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CHANGES IN PERCEIVED SIZE OF ANGLE AS A FUNCTION OF ORIENTATION IN THE FRONTAL PLANE[1]

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Continuous subjective bisection of a right angle rotating through 360° in a frontal plane was performed by 10 Ss using the Békésy technique. The largest and most consistent constant errors in bisection, ranging up to 10°, occurred in upper-right and upper-left quadrants. Interindividual and interquadrant differences indicate that the constant errors cannot be attributed solely to the effect of the main axes of space. An influence of the distribution of oriented contours in Ss' normal visible environment is suggested.

Many studies have demonstrated that perceptual space is anisotropic, as evidenced by the fact that either the position or the orientation of objects in space make a difference in the way *S*s perceive their spatial magnitudes. These effects can be described as *position ordered* or *orientation ordered* to characterize the condition under which varying perceptions of a particular spatial magnitude (length, size, shape, area, angular extent, etc.) are obtained. A familiar example of an orientation-ordered effect is the vertical-horizontal illusion. Vertical lengths are overestimated in reference to horizontal lengths. The effect, however, is not limited to the vertical and horizontal. Pollock and Chapanis (1952) reported orientation-ordered asymmetries in the length of a line matched to a horizontal standard: The test line was presented every 10° from 10° counterclockwise from vertical through the upper right quadrant to 10° clockwise from horizontal. The effect of orientation on the perception of spatial magnitudes other than length has also been studied. Extensive experiments by Rogers, Volkmann, Reese, and Kaufman (1947) demonstrated that the errors of perceived inclination of a line in the frontal parallel plane were orientation ordered. In one experiment *S*s were required to set a line to a specified bearing; in another, they were asked to report the bearing of a presented line. The results indicated small but stable, orientation-ordered errors. Onley and Volkmann (1958) demonstrated that the accuracy and consistency of settings to perceived perpendicularity are orientation ordered. In their experiment, the most thorough investigation of this variable to date, stimulus figures composed of two line segments forming "X," "T," and "L" were presented in a frontal plane and *S*s were required to set the variable segment perpendicular to the fixed one. The fixed segment was presented in meridional orientations ranging from 000 to 358. Systematic constant errors in the settings as well as differences among individuals, were observed. Most of these orientation-ordered effects have been attributed to the anchoring influence of the main

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coordinates of space (up–down and right–left) on spatial judgments.

Many other studies with orientation as the major variable have been performed. In general, these studies have concentrated on a few particular orientations or set of orientations (mainly in the upper-right quadrant) to study specific effects demonstrable with large groups of *S*s. We have attemped to determine the orientation order in judgments of the size of an angle using a method that allows inter-*S* comparisons and generates a continuous function over 360 meridional degrees. This report describes the technique developed for these purposes and the results obtained.

Method

A psychophysical technique was adapted from Békésy which, in essence, consists in automatically recording a continuous series of responses to a continually changing stimulus (Békésy, 1947). The *S* served as a null instrument and made continuous "yes" or "no" decisions concerning deviations from equality of two angles as they changed orientation in the frontal parallel plane. Complementary angles were chosen as stimuli for this experiment. The *S* sat comfortably while chin and brow rests helped maintain his head position. Appropriate shielding limited vision (binocular) to the stimulus field which was 11.5 in. in diameter and 76 in. in distance. Three lines, each .12 in. wide, appeared as radii in the field. Two of the lines formed a right angle and were painted on a translucent glass disk which could be rotated in *S*'s frontal parallel plane at a constant velocity (53.3°/min) around its center. The third line, which normally appeared to divide the right angle into complements, was painted on a clear glass disk placed just in front of the translucent disk. The clear disk could be rotated around its center coaxially with, but independently of the disk carrying the right angle. The *S* controlled the direction of rotation (clockwise or counterclockwise) of the dividing line with a two-position microswitch. The speed of the line (2.0°/sec) was practically constant with respect to the right angle. In operation, the room was darkened and a single 60-w. incandescent bulb, operated at 50-v. ac and placed 5 in. behind the glass disks provided radially uniform transillumination of the field (8.3 ftl.). The *S* was instructed to allow the dividing line to rotate in one direction until one complementary angle was seen as larger than the other at which time he was to reverse the rotation. The midposition of the line between successive reversals then represented subjective equality of the angles, i.e., subjective bisection of the right angle. The *S* was instructed not to adopt any sort of rhythm in switching but to watch the size of the angles carefully and to rotate the dividing line accordingly while fixating a small gap 2.6 in. from its center of rotation. The *S*s were trained for a number of sessions, during which the instructions were repeated, until consistency in the task was achieved. The *S* then had five experimental sessions each consisting of four complete rotations of the right angle (two clockwise and two counterclockwise) separated by 5 to 10 min. rest intervals. The results from each *S* were found stable over intervals between trials as long as several months. Ten undergraduate students (2 male, 8 female) served as *S*s. All had normal acuity either with or without correction.

The rotations of the dividing line, following the switching responses of *S*, were recorded by a pen that moved at right angles to the movement of the chart paper on a Grason-Stadler recording attenuator. An event marker at the side of the chart recorded calibrated orientations of the right angle. The midline of the chart was the reference for zero deviation, i.e., objective bisection of the right angle. The dividing line rotated back and forth within the rotating right angle and when *S*'s judgments of equality agreed with objective equality, a zig-zag line was drawn centered around the midline of the chart paper.

Results

The data were combined in a simple manner: A line was fitted by eye connecting the midpositions between reversals along each chart trace generated by *S*. The eye-fit lines for the data curves of each *S* were then traced onto a single chart. Examples from a typical *S* are shown in Fig. 1. Each line is a tracing from one data curve and the consistency among the lines is clearly seen. The two mean curves obtained from the

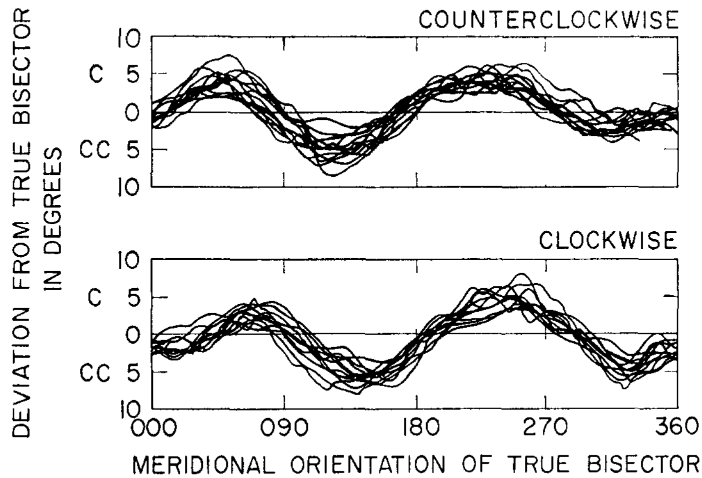

FIG. 1. Smoothed tracings of responses from a typical *S* during counterclockwise and clockwise rotations. (Orientation reads from 000 clockwise to 360.)

10 curves for clockwise rotation and the 10 curves for counterclockwise rotation were then calculated. These curves are shown in Fig. 2. The two curves for each *S* appear to differ in most cases only by a phase shift of approximately 20°. This shift was apparently produced by a lag in *S*'s response to the changing appearance of the angles. In a different experiment, subjective bisections made with a static right angle, but with a moving divider, were found to approximate the mean of the two values obtained at the same orientation during clockwise and counterclockwise rotations of the right angle. The data are plotted with the orientation of the true bisector on the abscissa. When the curve is above the zero difference line, the more clockwise angle was made objectively larger than the more counterclockwise angle by *S*, thereby implying that of two equal complementary angles of the same orientation the more clockwise would have appeared smaller.

The data show consistencies among *S*s, particularly in the orientations at which the peak deviations occur. In general, the angle nearer the horizontal is made smaller. The mean differences between angle settings vary with orientation, average more than 5°, and, with some *S*s, exceed 10° at the two most consistent peaks near 045 and 315. Subjective equality tended to agree with objective equality when the right angle was close to being centered around the vertical and horizontal axes. However, small but significant deviations from these axes predominated at subjective equality.

Discussion

Interpretation of this data in terms of the presumed influence of the main coordinates of space (up–down, left–right) is inadequate for two reasons. The first involves the stable differences among *S*s detectable in the data curves. Clearly, individual differences are important in orientation-ordered effects and they are reliably measured with the technique used. The second reason involves the spatial asymmetries in the data. The upper half of the field tends to be unlike the lower, the left side unlike

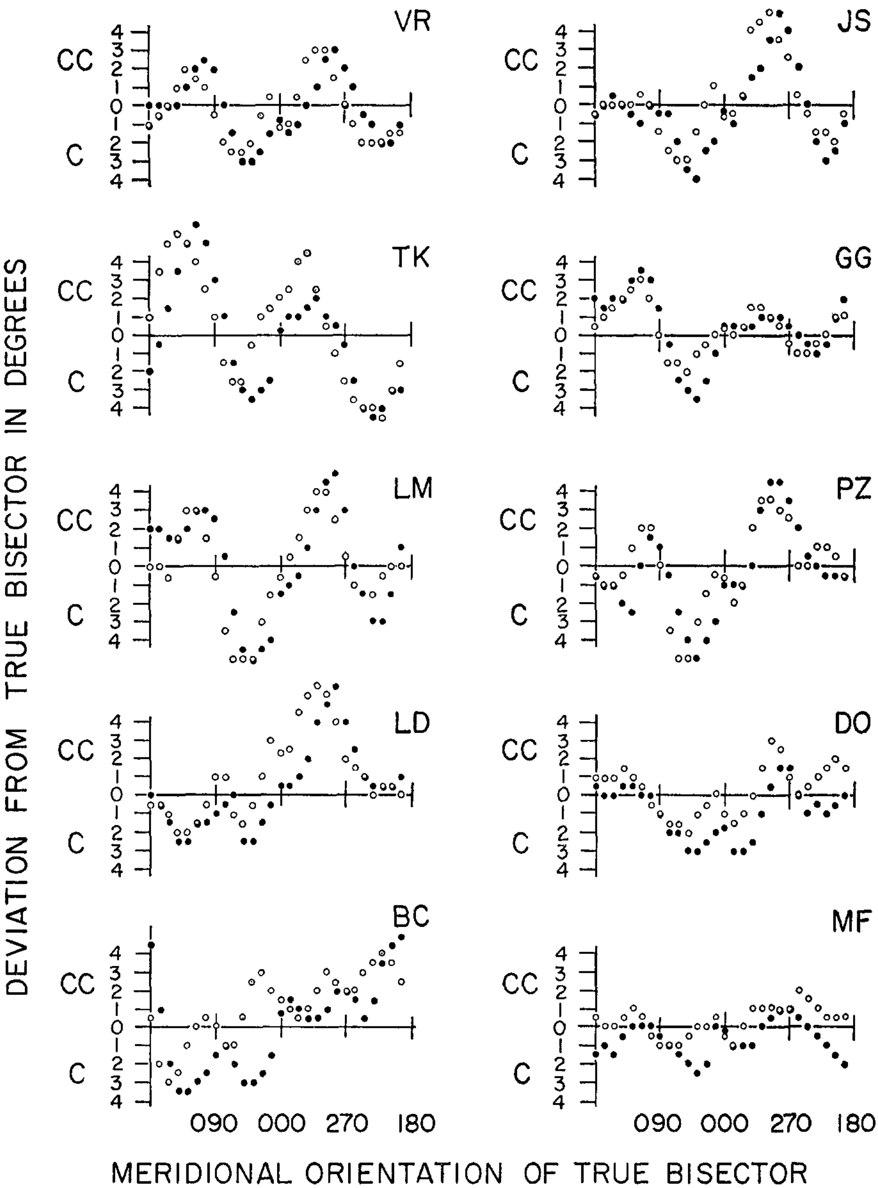

FIG. 2. Averaged responses of individual *S*s. (Each point is the mean of 10 chart-traced values at the given orientation. Open circles represent clockwise runs; closed circles, counter-clockwise runs.)

the right, and the quadrants tend not to resemble each other. On the other hand, there is good agreement among *S*s on the orientation of the two peak differences centered around the vertical (000), suggesting a common factor. Although data were not available on the refractive status of all *S*s' eyes, it is unlikely that refractive errors could account for either the magnitudes of the size differences in individual *S*s or the agreement among *S*s.

Some attribute or set of attributes inherent in the stimulating environment may contribute to the generality of this orientation-ordered effect and to other spatial anisotropies found in studies of perception. One such attribute is the density distribution of contours in the visible environment. Brief studies of our own indicate that the normal orientation-ordered effects can be increased by prolonged exposure to a field of parallel lines, i.e., an environment with a markedly atypical distribution of oriented contours. Kohler and Pissarek (1960) demonstrated changes in the vertical-horizontal illusion after *S*s had worn lenses with meridional magnification. These findings coupled with the present data, are presumptive evidence for the existence of an asymmetric distribution of contours in the normal environment of city-dwelling *S*s. They suggest that a greater density of contours occurs within a sector at or near horizontal than in any other sector. If this presumption is correct, considerable differences in the perceived size of angles, and by implication, in other size perceptions, are produced as a function of exposure in natural environments. Some of the intercultural differences in size of spatial illusions may result from exposure to differing visible environments (Segall, Campbell, & Herskovits, 1963).

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