between two attitudes of observation. An *S,* it appears, may be set by appropriate instructions to respond in alternative ways to the same complex conditions of stimulation. As an object recedes into the distance its size may be judged to get either a little larger or much smaller than its actual size, depending upon what question has been put to *S,* upon what he means by his judgment.

It is instructive to try to relate these findings to Gibson's two systems, the visual world and the visual field. For Gibson the visual world is the experience of unbounded stable three-dimensional Euclidean space, one in which parallel edges do not converge and in which an object stays constant in size wherever it is moved. An object-directed attitude ought.

[19] Gilinsky, *op. cit.,* 490.

it would seem, to duplicate in perception this natural world of objects. It does not—not exactly.

Matches of 'objective' size do not strictly follow the rule of size constancy. Instead, objects tend under this attitude to *expand* as they move further away. Nor are these data of the present experiment exceptional. Holway and Boring obtained this result from four out of five *S*s but at the time doubted the validity of 'overconstancy' and corrected their data for a presumed space error.[20] Their data for one *S* (*EGB*), even when unadjusted, did not show overcompensation but was typical of the present 'retinal' matches. Presumably the other four *S*s were set to match 'objective' size. At least this inference may be drawn from the nature of the results and from similar data found by Chalmers,[21] who did use explicit 'objective' instructions in a replication of the Holway-Boring experiment. Gibson's own results showed that for every test-object and at every distance except 28 yds., size was overestimated.[22] Smith reported a similar tendency for size to *increase* with distance.[23] In his study *S* was asked to judge the physical size of wooden cubes placed out of doors at 16, 80, and 320 ft. As the physical distance of the standard object increased, *S* required a larger and larger comparison to satisfy his judgment of equality. As in the present experiment, the studies reported by Gibson and by Smith used binocular vision under conditions affording many cues to distance and explicitly set their *S*s for accurate and objective judgments.

There is considerable evidence then that, even when we are set to perceive objects as they really are, we simply do not perceive a visual world that corresponds with rigid accuracy to the physical, tape-measured world. The hypothesis of size-constancy is at best an inexact approximation to a scientific description of the 'visual world.' This discrepancy may surprise those who try to account for perception in terms of its purposiveness. Evolution or the individual's life history, or both, appear to have achieved an organism whose 'best bet' is to overestimate object-size. The amount of overestimation increases with the difference in conditions between the objects being compared, revealing more and more discrepancy between behavior and the basic sensory excitation. Perhaps this tendency toward overadaptation is somehow useful. Still it is difficult to understand how an error in one direction or another could increase

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[20] Holway and Boring, *op. cit.*, 34.

[21] E. L. Chalmers, Monocular and binocular cues in the perception of size and distance, this JOURNAL, 65, 1952, 415-423.

[22] Gibson, Motion picture testing, *op. cit.*, 206-207.

[23] W. M. Smith, A methodological study of size-distance perception, *J. Psychol.*, 35, 1953, 143-153.

the organism's chance of survival or be the necessary outcome of past interaction with the environment. The discrepancy, though small, is puzzling, and the evident adequacy of adjustment to the environment should not prevent us from seeking to discover how such adjustment is controlled and limited.

Let us turn to the results obtained with the 'retinal' or 'perspective' attitude. This attitude does indeed seem to give us Gibson's visual field, defined by him as "a picturelike phenomenal experience at a presumed phenomenal distance from the eyes, consisting of perspective size-impressions."[24] Gibson is careful not to identify the visual field with the retinal pattern unmodified, for the values of the visual field depend upon both the dimensions of the retinal image and discrimination of the distance of the perceived object.

In the present experiment the set for matching 'retinal' size never achieved complete reduction to retinal size. The receding triangle was seen to shrink but also to recede. With complete reduction, with all cues to distance eliminated, one would expect perceived size under this attitude to vary with retinal size. Reduction, however, in most of these experiments has been but partial and the cues to distance have been many. Observe the cues in Figs. 1-2. Even in the case of the perception of the full moon's disk, where distance cues would seem to be minimal, the matched comparison disk, a dozen feet away from the *S*, is not reduced as much as is the size of the moon itself on the retina.[25] The perceptual pattern is not the pattern of the retinal image without regard to distance. Instead perceived size appears to depend upon perceived distance in accordance with the mathematical account of visual space developed previously.[26]

The present data clearly show that the experience of the visual field need not depend on the elimination of cues to distance or on long and arduous training but may be achieved readily by attitudinal control. Given many cues to distance, *S* uses such as are basic and compelling, but he may ignore the others and so responds quickly and with assurance.

All of the *S*s reported that they made the 'retinal' or, as they preferred to call them, the 'picture-image' settings with greater ease and confidence than the 'objective' matches, particularly at the larger distances.

The task demanded by the 'objective' instructions appeared to the *S*s

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[24] Gibson, The visual field and the visual world: A reply to Professor Boring, *Psychol. Rev.*, 59, 1952, 151.

[25] Boring, The moon illusion, *op. cit.*, 59.

[26] Gilinsky, *op. cit.*, 460-482. For an independent derivation of the same formula see G. A. Fry, Visual perception of space, *Amer. J. Optom.*, 27, 1950, 531-553.

as less direct and more interesting. Several of them stated that they proceeded by first setting the variable as if for a 'picture-image' match, then tried to estimate how far away was the standard triangle, and how much bigger it must actually be to look that size and that distance away. One said: "I might decide that it really is 6 ft. tall. Then I turn to the variable triangle and increase it until it looks 6 ft. tall." Certainly in this instance objective size is being estimated inferentially and is not being immediately perceived.

The *S*s were curious and pressed for knowledge of results following their attempts to judge 'objective' size correctly. The 'retinal' task, on the other hand, seemed a challenge only to their manual dexterity in setting the comparison precisely. Uncertainty with regard to the estimates of 'objective' size was often expressed by such statements as, "That was a sheer guess," or "I'd hate to bet on that."

Unfortunately, no data on intra-individual variability are available to reinforce this reported difference in subjective assurance. The inter-individual variability, in terms of the standard deviations of the average settings, is shown in Table I. These *SD*s appear to indicate closer agreement between *S*s and therefore a more determinate, less highly individual basis for the responses under the 'retinal' attitude, especially at the larger distances. Nevertheless, no sure conclusions about the relative ease or stability of judgments under the two attitudes can be drawn from the data on variability for the reason that the variability of the comparison stimulus was restricted at both extremes.

These results suggest that the classical distinction, drawn by Hering and others, between *perception* (immediate experience) and *estimation* (knowledge or inference) may still be pertinent despite the explanation offered by Gestalt psychology.[27] This school and Gibson regard the phenomena of perception as being directly given when the world of objects is attended to. Object-constancy, they hold, is the natural outcome of ordinary perception and is destroyed only by the artificial reduction of stimulation or by the critical efforts of the trained artist or introspective psychologist.

The present study shows that a sincere attempt to make this supposedly natural phenomenal objective world easily observable can fail, forcing the *S* away from immediacy of judgment into an inference of which he is often quite unsure. The further finding that size-constancy does not hold precisely in the visual world seen under the 'objective' attitude also suggests that the Gestalt conceptions of the phenomenal

[27] Boring, *Sensation and Perception in the History of Experimental Psychology,* 1942, 289.

world need revision. It required the use of long distances by Gibson, by W. M. Smith, and by the present writer to make the latter discrepancy plain. At close range the well-practiced observations of ordinary existence are quick and sure, creating the false impression of being purely passive affairs. It now appears that we may have a right to call the 'objective' attitude *estimation* and the 'retinal' attitude *perception,* thereby reversing the position of the phenomenologists. Distant objects may be estimated or judged to be larger than their actual size, although there is at present no evidence that conditions can be set up under which they would be 'seen' or 'experienced' as actually expanding when they recede. The 'set' in which size appears to decrease with increasing distance is the stimulus-controlled set for perceived or apparent size in visual space. A corresponding and equally important distinction exists between estimated distance and perceived distance in visual space. The familiar names have the advantage of calling attention to important aspects of the two kinds of data, and the complex problems that remain to be investigated.

The distinction between sense-perception and estimation may be useful in keeping separate the two lines of psychological investigation which Graham has identified as the major directions of current research in perception. One is the study of sensory discriminations and their relations to systematic variations in stimulus conditions. The second and more recent area of interest is the study of discriminative behavior as it is influenced by the attitudes, motives, and past history of the subject. In order to evaluate the results of any experiment it is crucial to determine what kind of data we have. Experiments using similar equipment and apparently similar design may turn out to be solving very different problems and producing entirely discrepant results. Serious confusions may be avoided if a given set of observational data can be identified as belonging to one or another class of discriminations.[28] The particular instructions used, or the fact of their ambiguity, may be as decisive as any other feature of the method of investigation.[29]

Thus an attempted reproduction of the 'physical' value of a stimulus-object may be specified in terms of quantified stimulus-energies; it is nonetheless a stimulus-*rating* and may be shown to possess limitations in common with the verbal estimates or numerical naming responses of the

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[28] These considerations may help to clarify the questions raised by W. M. Smith, Gilinsky's theory of visual size and distance, *Psychol. Rev.,* 59, 1952, 239-243.

[29] The discrepant results reported by different investigators of the perception of verticality further illustrate this point. See C. W. Mann and R. O. Boring, The role of instruction in experimental space perception, *J. Exper. Psychol.,* 45, 1953, 44-48.

rating method. The responses are not highly restricted by the instructions and they may show wide individual differences, reflecting differences in attitudes, training, and other variables of *S*'s past activities. Such data may be usefully related to learning, and the individual's habitual pattern of responding. They do not permit the identification of critical stimulus-energies or physiological limits of discriminative capacity. Problems of the latter type need to be investigated by methods which involve a narrowly specified criterion of response. A genuine psychophysics of perception might best concentrate on those data which reveal, as Boring says, "the parametric invariances of the stimulus."[30]

Graham has presented a systematic view of the field of perception which emphasizes the determination of perceptual functions.[31] These functions are obtained by finding how one stimulus variable varies as a function of another in order to produce a constant response effect. The discovery of such functions for invariant perceived size has been clearly recognized by Boring as basic to a science of perception.[32]

With the aid of Equation [1], such functions for size-invariance may be derived readily from the present data for 'retinal' matching. The 'objective' set does not yield data which allow a general description in terms of stimulus-relations.

Consider Fig. 5 again and note the positions of the successive curves. Each curve represents the data obtained for a given standard as its distance varied. One can select a particular value of the dependent variable, say 10 in., and from each curve determine the distance on the abscissa which corresponds to 10 in. on the ordinate. Thus the 10-in. comparison at 100 ft. was matched to the 42-in. standard at 1300 ft., to the 78-in. standard at 3000 ft., and to the intermediate standards at intermediate distances. When we plot the size of each standard against the appropriate distance we obtain a straight line. The extrapolated curve shows how large different objects that look alike (are matched in perception by a 10-in. object) must be if they are from 100 ft. to 4000 ft. away. This relation has been plotted for several arbitrarily selected values of the stimulus variable in Fig. 8.

Fig. 8 thus exhibits a family of perceptual curves derived from Fig. 5 and extrapolated by means of Equation [1] for various response settings. Each derived curve is a rising straight line which describes how the actual size of an object, referrable to a constant response setting, varies as a

[30] Boring, Visual perception as invariance, *op. cit.*, 147.
[31] Graham, Behavior and the psychophysical methods: An analysis of some recent experiments, *Psychol. Rev.*, 59, 1952, 62-70.
[32] Boring, Visual perception as invariance, *op. cit.*, 146 f.

function of the distance of the object from *S*. The slopes of these lines may be computed directly from Equation [1] for any value of St_c. This plot would yield for size constancy, a family of straight lines of zero slope; and for true visual angle matches, ascending straight lines, but steeper than the corresponding equal size contour for a given perceived size.

This treatment of the data emphasizes that for perceived size to be invariant under the attitude for observing 'retinal' size, neither actual

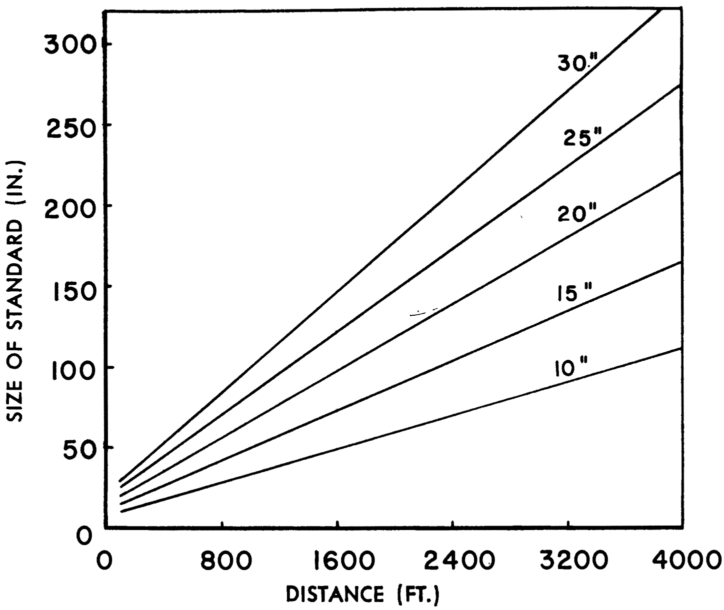

FIG. 8. FUNCTIONS FOR PERCEIVED SIZE INVARIANT UNDER THE 'RETINAL' ATTITUDE

This family of curves is derived from the data of Fig. 6 and Equation [1] for five settings. It shows how the actual size of a test-object must vary with distance to give an invariant response under this attitude.

object-size nor actual retinal size can be invariant; at least, not as long as determinants in addition to retinal size are available. A lawful principle of invariance is disclosed however, which, to paraphrase Boring, tells us how the organism does perceive its own physiological bases; the data out of which it can create, after much evolution and under a sensible, practical, real-life attitude, a sufficiently useful apprehension of the world that it accepts as its reality.[33]

[33] *Ibid.*, 147.

If we designate this manifold a visual field, then surely it is a visual field for partial reduction of cues to distance. Perception under this attitude was always influenced by perceived distance; yet there was no conscious inference that took distance into account, as there was with the 'objective' attitude. Boring suggests that there might be more than one visual world, and also, corresponding to different degrees of reduction, a whole series of visual fields, including the limiting case where reduction is complete and perceived size varies only with retinal size without regard to change in distance.[34] In this way, it seems, the present experiment throws light on Gibson's two visual systems, and suggests even that we may eventually be able to specify, for various observational attitudes, and various degrees of reduction of the cues to distance, an inclusive system of relations to define and explain the phenomena of visual space perception.

SUMMARY

The perception and the estimation of object-size was studied as the distance of a standard object was varied from 100 to 4000 ft., out of doors under conditions affording many cues to distance. The standard stimulus-objects were plane, white isosceles triangles, 42, 54, 66, and 78 in. in base and altitude. Functions relating the adjusted size of a variable triangle, 100 ft. away from *S*, to the distance of each standard triangle were obtained from 32 to 36 *S*s. Each *S* served under two different conditions of instruction which demanded contrasting observational sets; a set for matching 'objective' size and a set for matching 'retinal' size.

(*1*) The data show clearly that instructions were effective in producing two distinct functions relating the settings of the variable triangle to distance.

(*2*) 'Objective' instructions gave matches in size which increased with distance, exceeding size-constancy. The finding that 'objective' judgments overestimate object-size confirms and extends previous studies of size-estimation.

(*3*) 'Retinal' instructions gave matches in size which decreased as distance increased. This relation between perceived size and distance is intermediate between the function for size constancy and the function for matches of retinal image or visual angle. These results are consistent with past findings for apparent or perceived visual size and with a previously developed mathematical formulation of visual space.

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[34] Boring, The Gibsonian visual field, *Psychol. Rev.*, 59, 1952, 246-247.