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Slope of regard as a distance cue

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It is proposed that some distance cues are learned when a perceptual parameter that varies with observation distance is regularly associated with objects whose distances are perceived because another distance cue operates. If that is the way distance cues can come into existence, it may be possible to identify a parameter that varies with distance but is not a known distance cue and to show that it functions as one. The slope of regard with which an object on the ground is viewed is such a potential distance cue. Its angle varies approximately with the reciprocal of distance. An experiment was done that showed that this slope angle functions as a distance cue. Subjects who looked through a device that altered slope angles gave estimates of the dimensions of an object on the ground. Perceived sizes, which vary inversely with distance, were found to be altered in accordance with the altered slope angle.

It has been known for some time that the relation between oculomotor adjustment and perceived distance can be altered very rapidly by perceptual adaptation (Wallach & Frey, 1972). This fact suggests that accommodation and convergence are learned cues for distance. Such an assumption makes good sense, for the oculomotor adjustments primarily serve to produce sharp images and fused binocular vision. In performing this task, they vary with observation distance, and this makes them potential cues for this perceptual variable. Since other cues for observation distance, such as location in the patterns of linear perspective and image sizes of familiar objects, are present more often than not, simple associative processes may cause oculomotor adjustments to become distance cues. Specific oculomotor adjustments are simultaneous with particular perceived distances that result from other distance cues, and such contiguous pairings between oculomotor adjustments necessary to converge and to focus on objects whose distances are also perceived will occur again and again. If this produces a series of connections between different oculomotor adjustments and different perceived distances, oculomotor adjustments will become distance cues.

If this were really a way in which oculomotor adjustments could become distance cues, it would seem inevitable that they function as such in most individuals. This would also apply to any other viewing condition that varies with the distances of objects we look at. If a further viewing condition of this sort existed, it should be found to be a distance cue also. On the other hand, if a further viewing condition that varies with object distance could be identified and if it would then be discovered to function as a distance cue, such a finding would make it more likely that distance cues are as readily learned as our hypothesis assumes they are. The more inconspicuous and limited in scope a potential cue that is eventually found to function as one is, the better would its discovery argue for our proposal that such perceptual learning is inevitable.

A viewing condition that varies with observation distance and is therefore a potential distance cue consists of the slope of the line of regard with which a standing observer views an object on the ground on which he stands. The sine of this slope angle is inversely proportional to the distance between the eyes and the object, and the same is approximately true of the slope angle itself. It if were possible to show that this slope angle actually operates as a distance cue, we would have gotten hold of a fact that argues for such perceptual learning.

To demonstrate that the slope of the line of regard serves as a distance cue, it is best to use experimental conditions in which the slope angle functions nonveridically. This is preferable to an attempt to create conditions from which all other distance cues are eliminated, because we cannot be certain that all distance cues are known. Because using the slope angle nonveridically would, if it actually operated as a distance cue, create a conflict with other distance cues, an effort should still be made to eliminate from the experimental conditions as many of the other dis-

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tance cues as feasible in order to bias the cue conflict as much as possible in favor of the slope angle. If such conditions were found to yield perceived distances that differed from normal in the direction conforming to the altered slope angle, its effectiveness would be established.

We constructed an optical device that diminished, by a constant fraction, the slope angle with which an object on the ground is seen. It was an analogue of a Galilean telescope of .7 power, composed of cylindrical, rather than spherical, lenses. This scope diminished the visual angles of frontal extents in one dimension only. When it was oriented to minify the vertical dimension, it diminished slope angles, that is, the angles between the horizontal and a point on the ground, by a factor of .7. An object on the ground that is seen through the scope when it caused contraction of the vertical dimension will be seen with diminished slope angle, and, if the slope angle serves as a distance cue, the registered distance of the object may be affected. If the veridical distance cues that are also present do not overcome the effect of the slope angle, the registered distance of the object will be larger than normal. (It will be remembered that the slope angle with which an object on the ground is viewed is approximately inversely proportional to the distance of the object from the eyes.) Since, by Emmert's law, perceived size is proportional to registered distance, the perceived size of an object on the ground should be larger when seen through the scope. Our experiments demonstrated such an effect of the altered slope angle.

PROCEDURE

The experiment was conducted in a large room with wall-to-wall carpeting. This place was selected because it was the only large ground area available that showed no texture. A square of black construction paper, 28 × 28 cm, served as target. It was fastened to a wooden base so that it stood upright with its lower edge touching the carpet. To make certain that the axis of the scope was horizontal, it was mounted on a stand whose height was adjustable so that the scope could be raised to the level of the subject's eye. There were two identical scopes, each fastened to a rod that could be fitted into an attachment at the stand. When in place, one scope minified the vertical dimension and the other, the horizontal dimension. The black square was presented in two locations; it was placed on the floor either 6 or 9 m from a point perpendicular below the subject's eye in the direction of the axis of the scope. When it was seen through the scope, the square was given as a rectangle with one dimension smaller by a factor of .7 than the other. The orientation of the oblong depended, of course, on the position of the scope. At each scope position, the subject made two size estimates for the optically given rectangle, one for its horizontal width and the other for its height. Size estimates were given by adjusting the length of a small antenna rod. The scope was inserted into a hole in a large black curtain that prevented the subject from seeing the part of the room in which the square was displayed, unless he looked through the scope. Thus, the square was seen only monocularly, but when the length of the antenna rod was adjusted both eyes were used.

There were two groups of experimental subjects. Group A first gave the size estimates for the two distances of the square with the scope that minified the horizontal dimension and then with the scope that contracted the vertical dimension. For Group B, this order was reversed. The order of height and width estimates and of the distances of the square were properly varied within each group. When these estimates had been made, the subjects of both groups made estimates without the scope. The subjects saw the scene with the square through an aperture that subtended a visual angle of 42 deg, the same as that of the field of the scope in the unaffected dimension. They were instructed to hold their heads upright. Again, the order of height and width estimates and the two distances were varied. Because the results of these estimates showed a strong order effect, the estimates without the scope were obtained again from a new group of subjects (C).

Thirty-six paid undergraduates, all with normal uncorrected vision or wearing contact lenses, served as subjects, 12 in each of the three groups.

RESULTS

The mean height and width estimates are listed in Table 1. The results for Group C, in which estimates were given with direct viewing, show good constancy. While the image size of the square at 9 m distance was one-third smaller than the image size at the shorter distance, mean size estimates, with those for height and width averaged, were 35.7 cm for the longer and 34.8 cm for the shorter distance, with the confidence limits averaging 4.44 cm. There was also no horizontal-vertical illusion; the average of the mean height estimates amounted to 35.3 cm; for width, it was 35.2 cm.

Because there was a large order effect, the first and second sets of results obtained with the scope will be discussed separately. When the scope caused contraction of the vertical dimension and diminished the slope angles by a factor of .7, the implicit distances between the eye and the square changed by the reciprocal of .7, that is, by 1.43; the perceived sizes should change by the same factor, provided that no conflicting veridical distance cues are in operation. Because perceived sizes of the square are expected to change in the same proportion at both distances, averages of the two mean estimates will be used for the discussion of the scope results.

The scope had two effects, the optical deformation caused by the one-dimensional minification, which caused the square to reach the eye as an oblong, and the size effect just discussed, which affected both height and width of the oblong equally. Since the scope contracted one dimension of the square by a factor of .7, the ratio of the shorter to the longer dimension of the oblong was .7. In the case of Group A, for which the scope contracted the width of the square, this ratio, the mean width estimate to the mean height estimate, was 27.0/40.3 = .67. For Group B, for which the scope contracted the height of the square, the height to width ratio was 41.8/63.1 = .663. That both these shape ratios were close to the given optical shape ratio of .7 shows that our way of obtaining estimates of the apparent width and height of the square was adequate.

Table 1
Mean Height and Width Estimates, With Their Standard Deviations, Showing the Optical Contraction Effect and the Psychological Slope Effect (in Centimeters) for Three Groups of 12 Subjects

First Set

	Group A					Group B				Group C			
	Height Normal		Width Contracted			Width Normal		Height Contracted		No Scope, Height		Normal Width	
HC/N	Mean	SD	Mean	SD	VC/E	Mean	SD	Mean	SD	Mean	SD	Mean	SD
6m	39.1	5.67	26.2	4.68	6m	64.7	11.21	42.8	8.85	35.2	7.70	34.4	7.51
9m	41.6	8.05	27.8	5.03	9m	61.6	12.04	40.9	8.81	35.4	6.63	35.9	6.10

Second Set

	Group A					Group B			
	Width Normal		Height Contracted			Height Normal		Width Contracted	
VC/E	Mean	SD	Mean	SD	HC/N	Mean	SD	Mean	SD
6m	47.7	6.69	30.7	4.57	6m	49.4	8.85	36.3	4.45
9m	48.6	9.86	29.3	5.74	9m	50.4	7.97	36.1	5.60

Third Set

	Group A					Group B			
	Width Normal		Height Normal			Height Normal		Width Normal	
No Scope	Mean	SD	Mean	SD	No Scope	Mean	SD	Mean	SD
6m	34.5	5.1	33.8	5.5	6m	43.3	9.1	46.2	9.6
9m	33.9	4.0	34.7	4.3	9m	45.2	9.1	45.9	8.6

Note–NC/N = horizontal contraction, no slope effect; VC/E = vertical contraction, slope effect.

The mean estimates of the subjects in Group B, who observed through the vertically contracting scope, show the effect of the diminished slope angle on perceived size. Both mean width and height estimates were larger than those obtained from Group A. Two comparisons can be made, one for those dimensions of the oblongs that were not contracted by the scope, width for Group B and height for Group A, and a second for the contracted dimensions. The average mean width estimate for Group B was 61.3 cm, and the average mean height estimate for Group A was 40.3 cm. The ratio of these means amounted to 1.566. The corresponding ratio for the contracted dimensions, height for Group B and width for Group A, was 41.8/27.0 = 1.548. These size effects are somewhat larger than the expected value of 1.43, but these differences are not significant. The differences between the corresponding mean estimates for Groups B and A, however, were highly significant. For the difference between 61.3 and 40.3 cm, t(22) was 5.97, and for the difference between 41.8 and 27.0 cm, t(22) was 5.12. These results make it clear that the slope of regard was the prevailing distance cue in our experiment.

The effect of the diminished slope angle on perceived size completely disappeared in the second set of estimates, for which the subjects of Group A observed through the vertically contracting scope and Group B did so with slope angle normal. The subjects of Group A, who in the first set had seen the normally sized oblong and had given appropriately smaller size estimates, now observed with diminished slope angle; they gave size estimates only slightly larger than those they had given just before. The subjects of Group B, who had given large size estimates in the first set, now observed with normal slope angle; they gave size estimates that were larger than those that had been given under the same conditions by Group A in the first set. These two order effects combine when the size estimates given by the two groups are compared in the same manner as before; in the second set, the effect of the diminished slope angle is wiped out. For the contracted dimensions, the size ratio was 30.0/36.2 = .829, and for the normal dimensions, it was 48.2/49.9 = .966.

This order effect did not occur only in connection with the scope. When, in the third set of estimates, the subjects of Groups A and B viewed the square directly, the tendency of Group B to make larger size estimates was still strong. The average mean height and width estimates were 44.2 and 46.0 cm for Group B and 34.3 and 34.2 cm for Group A, and the differences between the means from the different groups were highly significant, with t(22) as high as 3.57 for the difference in height and 4.32 for the difference in width. These large order effects show that the slope of regard is not a potent distance cue; its effect on size perception is easily overcome by an effect of expectation.

DISCUSSION

Slope of regard should not be confounded with "height in field." As conceived by Gibson (1950, pp. 176-180), height in field is a depth cue; of two objects, the one that is higher in the visual field is usually perceived as farther away. Slope of regard, on the other hand, mediates the distance between the eyes and an object. Another important difference between the cues is that "upness," Gibson's term for height in field, is given through the "optical contact with the background" that is perceived as "terrain or floor." Usually, when two objects are seen against a background that is perceived to extend into depth, the higher one seems farther away, unless the objects are perceived to be in contact with an apparently horizontal surface from below; in that case, perceived depth is reversed (see Gibson, 1950, Figure 70). Gibson envisioned the possibility that such a background might operate when it was present only by inference, but an experiment by Epstein (1966) contradicts this. Epstein obtained estimates of separation in depth of two small frontal-parallel luminous disks that were arranged one above the other. They were seen monocularly against a textured background that "yielded the impression of a receding ground," against the homogeneous area of an outline figure that provided the same impression, or in complete darkness. Estimations of depth between the two disks were obtained for three vertical separations, 3.5, 5.5, and 7.5 in. When the disks were seen against the textured background, the corresponding mean depth estimates were 3.1, 5.9, and 12.8 in., with the upper disk appearing always farther. Mean depth changed much less with vertical separation, namely, 2.1, 4.0, and 5.4 in., when the outline figure was the background. Finally, differences in vertical separation had no effect on depth estimates in the dark (2.1, 1.9, 2.5 in.). Altogether, these last means were not significantly greater than zero. Epstein also found that inverting the background patterns gave similar results, except that now the lower disk was perceived as more distant. Epstein's experiment shows that the depth effect of height in field results from the configurational context of the object and the surface to which it appears attached.

The large order effects that emerged in the second and third set of our experiment are an important finding. In the second set, one order effect lowered the effect of the diminished slope of regard for Group A and another order effect raised the estimates of sizes viewed with normal slope angle by Group B. The latter made itself felt even in the third set under normal viewing conditions. These results argue that slope of regard is a learned cue. Only the effect of a learned cue would yield so readily to expectations set up by sizes previously perceived. The large order effects also characterize slope of regard as a weak cue; the degree to which it yields to expectation is unusual.

So far we have argued that the change of slope of regard into a distance cue results from a formation of associative connections that are formed between various slopes and the perceived distances which they eventually come to represent because of their contiguous occurrences. This point needs further discussion. In the first place, it should be pointed out that contiguity here is of a particular sort. When an observer looks, with a particular slope of regard, at an object on the ground, that object is assigned a particular distance on the basis of the operation of other distance cues. A link exists that has the potential of bringing a slope of regard and a perceived distance together. Secondly, a particular slope of regard is not an isolated event; rather, it is on a continuum on which individual instances vary along a single dimension, and the same is true of perceived distance. The question arises as to whether this feature is important here. It may be particularly effective when there are frequent occasions in which the covariance between the two continua becomes manifest. This is so in the case of distance cues when we move forward. Here, all established distance cues vary, and along with them perceived distance, and a potential distance cue like the slope of regard varies not only with perceived distance, but also with the other distance cues as well.

The hypothesis that slope of regard becomes a distance cue on those occasions when we move forward and look at an object on the ground has an attractive feature. If a stationary subject forms a connection between a particular slope of regard and a particular perceived distance, he may be standing or sitting, and the slope of regard differs accordingly. Posture would be part of an array of connections that would make slope of regard a distance cue. But when we look at objects on the ground as we move forward, we usually walk, and what we learn about the connections between slope of regard and distance applies only to the upright posture.

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NOTE

1. At slope angles of 16 deg or less, radians and sines of the same angle differ by 1.3% or less.

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