The use of size matching to demonstrate the effectiveness of accommodation and convergence as cues for distance*

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The capacity of accommodation and convergence to serve as cues to distance was assessed. As is usual, size perception was employed as an indicator. The standard technique of obtaining size matches between figures of identical shape yielded poor results. The inadequacy of this technique was revealed when matching the length of two edges that were parts of different figures produced nearly veridical results. A tendency to match image sizes was held responsible for the failure of the standard technique. The absence of extraneous distance cues from our experimental conditions was demonstrated with the help of spectacles that altered the accommodation and convergence with which objects were viewed.

The work to be reported was undertaken to clarify the role of accommodation and convergence as distance cues. Size perception rather than distance perception as such was used as an indicator for the effectiveness of these oculomotor cues for distance. This has become an accepted procedure, probably because size matching is easier for Ss than distance matching. The work of Heinemann, Tulving, and Nachmias (1959) and of Biersdorf, Ohwaki, and Kozil (1963) are examples. When the perceived sizes of objects located at different distances from S are matched, the accuracy of these matches measures the accuracy with which the available distance cues represent the different distances. This is so because the perceived size of an object depends on its registered distance as well as on the size of its retinal projection. Accurate size perception is described by Emmert's law, according to which, for an image of a given size, perceived size is proportional to registered distance of the object causing the image.¹ Where distance cues are available, perceived size then becomes a measure of the effectiveness of these cues.²

An investigation of the effectiveness of oculomotor adjustments as cues for distance requires that all other distance cues be eliminated from the test situation, and, since we cannot be quite sure what properties of the experimental condition can serve as distance cues, this is not an easy task.

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A good way to go about this is to let S see the test object through spectacles or other optical arrangements that simultaneously alter the accommodation and convergence needed to produce sharp and fused images of the test object. Under these circumstances, extraneous distance cues will contradict the effect of the given oculomotor cues, for they will represent the true object distances. Size matches in agreement with predictions made on the basis of the altered oculomotor cues would prove the operation of only that kind of distance cues, while certain systematic errors may reflect the operation of extraneous cues that represent the true object distance.

Techniques of this sort have been used by Gogel (1962) and by Wallach and Zuckerman (1963). The latter seem to have been the first to obtain results showing that these oculomotor adjustments can serve as fairly adequate distance cues. They altered by optical means these oculomotor adjustments in equivalent amounts and obtained size estimates that approximated predictions derived from the altered oculomotor cues. In 1966, Leibowitz and Moore published an extensive experiment with optically altered accommodation and convergence, which demonstrated the investigative power of the cue alteration technique. They provided optical arrangements that required S's eyes to view test objects with a number of combinations of accommodation and convergence that corresponded to distances either larger or smaller than the true distances of the test objects. These artificial distances, which the authors call "equivalent" distances, thus depended

on the true distances of the test objects and on the alterations in accommodation and convergence produced by the lenses and prismatic effects employed in the optical arrangements. S had to match the apparent size of the test objects by adjusting the size of a comparison object located at a distance of 200 cm and seen directly. The sizes of the test objects whose true distances varied between 400 and 10 cm were so chosen that they all produced identical image sizes. Therefore, if accommodation and convergence provided effective distance cues and if there were no extraneous distance cues operating, the matching sizes should be found to be proportional to the "equivalent" distances of the test objects. The results showed that this was so only within limits: where the "equivalent" distance differed much from the true distance of the test object or where the true distances were large, the obtained matches deviated strongly from the theoretical values. Both kinds of deviations were such that they could have resulted from extraneous cues for the true distances of the test objects.

Of the experiments to be reported by us, Experiment 1 showed that results did not improve when, under our experimental conditions, distance cues other than accommodation and convergence were eliminated and were thus prevented from interfering with the effect of the optical arrangements. Poor results were obtained also when, under the same conditions, size matches between test objects at different distances were made with normal viewing, that is, without optical arrangements. In Experiment 2 the size estimation technique used by Wallach and Zuckerman produced good results with normal viewing, with conditions the same as in Experiment 1. Experiment 3 cleared up this discrepancy and, together with Experiment 4, established accommodation and convergence as fair cues for distances up to 2 m. In Experiment 5, results are reported that provide evidence that our experimental conditions did succeed in eliminating all distance cues other than accommodation and convergence.

EXPERIMENT 1

Our first experiment was similar to that of Leibowitz and Moore and was designed to eliminate all distance cues other than accommodation and convergence with the hope that we would obtain matches that corresponded to the "equivalent" distances. There was one further difference: both the standard test object and the comparison object were viewed through spectacles that altered

the accommodation and convergence with which they were given. There was also a match in which both objects were viewed without glasses. Extraneous distance cues were eliminated in the following manner: the objects were luminous diamonds viewed in complete darkness through an aperture in a large screen that hid all light reflected from floor and furniture. S's head was held at a fixed distance from the diamonds and could only turn to face one or the other. The diamonds remained dark while S turned his head and only one lit up when the head had reached the position for which the diamond's center was in S's median plane; it remained lit only as long as the head was kept still.

The standard test object was always at a distance of 120 cm from S's eyes and the comparison object at 60 cm. Seen from S, they were located at eye level and 20 deg apart. The standard diamond measured 12 cm on the diagonal. Two different spectacles were used. The "near" glasses consisted of 5-diopter prisms oriented to force an increased convergence on the eyes and of a pair of lenses whose strength in the case of Ss with near normal interocular distance amounted to -1.5 diopters. These lenses would induce an increase in accommodation corresponding to the convergence change caused by the prisms. For these glasses, equivalent distances amounted to 42.9 cm for the 120-cm distant object and to 31.6 cm for the one at 60 cm. The "far" glasses were equipped with 2.5-diopter prisms, forcing divergence of the eyes and .75-diopter positive lenses; they caused equivalent distances of 1,200 and 109 cm. The spectacles, hence, altered the ratio of the test object distances implied by the oculomotor adjustments caused by the glasses. While that ratio was 2:1 for normal viewing, it was only 4:3 for the near glasses and 11:1 for the far glasses, and thus led to very different theoretical predictions for size matches.

Preliminary experiments performed with a technique similar to the one just described had given results that strongly deviated from Emmert's law and the altered oculomotor cues. This seemed to contradict a result obtained by Wallach and Zuckerman (1963) with a different procedure. In attempting to explain this discrepancy, we hypothesized that oculomotor cues operate best when oculomotor adjustment has just changed in response to an altered viewing distance. To test this hypothesis, two lightboxes, each exhibiting a thin vertical line, 9 cm long and .05 cm wide, were added. Each was placed

beyond one of the diamonds so that from S's vantage it was visible just to the side of it. The line that appeared next to the standard diamond was twice as far from S as the standard, namely, 240 cm, and the one next to the variable diamond was correspondingly placed at 120 cm distance. The lightboxes exhibiting the lines were so wired that either both could be made to stay dark or that one of them was lit when the test diamond with which it belonged was visible. During trials in which the lines were visible, S was under instruction to look back and forth between the test object and the line before giving a judgment.

Equipment

The diamond-shaped test objects were cutouts attached to the front of lightboxes equipped with milk-glass faces. The brightness of the diamonds' surfaces was so chosen that they were clearly visible but not so bright that irradiation noticeably blurred their contours, even after one's prolonged stay in the dark. A variable aperture operated by a screw and a crank provided the size variations of the comparison diamond.

Locating of S's head and elimination of movement parallax was achieved in the following manner: S wore a welder's headgear which could be attached to a vertical shaft, an arrangement that permitted only a turning of the head and prevented all other kinds of head displacement. Fixed to the shaft was a horizontal bar which turned with the head. Stops for its angular displacement were so set that a head turning had to terminate in either one of the two positions in which the head's median plane was aligned with a center of a test diamond. Microswitches were mounted near the stops in such a way that on the bar's approach it caused a switch to make contact less than 1 deg of angular displacement before the stop was reached. Each switch operated the light for the corresponding diamond and, in the case of the trials at which the lines were present, also the line that belonged with it.

In Experiments 1 and 3, the spectacles consisted of trial frames into which lenses and prisms in appropriate combination were inserted. In the case of prisms, the equivalent distance also depends on the interocular distance. Therefore, the lenses we used in combination with the two sets of prisms were appropriately varied, and equivalent distances were computed for individual Ss. The means of the individual equivalent distances for the Ss who participated amounted in the case of the near glasses to 41.8 and

31.1 cm, not much different from the previously stated values of 42.9 and 31.6 cm that were computed on the basis of 1.5 lens diopters.

PROCEDURE

In order to obtain a match between the apparent sizes of the standard and the variable test diamonds, E varied the objective size of the latter, specifically the length of its diagonal, in steps of .1 cm. For half of the 16 Ss, E set this length so that the variable diamond seemed clearly too large, made it smaller by one step, and asked S to make a comparison by turning his head back and forth between the two stops that caused the test diamonds to light up. E went on in this fashion until S judged the two sizes as equal. For the other eight Ss, the variable diamond was initially adjusted to appear too small, and this applied to all five trials of which this experiment consisted. Thus, for half of the Ss only the upper limit of the range of equality was always obtained and for the other half only the lower one. This was done to keep the experiment from becoming too long. It caused, of course, an increase in variability which, however, did not interfere with the significance of our results.

There were three experimental conditions: in the "normal" condition, S wore no glasses; in the other two, he wore either the near glasses or the far glasses. Under the first two conditions, S made two matches, one with the added vertical lines and the other without them. For half of the Ss all matches were made first with the lines and then, still for the same condition, without the lines, and for the other eight Ss this order was always reversed. In the case of the far glasses, the lines could not be used because the 240-cm distance of one of the lines could not be increased by .75 lens diopters.³ All experiments began by having S make two practice matches with the near glasses, with the three experimental conditions immediately following. Of the six possible sequences of these conditions, four were actually used. The two that started with the near glasses were omitted, because the near glasses were used in the practice matches.

Results

As presented in Table 1 under the heading Experiment 1, results were obtained that were far from the matches to be expected, if accommodation and convergence were fully effective as cues to distance. The mean match of 8.7 cm obtained for the normal viewing condition was closer to the value of 6 cm expected if Ss were matching the sizes of retinal

Table 1
Mean Sizes in Centimeters of Near Object When it Matched Far Object

Conditions of Viewing	Expected for		Experiment 1, Two Diamonds			Experiment 3	Significance of Difference Between Experiments 1 and 3	
	Complete Constancy	Image Size Match	With Line	Without Line	Combined	Oblong and Triangle	t	p
Normal	12	6	8.6	8.7	8.7 ± .50	11.0 ± .58	5.29	< .001
Near Glasses	8.2	6	6.9	6.9	6.9 ± .28	8.1 ± .46	4.58	< .001
Far Glasses	66	6	—	7.9	7.9 ± .60	9.9 ± 1.51	2.88	< .01

images—the result that would have been expected in the absence of all distance cues—than to a veridical match of 12 cm. The same was true of the mean match of 6.9 cm made with the near glasses, where a value of 8.2 cm should have been obtained, had the accommodation and the convergence forced by the glasses been fully effective in representing the equivalent distances of the two diamonds.⁴ The matches obtained under normal conditions (8.7 cm) and with the near glasses (6.9 cm) were significantly different from each other ($p < .01$). Changing accommodation and convergence between simultaneously visible objects at different distances, which happened when one of the lines lit up together with a diamond, did not improve the matches substantially. The same mean matches were obtained with and without the line (Table 1).⁵ Whether a match was begun with the diamond apparently too large or with a diamond that appeared too small had little effect. In the normal condition, the mean for the eight Ss who were first shown the diamond too large was 8.5 cm, and for those who were first exposed to the smaller diamond it was 8.8 cm. For the near glasses, the corresponding values were 7.2 and 6.6 cm, and for the far glasses they were 8.5 and 7.3 cm. The far glasses seem to have been completely ineffective. Whereas the expected match should here have been much larger than the match under the normal condition, it actually did not even reach that value. This result will be discussed with those of Experiment 3, where a quite similar result was obtained for the far glasses.

Though this experiment did show a significant influence of the oculomotor adjustments on perceived size, the results were no improvement over those obtained by Leibowitz and Moore. But the deviation of the mean matches from the expected values toward image size matching can no longer be ascribed to extraneous distance cues, for it also occurred under normal conditions; here the presence of extraneous distance cues would have had the opposite effect of favoring the expected match. Hence

we turned to the question of how image size influenced our results. Experiment 2, which employed a size estimation technique, provided part of the answer.

EXPERIMENT 2

The same setup was used as in Experiment 1 except that the two diamonds were given the same fixed size of 8.5 x 8.5 cm. S's head was again attached to the switch device that caused the appropriate diamond and line to light up only as long as the head remained in one position, but now E controlled which one of the two diamonds would do so. S gave his estimates by changing the length of an adjustable rod to match the apparent length of one of the diamond sides which was objectively 8.5 cm for either. A small lamp near S's hands enabled him to see the adjustable rod. There were four different presentation sequences: either the near or the far diamond was presented first and, of the two estimates made for each diamond, the one with the line present was made either in the first or second place. No glasses were used in this experiment.

Again, the presence of the line had no effect. The average of the mean estimates for the near and the far diamond made with the line was 7.28 cm and without the line it was 7.35 cm. The mean estimate for the diamond at 120 cm distance ($7.13 \pm .83$ cm) was smaller than the mean estimate for the one at 60 cm distance ($7.50 \pm .70$ cm), and this difference was statistically significant ($p < .05$). But the difference was very small compared to the matching result for the normal condition in Experiment 1. While in that case the constancy ratio (objective size of matched near object/objective size of far object) amounted to .725, the constancy ratio in the present experiment (estimate of far size/estimate of near size) was .95.

This result showed that accommodation and convergence can serve well as cues for distance. The poor results obtained in Experiment 1 seemed to be caused by some factor operating in matching tests. We assumed that it consisted in a

tendency to match image sizes, which interfered with the result of size perception that takes distance into account. We therefore tried to find a form of matching test where this tendency would not operate. Instead of presenting two figures of identical shape for size matching, we presented two figures of different shapes and asked S to match the length of two lines in the different figures by adjusting the size of one of them.

EXPERIMENT 3

The same equipment was used as in Experiment 1 except that the diamond of standard size was replaced by an oblong 18 cm high and 8.5 cm wide, and the variable diamond was changed into a triangle by covering its lower half. Thus, changing the size of the triangle did not alter its shape. Because in Experiments 1 and 2 the lines proved to have no effect, they were omitted. S's task was to match the horizontal base of the triangle to the 8.5-cm width of the oblong. To protect our results against possible extraneous effects connected with the shapes of these figures, half of our Ss made the match with the triangle in the near position, at a distance of 60 cm, and with the oblong 120 cm from the eyes, and the other half with the triangle 120 cm distant and the oblong at the distance of 60 cm.

We first tried this setup for the normal viewing condition and, when it proved successful, went on and used the near and far glasses also. Therefore, different groups of 16 Ss participated in the two parts of this experiment. Since this, together with the omission of the matches made in the presence of the lines, shortened S's task considerably, an individual trial now consisted in obtaining the upper as well as the lower limit of equality and recording as S's match the average of these two values. Again, the sequence of presentation was appropriately varied from S to S.

In the case of the normal viewing condition, the matching length of the base of the triangle was 8.2 cm when it was in the near position and 9.8 cm when it was in the far position. There are two reasons why the latter matching length was higher. First,

because of a lag in constancy, any far object looks somewhat smaller than it should, and, compensating for this, the matching size of the triangle when it is in the far position is larger than when it is in the near position. To make the two matching lengths comparable, the result of the match between the near oblong and the variable triangle in the far position (8.5 to 9.8 cm) must be transformed into one where the length in the far object is chosen to be 8.5 cm. We therefore ask what value of length in the near object would stand in the same ratio to the standard length of 8.5 cm as does 8.5 to the matching length of 9.8 cm obtained when the triangle was the far object ($x/8.5 = 8.5/9.8$). The result of this transformation is an equivalent length in the near object of 7.4 cm. With the mean match for the triangle in the far position so transformed, our two matches were 8.2 to 8.5 for the triangle in the near position and 7.4 to 8.5 when the triangle was the far object. There was, then, still a difference. It was due to the effect of the figure shapes on the apparent lengths of the lines that were compared. Specifically, it was due to the Mueller-Lyer illusion, which operated in the triangle and diminished the apparent length of its base. It was precisely to eliminate the effect of such errors that we presented to half of our Ss the triangle in the near position and to the other half in the far position. Since, as it must compensate for the illusion, the matching length of the triangle base was always larger than it should have been, the effect of the illusion was to produce too large a matching near length when the triangle was the near object and too small a matching near length when the triangle was the far object. The true mean match, then, is the average of (1) the matching length obtained with the triangle in the near position and (2) the equivalent matching length computed from the match made with the triangle in the far position. This average was 7.8 cm for a standard of 8.5 cm and was thus close to objective equality. The constancy ratio of .92 computed from these values is not much different from the constancy ratio of .95 obtained in Experiment 2.

To make the reported match of 7.8 to 8.5 cm comparable with the corresponding result from Experiment 1 as presented in Table 1, it must be transformed once more to conform to the standard length of 12 cm of the far object, the basis for all data in this table. The transformed value of the matching length in the near object is computed from $x/12 = 7.8/8.5$ and amounts to

11.0 cm. It is found in Table 1 under the heading Experiment 3.

In the case of the near glasses, the mean matches actually obtained were 6.0 cm for the triangle in the near position and 13.1 cm for the triangle in the far position, and the true matching length computed in the same manner as before was 5.8 cm. This result can be appreciated only in the context of Table 1, where it can be compared with the value expected for complete constancy and with the match obtained for the diamonds. For this purpose, it also must be transformed to correspond to the standard length of 12 cm. This was done by multiplying the true match of 5.8 cm by $12/8.5$. The resulting value of 8.1 cm, found under the heading Experiment 3, is close to the one expected for complete constancy. For the far glasses, the actual matches were 6.8 and 10.0 cm, respectively, and the true matching length came to 7.0 cm, which transformed to 9.9 cm.

In the case of the normal viewing condition and when the near glasses were used, the transformed values obtained from the mean matches between triangle and oblong (11.0 and 8.1 cm) were much nearer to the veridical match of 12 cm and to the expected match of 8.2 cm than the corresponding values obtained from matching two diamonds. The difference of the mean matches obtained with the different pairs of test objects was highly significant, as the statistical data presented in the last columns of Table 1 show.⁶ This outcome confirms our explanation of the poor results obtained by the ordinary matching method: a tendency toward matching the sizes of the retinal images of the compared objects has a strong influence on these matches. Such a tendency does not seem to operate in our new method, where lengths of lines that are parts of different shapes are being matched, nor will it have an influence in a brief size estimation test. In speaking of a tendency toward matching the sizes of the retinal images, we do not mean to favor a particular explanation of this tendency. It may be due to an effect that assigns the same distance to similar shapes, which then, through the operation of Emmert's law, will cause these shapes to appear of equal size when their image sizes are equal; or it may be due to a tendency to match image sizes as such; or it may operate for still another reason.⁷

In the case of the far glasses, though the difference between the mean matches obtained under the two conditions was significant, the use of different shapes did not improve the results markedly. There seems to be a good reason why we might not expect

the far glasses to be fully effective. The equivalent distance for the 120-cm distant test object is here 1,200 cm and the size of the experimental room known to our Ss could not accommodate such a distance. On the other hand, the match of 9.9 cm that was actually obtained implies a registered distance of 180 cm for this object, still a small distance compared to the space known to our Ss to be available. Twice the distance would have fitted into the room. A matching size of 20 cm of this object could have resulted from such a registered distance. A match much larger than 9.9 cm was thus compatible with the known size of the room. We therefore prefer another explanation. We believe that oculomotor adjustments do not serve as distance cues for large distances. We do not, however, assume that states of convergence caused by the larger object distances are less accurate. We can see no reason for such an assumption. But in the case of larger object distances, a difference between two states of convergence corresponds to a much larger difference in distance than where short distances are concerned. (This is a consequence of the fact that the degree of convergence is inversely proportional to distance.) The small convergence angles are therefore not associated with well-defined distances, and this, we believe, interferes with the establishment of the learned connections between small convergence angles and registered distance.

EXPERIMENT 4

Because of the importance of Experiment 3, we repeated part of it with a new group of Ss and larger distances of the test objects. We obtained matches under normal viewing conditions with the oblong and triangle at distances of 100 and 200 cm, with 12 Ss participating.

The mean matching length of the base with the triangle in the near position was 8.2 cm. It was 11.3 cm when the triangle was in the far position, from which the equivalent value was computed as 6.4 cm. The true matching length for the near position, the average of 8.2 and 6.4, was therefore 7.3 cm for a far length of 8.5 cm. The constancy ratio amounted to $.86 \pm .096$.

EXPERIMENT 5

A large part of the evidence in this report stems from comparisons made without the glasses. It therefore seems worthwhile to present further evidence for the absence of extraneous distance cues from our experimental conditions. Such cues would, where

Table 2
Mean Tactile Size Estimates in Centimeters of Two Diamonds Yielding Identical Image Sizes

Size	Actual Distance	Condition	Equivalent Distance	Oculomotor Adjustments for	Size Estimates	Difference
12	66.7	Near Glasses	33.3	33.3	8.03	.01 ± .41
6	33.3	No Glasses		33.3	8.02	
6	33.3	Far Glasses	66.7	66.7	12.17	.59 ± .70
12	66.7	No Glasses		66.7	12.76	

normal viewing conditions were employed, contribute to the veridicality of the matches and the size estimates. The new evidence was obtained by obtaining size estimates under two conditions, one with glasses and the other without them, causing the same oculomotor adjustment. To bring this about, the object distances were so chosen that an equivalent distance of a test object seen through the glasses was the same as an actual distance of the normally viewed object. In the absence of extraneous distance cues from the tests, mean size estimates made under two such conditions should be the same.

Two spectacles were used. One was identical with the near glasses employed in our experiments and caused the eyes to increase accommodation and convergence by the equivalent of 1.5 lens diopters. The other, a different pair of far glasses, forced a decrease of oculomotor adjustments equivalent to 1.5 lens diopters. Two test distances were selected because they were 1.5 lens diopters apart, namely, 33.3 and 66.7 cm. Wearing the near glasses, our Ss made size estimates of an object 66.7 cm away, which made its equivalent distance 33.3 cm. These estimates could then be compared with estimates of an object actually 33.3 cm distant and viewed without glasses. Similarly, an object 33.3 cm away was viewed through the far glasses, and the resulting estimates could be compared with those obtained with normal viewing of an object 66.7 cm distant. The objects were two diamonds, but they were not of equal size. Instead, their sizes were so chosen that they produced the same image size. This made easier the critical comparisons ultimately to be made, namely, of size estimates that were obtained with the same oculomotor adjustments but were of objects actually located at different distances. The diagonal of the nearer diamond was 6 cm and that of the one twice as far away was twice as long. As in Experiment 2, S gave his size estimate by changing the length of an adjustable rod to match the apparent length of a diagonal. Because Ss wore glasses for some of the size estimates, they made the adjustments of the length of the rod by touch only. In all

other respects the experimental conditions were the same as in our other experiments for which the present one served as control. The order of presentation of the four experimental conditions was varied. Twenty-four Ss participated.⁸

The results are given in Table 2. As can be seen, the mean size estimate obtained when the diamond at 66.7 cm distance was seen through the near glasses was the same as the mean estimate for the diamond at 33.3 cm seen without glasses. Inasmuch as the retinal images of the two diamonds were the same, identical size estimates imply identical registered distances. The same applies to the other two conditions where oculomotor adjustments were for the same distance, namely, 66.7 cm. The obtained mean estimates were quite similar also. Since extraneous distance cues would counteract the effect of the glasses by causing registered distance and therefore size estimates to be more veridical, the close agreements of the mean size estimates within the pairs of conditions that produced the same oculomotor adjustments demonstrates absence of extraneous distance cues.⁹

CONCLUSIONS

We would like to draw two conclusions from our results: (1) A tendency toward making image sizes equal operates in experiments where the sizes of figures of identical shape are being matched. This tendency competes with the given cues for distance and makes them appear less effective than they really are. (2) Under conditions where both accommodation and convergence respond to the same distance, these oculomotor adjustments serve as fairly good cues for distances of at least up to 2 m, but this can be demonstrated with size matching only if the tendency toward image size matching is prevented from operating.

Image size matching has often been obtained when all cues for distance had been eliminated. This fact has been attributed either to a capacity to perceive size according to the size of the retinal image (Rock & McDermott, 1964) or to a tendency to perceive the objects to be matched at a common distance (mainly Gogel, 1969). Our

results are compatible with either one of these explanations.

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NOTES

1. Registered distance is a theoretical term denoting the representation of distance in the nervous system usually resulting from the available cues for distance. Registered distance must be distinguished from apparent or judged distance, which is often affected by conditions other than cues for distance.

2. In the absence of distance cues, S, asked to make size matches, in effect matches image sizes.

3. A distance of 240 cm normally requires an accommodation of .42 diopters, which cannot be diminished by .75 diopters.

4. The matching size of 8.2 cm under the assumption of complete constancy was computed in the following manner: The equivalent distance of the far object (D_{ef}) amounted to 42.9 cm and the one for the near object (D_{en}) to 31.6 cm. These values were obtained by transforming the real distance into lens diopters, adding 1.5 (the lens diopter strength of the near glasses), and transforming the result back into the corresponding distance values. According to Emmert's law, the perceived size of the far object is proportional to its image size times D_{ef} , and, since that image size is proportional to its objective size (12 cm) over its objective distance (120 cm), the perceived size is proportional to

$$\frac{12}{120} \cdot D_{ef}$$

The corresponding formula for the near object is

$$\frac{x}{60} \cdot D_{en}$$

where x is the size of the variable near object whose size we want to predict. Since our S's task was to match the two perceived sizes.

$$\frac{12}{120} \cdot D_{ef} = \frac{x}{60} \cdot D_{en}$$

When the values given above are substituted for D_{ef} and D_{en} , $x = 8.2$. The equivalent distances for the far glasses are computed by subtracting .75 lens diopters from the diopter values of the objective distances of the test objects.

5. The negligible difference obtained under the normal conditions was opposite to the expected direction.

6. It was obtained in the case of the normal viewing condition by changing the average matches made by individual Ss into constancy ratios, which then served as raw scores. For the matches obtained with glasses, individual average scores in the triangle and oblong condition were transformed to conform to the standard length of 12 cm and then treated as raw

scores for comparison with the matches of Experiment 1.

7. The stated explanations were proposed recently by Gogel (1969) and by Rock and McDermott (1964) in another context.

8. We are grateful to Dr. Karl Josef Frey for making this experiment available to us.

9. The mean size estimates obtained under normal viewing conditions can be

used to compute a constancy ratio. It amounts to .80, considerably lower than those obtained in Experiments 3 and 4. We ascribe this to the estimation procedure of adjusting the length of the rods by touch only.

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