Depth information in single triangles and arrays of triangles¹

HOWARD R. FLOCK, YORK UNIVERSITY, JAMES H. TENNEY, HARVARD UNIVERSITY
DAVID GRAVES, DARTMOUTH COLLEGE

When 6 obtuse triangles varying in angular height from 75° to 10° were presented singly at 6 different slants, slant judgments were at chance level. When the view of an array of triangles was varied from 82° to 40° to 22° for the same 6 slants, the accuracy of slant judgments correspondingly varied. It was concluded that arrays of triangles carry information about their spatial orientation even though the individual elements of the array do not.

Considerable evidence exists (see Flock, 1965, for a detailed review of some of this evidence) that slanted, solitary, textureless rectangles under at least some conditions elicit relatively accurate slant judgments. This raises some questions for the general theory of space perception. For example, is the rectangle unique in this respect, or does it share this slant-eliciting property with all planar shapes presented individually at a slant? Moreover, if the rectangle is unique or belongs to a restricted set of planar shapes which elicits appropriate slant perceptions, is the presence of such shapes, either individually or as the irreducible elements of an array of shapes, a necessary condition for monocular non-parallactic slant perceptions?

To answer these questions two experiments are described below. In the first, 6 different obtuse triangles varying in angular size were each presented at 6 different slants. In the second experiment, an array of triangles was presented under 3 different fields of view.

Displays and Apparatus

Six obtuse triangles were cut from heavy-duty vinyl contact paper. The relative sizes, areas, and angular heights of the triangles when in a frontal parallel position are given schematically in Fig. 1B. Three of the triangles (Group I) had a hypotenuse to width (distance from hypotenuse to opposite angle) ratio (H/B) of 2.8:1; and 3 (Group II) had a H/B ratio of 2.5:1. Each triangle was mounted on a transparent sheet of Plexiglas so that when viewed in a frontal position by a S the mid-point of the hypotenuse was exactly in the middle of his field of view. Group I triangles were mounted with the hypotenuse rotated 15° counterclockwise, Group II triangles with the hypotenuse on the vertical mid-line of the field of view. Each shape could be rotated on a horizontal axis through the objective mid-point of the hypotenuse to any one of six slants (30° , 20° , 10° , -10° , -20° , -30°) where 0° slant was the frontal-parallel position. The total angular views for each shape, regardless of slant, were 80° , 48° , 21° for the Group I and 71° , 24° , and 14° for the Group II triangles.

A seventh display was constructed: 512 random triangles were also cut from heavy-duty vinyl contact

paper. These shapes were randomly rotated through an arc of 90° centered on North and were randomly distributed within a construction grid over a sheet of transparent Plexiglas (see Fig. 1A). The heights of the triangles varied from .16 to 1.45 in., with a mean height of .64 in., and a standard deviation of .16 in. The shapes varied from acute to obtuse, there being no isosceles triangles in the sample and right triangles being low-frequency shapes. The shape-parameters tended to be normally distributed; those of rotation and distribution, rectangularly distributed. This textured surface was viewed under 3 different fields of view: 82° , 40° , and 22° , and could also be rotated on its horizontal axis to any one of the six slants described above. The method of presentation was the same as for the triangles described above.

The sheets of Plexiglas were placed 8 in. in front of a 25-W Sylvania zirconium point-source, at a distance of 27.5 in. from a 7 x 7 ft. translucent Plexiglas projection screen. By shifting the mount in which the Plexiglas sheets were placed each triangle could be located so that it was normal to the light and parallel to the screen. The total angular view of the shapes was controlled by diaphragms in front of the point-source and in front of the viewing position.

Fig. 1. A. array of random triangles. B. schematic representation of the relative dimensions of six obtuse planar triangles.

The Plexiglas sheets could be placed at any one of the several slants indicated above. The projected shapes, at a distance of 35.5 in. from the S, were monocularly viewed through a special eye-piece that minimized parallax head movement. This projection method eliminated binocular cues and controlled for accommodation. (See Flock, 1964a, for a more detailed description of the method.)

Procedure

Thirty-six undergraduates at Dartmouth College and 12 undergraduates at York University, all with 20/20 uncorrected vision in at least one eye were subdivided into 3 groups. Group I at Dartmouth (N=18) was assigned to the three 2.8:1 triangles and Group II at York (N=12) to the 2.5:1 triangles. Group III at Dartmouth (N=18) was assigned to the 3 fields of view of the textured surface. Each set of 3 conditions was presented at the 6 slants, generating a total of 18 judgments from each S. The order of presentation of the 3 conditions assigned to a group was counterbalanced within each group, whereas the order of presentation of the sequence of slants was randomized.

Each S was required to examine a slanted shape or surface and "from your impression of its slant" was required to rotate a dial to that angle of rotation which exactly matched the angle of slant of the display. Ss were specifically told to make their judgments on the basis of appearances and were warned not to try to infer the slant.

A S's sequence of slant judgments over a shape or over a field of view of the surface was reduced to a regression coefficient, b , in other words to the linear component in his distribution of slant judgments; and to Kendall's Tau (τ , Siegel, 1956), a measure of the data's monotonicity and therefore a rough measure in this case of their linearity. For each S there were 3 b s and 3 τ s.

Median b s and τ s (and their associated measure of variability, Q , the semi-interquartile range) were used to describe the effect of a shape or of a field of view on a group. Median coefficients of 1.0 indicated that the judgments were optimally accurate (in the case of b), perfectly monotonic, and approximately linear (in the case of τ). Median b s and τ s of 0 indicated that the judgments were at a chance level.

Results²

The median b s for the 3 Dartmouth triangles (75°, 42°, and 19° in angular height) and for the 3 York triangles (55°, 20°, and 10° in angular height) were: .02, -.01, .12, and -.02, 0, -.01, respectively. The Q s were: .26, .28, .14, and .24, .08, and .12, respectively. The τ s (and Q s) were: -.04, (.44), .03 (.37), .07 (.20), and -.07 (.50), .00 (.14), -.04 (.20), respectively. With all the median b s and τ s at chance level these data unequivocally imply that not all planar shapes, and certainly not some triangles, regardless of their angular size, elicit appropriate slant judgments.

The data for the surface textured with triangles yield a somewhat different story. For the 3 fields of view of 82°, 40°, and 22°, the median b s were .70, .20, and .09, respectively, with 18, 16, and 11 positive b s, the first two of which have $p < .001$. The Q s were .22, .22, and .14; the τ s (and their Q s) were .83 (.10), .40 (.20), and .17 (.26), respectively. It would seem, therefore, that arrays

of triangles elicit appropriate slant perceptions even though the individual elements of the array do not.

In this experiment the change in field of view was correlated to numbers of visible triangles. When the surface was at 30° slant, 139 triangles or bits of triangles were visible to the 82° view; 24, to the 40° view, and only 7 to the 22° view. When the surface was frontal there were 39, 21, and 6 visible elements to the 3 views, respectively. The small number of triangles visible at 22° and 40° could have accounted for the relatively inaccurate judgments at those views. Nevertheless, whether view, number, a combination or interaction of both was the contingent factor in the b of .70, arrays of triangles will elicit relatively accurate judgments of slant, even though individual triangles will not.

Discussion

If the finding that individual triangles carry no information about their slant orientation is general to all triangles it raises some problems for theories of space perception. Those theories have too often been generated from investigations with single shapes like rectangles and circles to explain the perception of man's artifacts rather than the perception of man's natural world. For example, the Helmholtzian theory of space perception places undue emphasis on the veridical perception of slanted rectangles (Flock, 1964b), which are not a commonplace in nature, and too little emphasis on the veridical perception of, for example, slanted triangles which, in various forms, are found more abundantly in nature (e.g., in mountain peaks, in hills, in the configuration of trees, in leaves, in blades of grass). If natural shapes, of which the triangle may perhaps be representative, carry information about their spatial disposition only when in an array, as the above experiments suggest, perhaps some of our theorists of space perception should reconsider their axiomatic assumptions.

References

- Flock, H. R. Three theoretical views of slant perception. *Psychol. Bull.*, 1964b, 62, 110-121.
- Flock, H. R. Some conditions sufficient for accurate monocular perceptions of moving surface slants. *J. exp. Psychol.*, 1964a, 67, 560-572.
- Flock, H. R. Optical texture and linear perspective as stimuli for slant perception. *Psychol. Rev.*, 1965, 72, 505-514.
- Siegel, S. *Nonparametric methods for the behavioral sciences*. New York: McGraw-Hill, 1956.

Notes

1. This research was supported by the National Science Foundation Research Grant No. GB 2474 and by the National Research Council of Canada Grant No. APA-143.
2. The tables of raw data from which these statistics were calculated may be obtained free of charge from Psychonomic Press, Box 38, Goleta, Calif., 93017. Document No. VI-8-1.