THE EFFECT OF OCULOMOTOR ADJUSTMENTS ON APPARENT SIZE

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An object of fixed angular size looks smaller when the eyes are adjusted for near vision than when they are adjusted for far vision. This fact was reported first by Wheatstone, the inventor of the stereoscope.[1] Wheatstone's qualitative observations were confirmed by several later investigators,[2] and quantitative studies of the phenomenon have been made by Adams, Frank, Hermans, and Swenson.[3]

The research reported below deals mainly with two questions to which the previous investigators have not given clear answers. The first is whether the changes in apparent size are related to changes in apparent distance in the manner postulated by several current theories of 'size-constancy.'[4] The second is which of the oculomotor adjustments, or possibly which combination of adjustments, controls the changes in apparent size.

The principal oculomotor adjustments that are made in response to a change in viewing distance are (1) changes in the angle of convergence of the visual axes, (2) changes in the power of the lens (accommodation), and (3) changes in the diameter of the pupil. Convergence and accommodation are so linked that a change in one produces a change in the other, and a change in either is usually accompanied by a change in the diameter of the pupil.

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[1] Charles Wheatstone, Contributions to the physiology of vision: II. On some remarkable, and hitherto unobserved, phenomena of binocular vision, *Phil. Trans. roy. Soc. (London), Part I,* (142), 1852, 1-18.

[2] C. H. Judd, Some facts of binocular vision, *Psychol. Rev.,* 4, 1897, 374-389; T. G. Hermans, Visual size constancy as a function of convergence, *J. exp. Psychol.,* 21, 1937, 307-324.

[3] O. S. Adams, Stereogram decentration and stere-obase as factors influencing the apparent size of stereoscopic pictures, this JOURNAL, 68, 1955, 54-68; Helene Frank, Ueber den Einfluss inadaquäter Konvergenz und Akkommodation auf die Sehgrösse, *Psychol. Forsch.,* 13, 1930, 135-144; T. G. Hermans, The relationship of convergence and elevation changes to judgments of size, *J. exp. Psychol.,* 48, 1954, 204-208; H. A. Swenson, Reported in H. A. Carr, *An Introduction to Space Perception,* 1935, 362-363.

[4] R. S. Woodworth and Harold Schlosberg, *Experimental Psychology,* 1954, 480-486.

Frank did not attempt to separate the various oculomotor adjustments.[5] She measured the changes in the apparent size of a test-object that occurred when *O*s alternately fixated a mark in the plane of that object and a mark some distance in front of the test-object. A shift of fixation from one mark to the other presumably involved all three of the oculomotor adjustments listed above. Moreover, the change of fixation from one mark to another was accompanied by changes in the retinal image. The retinal image of the test-object presumably was well focused when fixation was in the plane of the test-object, blurred when fixation was on a point in front of the test-object. The size of the blurred image varies somewhat with the diameter of the pupil. Thus it is possible that the size-changes measured in Frank's experiment were caused, at least in part, by changes in the size of the retinal image.[6]

Adams, Hermans, and Swenson all used stereoscopic devices to vary the convergence while the distance of the stimulus-object was held constant.[7] In these experiments blurred vision or double images could be avoided only by a disruption of the normal relationship between convergence and accommodation. The amount of 'play' in the linkage of convergence and accommodation is, however, generally considered to be quite small. The available evidence does not warrant the assumption that changes in convergence were wholly unaccompanied by changes in accommodation. Also, the changes in convergence were almost certainly accompanied by changes in the diameter of the pupil. As in Frank's experiment, one cannot determine whether the changes in apparent size were caused by one of the oculomotor adjustments, several of the oculomotor adjustments, or the optical consequences of these adjustments.

Three related experiments that bear on these problems are described below. In all experiments the *O*s observed under conditions of complete 'reduction,' except insofar as the occurrence of oculomotor adjustments may be held to be incompatible with this concept.

APPARATUS

The apparatus used in all our experiments consisted of an arrangement for presenting in quick succession two stimulus-objects whose size or distance was to be compared by *O*. One of these, the standard stimulus, was an evenly illuminated disk that subtended a constant angle at *O*'s eye and was presented at one of five distances.[8] The other, the variable stimulus, was one of a series of interchangeable disks of different size, presented always at a distance of 400 cm.

The disks were made by cutting circular holes in plates of aluminum. The borders of these holes were ground to knife-edges. Five disks were made for the standard stimulus. Their sizes were so chosen that there was one that subtended an angle of

[5] Frank, *op. cit.*, 135-144.

[6] For a demonstration of the fact that with inadequate accommodation, changes in the diameter of the pupil may alter the apparent size of an object see K. T. Brown, An optical illusion of spontaneous fluctuations in apparent size, this JOURNAL, 67, 1954, 533-539.

[7] Adams, *op. cit.*, 54-68; Hermans, *op. cit.*, 307-324; Carr, *op. cit.*, 362-363.

[8] Throughout this paper the reference-point for all angles and distances is the nodal point of the eye, assumed to be 7 mm. behind the vertex of the cornea.

1° at each of the following distances: 25, 33.3, 50, 100, and 300 cm. For the variable, a series of plates with holes whose diameter varied in successive steps of 5% was used. A holder permitted *E* to interchange these plates quickly.

The aluminum plates were shown in front of a piece of flashed opal glass which formed the front of a light-tight box containing a small frosted light bulb. The inside of this light-box was painted flat white, and between the frosted bulb and the flashed opal glass was placed a series of milk-glass diffusing screens. With this arrangement, the illumination on the flashed opal screen appeared completely even, and the screen had no visible grain.

In some of our experiments the light-box with its opal glass front was attached directly to the back of the aluminum plate. When this was done, two identical light-boxes were used, one attached to the standard and the other to the variable. In other experiments only a single light-box was used. It was placed about 410 cm. from *O*'s eye, *i.e.* 10 cm. behind the variable. Under these conditions, the variable and standard were seen against the same illuminated surface. Preliminary experiments showed that the location of the opal glass in no way affected the outcome of the experiments.

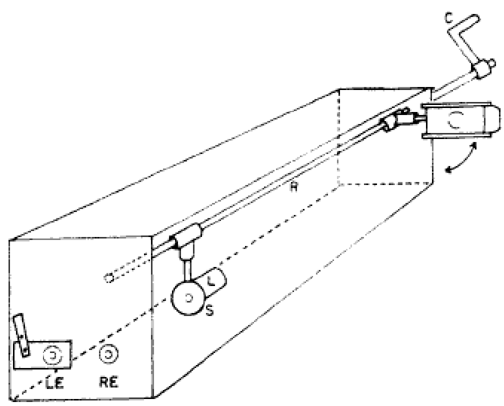

FIG. 1. SCHEMATIC VIEW OF APPARATUS USED IN EXPERIMENTS ON APPARENT SIZE AND DISTANCE

A schematic view of the apparatus is given in Fig. 1. The standard disk (S), to be used at a given time, and the holder for the variable disks were suspended from a long rod (R). This rod was so mounted on bearings that it could be rotated about its longitudinal axis by turning the crank (C). As shown in Fig. 1, the variable and the standard stimulus-objects were mounted in such a fashion that their positions in the XY plane could be interchanged by a 90° turn of the rod.

The entire arrangement was enclosed in a long, light-tight box. The inside of this box was lined with corrugated cardboard that had been painted flat black. The box was further provided with a system of stops and light-traps designed to eliminate all reflected light.

At the front of the box were mounted eye-pieces in which artificial pupils could be inserted. The right eye-piece and all the disks used were centered on a common axis to which they were also normal. The left eye-piece was provided with a sliding mount and a lever that enabled *O* to move the eye-piece quickly in the horizontal direction. When *O* observed with both eyes, rapid adjustment of the distance between the two eye-pieces was required to compensate for the change in the interpupillary distance that goes along with a change in convergence. The distance through which the left eye-piece could be moved in either direction was determined by adjustable stops. For each *O* and for each set of target-distances these stops were pre-set to give the desired interpupillary distances in the binocular experiments.

In several experiments we presented to *O*'s right eye the stimulus-disks and a fixation-point located in the center of these disks, while the left eye was shown only the fixation-point. To produce this stimulus-arrangement each of the holes that formed the disks was covered by a sheet of Polaroid. A small circular hole was cut in each Polaroid to serve as fixation-point. The size of this hole was made proportional to the distance so that all fixation-points had the same angular size. The left eye-piece was covered with a sheet of Polaroid turned 90° with respect to the Polaroid covering the disks, hence only the unpolarized light coming from the fixation-point reached the left eye.

Experiment I: Apparent Size and Apparent Distance in Monocular Observation

The first experiment is divided into two parts, one dealing with the relative apparent size of objects presented at different distances, the other with the relative apparent distance of these same objects.

Procedure. *O* observed with his right eye only. His head was lined up in such a way that, with his right eye in approximately the primary position, his visual axis coincided with the common axis of the stimulus-disks and eye-piece. In this way, no movement of the eye was required to cause two disks exposed successively at different distances to be imaged on the same region of the retina. No artificial pupil was used in this experiment.

O was shown either the standard or the variable first, and was instructed to signal *E* as soon as the disk appeared to be sharply focused. When *O* signalled, the exposure of the first disk was terminated and the second disk was presented. Approximately one second elapsed between the end of the first exposure and the beginning of the second. The illumination on the disks was turned on and off in such a way that *O* at no time saw the disks in motion. *O* was instructed to bring the second disk into focus as quickly as possible and then to make his report. In the part of the experiment concerned with apparent size, *O* was required to state whether the second disk was larger or smaller than the first. On successive trials the size of the variable disk was changed in accordance with the up-and-down or staircase method.[9] When enough judgments to compute a point of subjective equality (*PSE*) had been obtained, the procedure was repeated for standard disks at other distances. The order of presentation of the five standards was randomized and for each standard the *PSE* was determined twice, once with the variable disk always

[9] W. J. Dixson and F. J. Massey, *Introduction to Statistical Analysis*, 1957, 318-327.

exposed first and again with the standard disk always exposed first. It took two experimental sessions lasting about 90 min. each to determine a complete function.

The procedure used to investigate the relative apparent distance of the disks was identical with that described except for the following points. (1) *O* reported which of the two successively presented disks, standard or variable, was farther away, instead of reporting on the size of the disks. (2) The size of the variable disk was held constant at 1°. Thus both variable and standard disks subtended the same visual angle in this part of the experiment. (3) Only three standards were used: those at 25, 50, and 300 cm. *O* compared the distance of each of these standards with that of the variable 40 times. During 20 trials the variable was exposed first, during the other 20 trials the standard was exposed first. The judgments were distributed over two experimental sessions.

Twelve men, undergraduate students, served as *O*s in this experiment. None of them had any known ocular defects. Their acuity was measured on the Bausch and Lomb Orthorator. Eleven of them had acuity in the right eye equivalent to Snellen 20/20 or better, the remaining one had acuity equivalent to Snellen 20/25.

Each *O* served in four experimental sessions, two for judgments of size and two for judgments of distance. The size- and distance-conditions were run in the order SDDS for half the *O*s and DSSD for the other half.

Results. The results of the measurements of apparent size are shown in Fig. 2. The diameter of the variable disk that was matched to a standard disk subtending a visual angle of 1° is plotted against the reciprocal of the distance of the standard disk. The light dashed lines represent the results of the individuals *O*s. Each point represents the mean of two *PSE*s determined on two different days. The heavy black line connects the means of the entire group.

The results of matching the sizes of the retinal images would be represented by a horizontal line at y = 69.8 mm. in this spot. The negative slope of the mean line indicates an effect of distance on apparent size, in the direction of 'size-constancy': a 1° disk near the eye looks smaller than a 1° disk farther away.

Table I shows the results of the judgments of apparent distance. Each entry is the proportion of correct judgments. For the distances of 25 cm. and 50 cm. some *O*s perform at approximately the level of chance, 0.5, but most of them do considerably worse than chance. In other words, they usually say that the objectively nearer disk is farther away. For the 25-cm. and 50-cm. distances, 16 out of 24 are significant at the 1% level or better by the sign test. But 15 of these 16 are significantly poorer than chance. None of the proportions in the 300 cm. column differs significantly from 0.5.

These results of the judgment of distance are in good agreement with

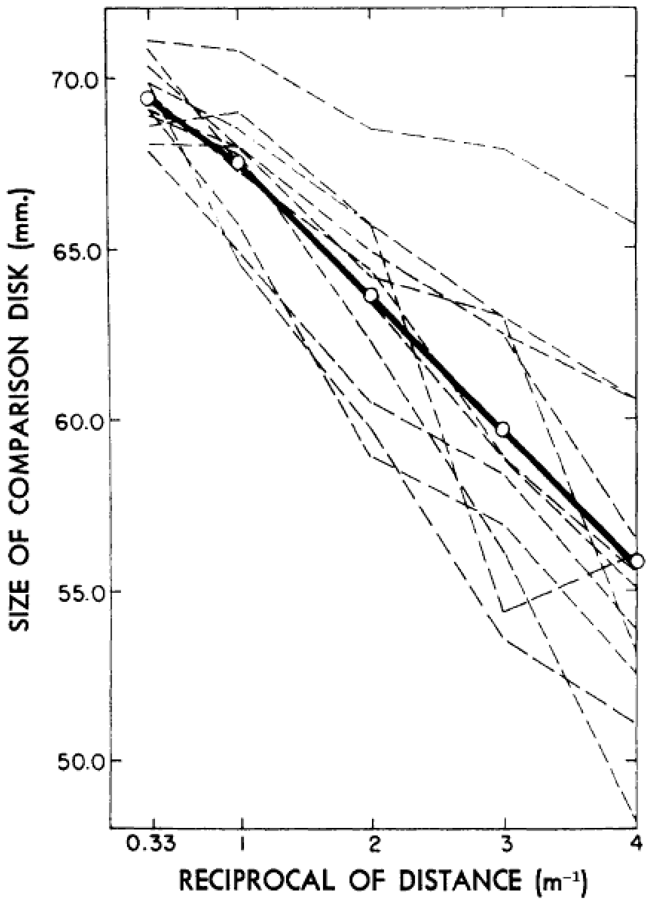

FIG. 2. THE APPARENT SIZE OF A 1° DISK AS A FUNCTION OF THE RECRIPOCAL OF ITS DISTANCE
Monocular observation with the natural pupil.

TABLE I

PROPORTION OF CORRECT JUDGMENTS OF DISTANCE

O	Distance of standard (in cm.)			O	Distance of standard (in cm.)		
	25	50	300		25	50	300
1	0.13	0.05	0.45	7	0.50	0.90	0.55
2	0.05	0.35	0.50	8	0.60	0.68	0.53
3	0.03	0.00	0.45	9	0.63	0.48	0.68
4	0.05	0.05	0.48	10	0.03	0.15	0.53
5	0.03	0.03	0.45	11	0.05	0.18	0.50
6	0.13	0.23	0.43	12	0.58	0.33	0.55

those obtained by Bappert under very similar conditions.[10] The peculiar inadequacy of distance-perception seen here may be due to the fact that the difference in the apparent size of the two disks controls the judgments of distance under these conditions. In any case, since our *O*s did not perceive the relative distances correctly, it is clear that theories that account for size-constancy in terms of processes depending on a correct perception of distance are not applicable to the phenomenon here under study. Since the *O*s looked with only one eye, explanations of the changes in apparent size in terms of binocular disparity and related factors are, of course, also excluded.

Experiment II: The Effect of Eliminating Oculomotor Adjustments

To make certain that the occurrence of oculomotor adjustments is indeed the essential condition for the changes in apparent size we repeated the measurements of apparent size with the following modification in the experimental conditions.

Procedure. An artificial pupil 0.5 mm. in diameter, was placed before *O*'s eye. This pinhole provides the eye with virtually unlimited depth of focus. Under these conditions no accommodative adjustment occurs in response to a change in viewing distance. To compensate for the decrease in the brightness of the disks produced by this small pupil the illumination of the disks was increased until the disks had the same apparent brightness as those used in Experiment I as determined by a successive visual match.

Seven men, undergraduate students, and one woman served as *O*s in this experiment. All had acuity equivalent to Snellen 20/20 or better as measured on the Orthorator.

Results. The results of Experiment II are shown in Fig. 3. The diameter of the variable disk that was matched to the standard disk is plotted against the reciprocal of the distance of the standard disk. The points are data from individual *O*s. The heavy black line represents the theoretical values, *i.e.* the values expected if the *O*s were matching the sizes of the retinal images. These theoretical values were computed for a reduced eye having a dioptric power of + 60 D. The line is not quite horizontal because the pinhole slightly enlarges the retinal images of near objects.[11] The agreement between the theoretical and empirical values is excellent. It is clear that in the absence of oculomotor adjustments variation of the distance of the standard disk has no effect on its apparent size.

[10] Jakob Bappert, Neue Untersuchungen zum Problem des Verhältnisses von Akkommodation und Konvergenz zur Wahrnehmung der Tiefe, *Z. Psychol.*, 90, 1922, 167-203.

[11] Hermann Helmholtz, *Physiological Optics*, I, 1924, 127-128.

A related control experiment deserves mention here for it shows that the results are not due, perchance, to some other effect of the pinhole such as the alteration of the distribution of scattered light over the retina.[12] In this experiment ophthalmic lenses rather than a pinhole were used to eliminate the need for accommodative adjustments. As in Experiment I, observation was with the natural pupil. For three emmetropic *Os*, *PSEs* were determined between the standard disk at 25 cm. and the variable disk under two conditions. Under Condition 1 the standard disk at 25 cm. was observed with the unaided eye, but the variable disk was observed through a lens of —3.75 D. Under Condition 2 the variable disk was observed with the unaided eye while the standard disk was observed through a lens of +3.75 D. Thus under both conditions the optical distance of the two targets to be

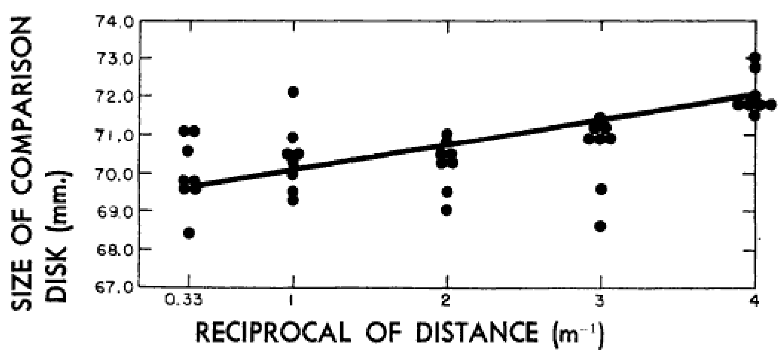

FIG. 3. THE APPARENT SIZE OF A 1° DISK AS A FUNCTION OF THE RECIPROCAL OF ITS DISTANCE
Monocular observation through a pinhole.

compared was the same. It was 25 cm. for Condition 1 and 400 cm. for Condition 2. As with the artificial pupil we found no effect of the actual distance of the disk on its apparent size.

EXPERIMENT III: FUSIONAL CONTROL OF CONVERGENCE

In Experiment I all three of the associated oculomotor adjustments occurred together, *i.e.* the adjustment in the power of the lens was accompanied by an adjustment in the diameter of the pupil and in the angle of convergence. The change in convergence that occurred was monocular in the sense that at the completion of the adjustment to a new viewing distance the right eye, which was viewing the disk, was always in its primary position while the orientation of the left (occluded) eye varied with the distance. Experiment III was designed primarily to determine whether changes in accommodation and pupillary diameter are essential for the occurrence of the changes in apparent size.

[12] This experiment was suggested by Dr. L. A. Riggs of Brown University.

Procedure. Five *O*s, three men and two women, took part in Experiment III. None of them had taken part in Experiment I, but four of them had served in Experiment II. The visual acuity, as determined on the Orthorator, was equivalent to Snellen 20/20 for four of them, 20/30 for the remaining one. Four of the *O*s fell within the age-range of 18 to 26 yr. The remaining *O* was a presbyope, a woman 56 yr. old, who was unable to make any accommodative adjustments under the conditions of the present experiment.

The conditions of observation in Experiment III were the same as those in Experiment II except for the following modifications: (1) A fixation-point was placed in the center of each disk. (2) The left eye, which had been occluded in the previous experiments was also presented with the fixation-point but not the disks. An artificial pupil 0.5 mm. in diameter was placed before each eye. The stimulus-arrangement then was this: the right eye saw the disk and a fixation-point in the center of the disk, the left eye saw only the fixation-point. As before, convergence was asymmetrical. For all distances the right eye remained in its primary position.

In Experiment I the oculomotor adjustments were evoked by presenting a stimulus that required an adjustment in accommodation. In the present experiment the oculomotor adjustments are evoked by imposing a requirement for fusion that serves as a stimulus to convergence.

The basic procedure followed in the present experiment differed in minor ways from that followed in previous experiments. Whereas in the previous experiments *O* was required to signal *E* when the target appeared to be in good focus, in the present experiment he signalled when the fixation-points were well fused. Also, as soon as the exposure of the first disk ended, *O* was required to press a lever that moved the left eye-piece to the new position required to view the second disk.

For each of the four non-presbyopic *O*s, the variation of apparent size with distance was measured under two conditions. In Condition 1 *O*'s eyes were left in their normal state. In Condition 2 adjustments of accommodation and pupillary diameter were prevented by applying homatropine to *O*'s eyes. For obvious reasons, Condition 2 was omitted for the presbyopic *O*. To ascertain that adequate accommodation was occurring under Condition 1 and particularly that no accommodation occurred under Condition 2, measurements of accommodation were made by a method of retinoscopy.

Measurements of accommodation. A discussion of the basic principles of retinoscopy may be found in most textbooks on physiological optics.[13] We shall discuss here only the conditions under which our measurements were made and the manner in which our method differed from the usual clinical practice.

Fig. 4 shows a schematic view of the apparatus used to determine the refractive condition of the right eye. The fixation-point (F) was mounted on an optical bench. Its distance from the *O*'s right eye could be varied from 10 to 400 cm. As indicated, the fixation-point was always presented on a line that coincided with the visual axis of the right eye when that eye was in its primary position. An artificial pupil 0.5 mm. in diameter was placed in front of each eye. Thus the viewing conditions were identical with those under which measurements of apparent size were made.

[13] See Hugh Davson, *The Physiology of the Eye*, 1949, 402-408.

The artificial pupil for the right eye was made by drilling a small hole in the first-surface mirror (M) that was placed in front of this eye. (L) is a holder for ophthalmic lenses. The retinoscope is a clinical instrument of the spot type. *E* held the retinoscope in his hand but rested its head against a firmly mounted metal bar to keep a constant distance (50 cm.) between it and *O*'s eye.

Light from the retinoscope passed through the ophthalmic lenses, was reflected by the first-surface mirror (M), and then entered *O*'s eye. The light emerging from the eye was reflected from the mirror (M), passed through the lens and then entered the peephole of the retinoscope.

O's head was held steady by means of a biting-board and *O* was instructed to signal *E* if the fixation-points became unfused at any time. Two *E*s worked together

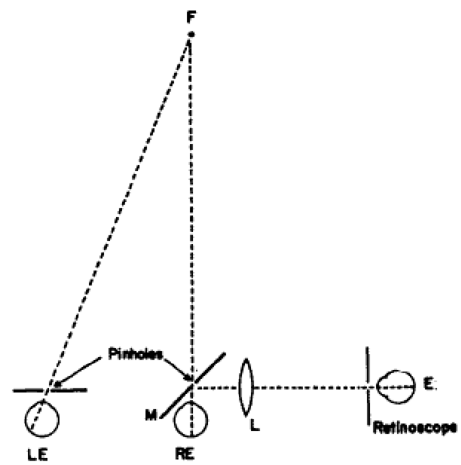

FIG. 4. SCHEMATIC VIEW OF THE APPARATUS USED TO MEASURE ACCOMMODATION

to make the measurements. One *E* manipulated the retinoscope and reported on the motion of the reflex, and the second *E* changed lenses in accordance with the method of constant stimuli. With this method changes in accommodation as small as 0.25 D could be reliably detected.

For all *O*s, the refractive condition of the right eye was measured for each of the viewing distances used in the experiment. Before the beginning of Condition 2 of the psychophysical experiment, 3 drops of 5% homatropine were applied to each of *O*'s eyes at 15-min. intervals. These applications were continued until the retinoscopic measurements showed no change in the refractive power of the right eye when convergence was varied over the range of viewing distances used. Immediately following the end of the psychophysical experiment, another set of retinoscopic measurements was made. In all cases the cycloplegia was still complete at the end of the experiment. For the presbyope, no measurable change in accommodation occurred under Condition 1.

A sample pair of functions obtained from one *O* is shown in Fig. 5 The reciprocal of the distance for which the eye is accommodated is plotted against the reciprocal of the distance for which it is converged, *i.e.* the distance of the fixation-point. The solid line represents the results for the eye in its normal condition, the dashed line shows the results after repeated applications of homatropine. Since the existence of 'convergent accommodation' has been questioned occasionally, it may be of interest to note that the accommodative adjustments that occurred were induced by changes in convergence. The pinhole-pupils eliminated any monocular optical stimulus to accommodation. Our findings in this respect are in agreement with those recently published by Fincham.[14]

Results. Fig. 6 shows the results of the psychophysical measurements. As before, the diameter of the variable disk matched to the standard disk is

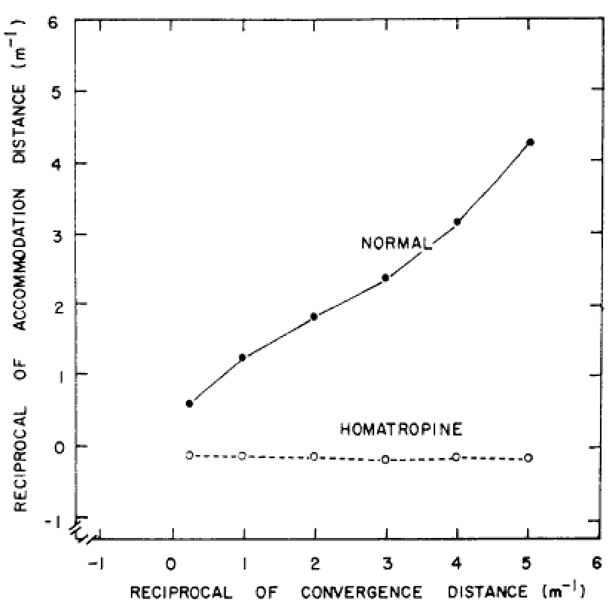

FIG. 5. RELATIONSHIP BETWEEN THE RECIPROCALS OF CONVERGENCE AND OF ACCOMMODATION

One *O* with eye in normal state and under cycloplegia.

plotted against the reciprocal of the distance of the standard disk. The points are based on data from individual *O*s, each point representing the mean of two *PSE*s. The solid black line connects the points representing the group means of the four non-presbyopic *O*s obtained under Condition 1, the dotted line connects the means of the same group obtained under Condition 2. The means of the presbyope are shown separately and are

[14] E. F. Fincham, The proportion of ciliary muscular force required for accommodation, *J. Physiol.*, 128, 1955, 99-112.

connected by a dashed line. All the functions are virtually identical with the group function obtained in Experiment I; the same tendency toward size-constancy is present.

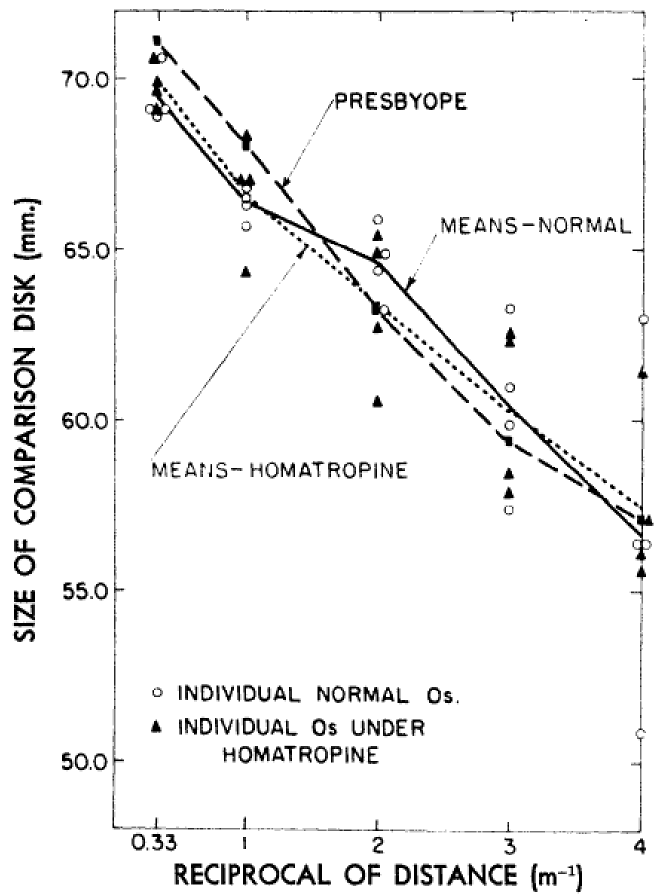

FIG. 6. THE APPARENT SIZE OF A 1° DISK AS A FUNCTION OF THE RECIPROCAL OF ITS DISTANCE WITH AND WITHOUT ACCOMMODATIVE ADJUSTMENT.

DISCUSSION

The results of Experiment III clearly show that changes in the angle of convergence, unaccompanied by changes in accommodation or in the diameter of the pupil, produce variations in the apparent size of objects viewed. The effects obtained as a function of variations in convergence alone are quantitatively identical with those obtained when the power of the lens and the diameter of the pupil are also permitted to vary.

Our experiments do not bear directly on the question of whether changes in accommodation alone are associated with changes in apparent size. What has been shown is (a) that changes in convergence are a sufficient condition for the occurrence of the changes in apparent size, and (b) that changes in accommodation and pupillary diameter are not necessary conditions for the occurrence of the changes in apparent size.

How changes in the angle of convergence of the eyes exert their influence on apparent size remains a puzzle. The results of Experiment I argue strongly against any explanation that assumes a correct perception of the distance relationships among the stimuli. This seems to leave two general possibilities. First, it is conceivable that the effects of convergence here under discussion are mediated by some obscure peripheral visual mechanism. For example, one mechanism we thought of and investigated briefly is this: Increased convergence might be associated with increased intraocular pressure, which in turn would presumably decrease the sensitivity of the retina. A lowered sensitivity of the retina in near vision might be expected to produce a decrease in apparent size by causing the margins of the image, which contain less light than the center of the image, to fall below threshold. If this were the mechanism, a black object on a white ground should appear larger in near vision than in far vision. We repeated some of our observations with such black stimulas-objects on a white ground. The results failed to support the hypothesis; as in our other experiments the nearer stimulus-object appeared smaller than a farther one of the same angular size.

The second possibility, more plausible in our opinion, is that information concerning the position of the eyes is one of the immediate determinants of judgments of visual size. Such information might come from proprioceptive impulses arising in the extrinsic eye-muscles, of from a central system that monitors the innervation to the eye-muscles, or from the visual changes, *e.g.* movements of double images, that normally accompany an adjustment of convergence. While it may be surprising, when considering a mechanism of this sort, that *O*s are unable to report correctly either on their condition of convergence,[15] or on the relative distances of points for which their eyes are converged, the existence of an effect that is confined to visual size violates no logical requirements.

It may be well to point out that the effects found by us are very small when viewed in the framework of constancy of size. The diameter of the

[15] S. R. Irvine and E. J. Ludvigh, Is ocular proprioceptive sense concerned in vision?, *A.M.A. Arch. Ophthal.*, 15, 1936, 1037-1049.

variable that was matched to the nearest of the standard disks was about 80% of the diameter of the variable matched to the farthest standard disk. For perfect constancy of size this value would be about 6%.

It would seem that the effect of oculomotor changes on apparent size plays a very minor role in producing the nearly perfect size-constancy that is found under more normal viewing conditions. This is certainly so when the objects to be compared are shown far from the eyes, as they usually are in such experiments. On the other hand, part of the reason our effects were so small may be that in our experiments, unlike most others, there was no angular separation between the two objects to be compared. Joynson has recently shown that constancy-effects increase with the angular distance between the two objects.[16] Until the influence of this variable, as well as some others (such as the time between presentation of the two objects) is better understood, precise comparisons with the results of other experiments are not possible.

[16] R. B. Joynson, The problem of size and distance, *Quart. J. exp. Psychol.*, 1, 1949, 119-135.