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ECOLOGICAL OPTICS AND VISUAL SLANT[1]

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Flock's "A Possible Optical Basis for Monocular Slant Perception" is criticized as being a theory of stimuli rather than a theory of perception. To account for accurate monocular slant perception, the theory requires 9 assumptions, including the unproved ability of the eye to register random texture density. The alternative hypothesis is proposed that monocular visual slant is a function primarily of contour perspective which varies with the size, shape, and viewing distance, as well as slant, of plane surfaces.

Flock (1964a), in a recent paper, elaborates on Gibson's (1950, 1959, 1961) gradient concept which relates visual ecology to retinal stimulation. Assuming that "slant perceptions . . . depend on optic variables [p. 391]," Flock presents an analysis of "optic variables" arising from textured, slanted surfaces. The arguments of this note are that the principal part of Flock's theory is not a theory of perception but a description of visual stimuli, that the casually mentioned "abilities" of the eye to register the proposed visual variables of surface slants involve an inordinate number of assumptions for what they accomplish, and that the visual variables chosen for description in the paper have already been experimentally demonstrated to be ineffectual and unnecessary for the perception of slant. An alternative stimulus for visual slant is suggested.

ECOLOGICAL OPTICS OF SLANT

The purpose of Flock's paper is to show how

> . . . *accurate* monocular slant perceptions are possible even though a motionless viewer has no previous experience with a particular substance, even though the textural elements of a motionless surface are irregular in size, shape, and separation, and even though parts of the surface are illuminated differently [Flock, 1964a, p. 380; italics, mine].

Flock attempts to accomplish this goal by describing a trigonometric transformation of surface elements which remains invariant with variations in stimulus conditions other than physical slant. His analysis is primarily an ecological description of the optics of slant: a description of the transformations which light reflected from real, planar surfaces undergoes in projection as it converges on the observer's eye.

His analysis is based on two postulates. Postulate I states that "substances" (presumably surfaces) of a certain class possess a unique pattern characteristic of that class. Postulate II states that such patterns consist of "like elements" which vary randomly in size, shape, and separation. Flock thus allows for variability in the distal stimulus, but the variability is counterbalanced by dividing the textured surface into linearly equal units of *n* like elements. Somehow it is argued that the larger the unit, and hence the larger the *n*, the greater the regularity.[2] It is not explained how the eye can register such a unit of *n* like elements from among a

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[2] An equation is presented for "degree of regularity" of like elements which has some peculiar properties. Regularity is made an inverse function of the variability of element size but a direct function of both average size and total number of like elements. Equation 4 has the result that stimulus elements of very high variability can have a high degree of regularity if there are enough of them. Conversely, if the *n* is small compared to *s*, negative regularity can result.

continuously variable series of like elements.

Flock then attempts to make "optical slant" a function of the relative projective angles of three such linearly equal units which are separated by equal visual angles perpendicular to the axis of apparent rotation. This is where Flock's optical theory of slant encounters its greatest trouble. It can be easily shown that the angular subtense of any three distances of equal length parallel to the axis of rotation of a plane surface changes in a complex fashion with rotation of the surface. This fact suggests that the texture gradient at the eye arising from elements scattered about a plane surface will not be a simple one and will vary with size, distance, and other variables, as well as slant (cf. Freeman, in press—b).

But, assuming that slanted, planar surfaces are perceived as slanted, planar surfaces at their true slant, Flock argues that there must be something in the stimulus situation which yields such a veridical perception. His Equation 5 represents an effort to turn a complex stimulus into a simple one so that the eye can have a simple percept. Equation 5 expresses the variation in visual angle subtended by a single unit of "optical *n*" with variation of visual slant ("optical *theta*") of the distal surface. Although the derivation of Equation 5 is not made available, it has the property that optical *theta* is invariant with the number of optical units involved in directions both parallel and perpendicular to the axis of rotation. Thus optical *theta* must be unrelated to the size of the plane surface. This requirement makes necessary a very complex equation of a form unknown to psychophysics. As will be shown below, such a complex function is unnecessary.

FLOCK'S PSYCHOPHYSICAL ASSUMPTIONS

Flock has argued for a potential visual stimulus for slant in the manner in which Gibson (1961) has presented a general description of "ecological optics" of the visual environment. But in presenting a potential visual stimulus, he must also postulate a potential sensory system to respond to the potential slant stimulus or optical *theta*. To do so, nine assumptions are required (Flock, 1964a, pp. 382, 389), the last of which is that the visual system registers texture in a manner conforming to Equation 5. Among other things, the eye is required to choose an appropriate optical *n* for each optical unit according to an additional set of four rules (Flock, 1964a, p. 384). With 13 assumptions and criteria involved, Flock's *psychophysical* theory of optical slant is complicated indeed. No suggestions are made as to *how* the visual system might be expected to bring about such a complicated analysis.

NEGATIVE EXPERIMENTAL EVIDENCE

Aside from the theoretical complexities of optical *theta* there are several experimental objections to the theory. Flock (1964b) himself has already provided evidence that the optical registration of motionless texture is poor. In his Experiment IX, using the Gibson-type shadow caster and an electrostatic texture, subjects adjusted a protractor to indicate the apparent slant of a 69° field of texture gradients corresponding to nine different physical slants at 10° intervals from − 40° (top toward the subject) to + 40° (top away from the subject). Flock regrettably gives the results in terms of the regression of the subjects' judgments of slant on the slant of the shadow caster rather than plotting the former as a function of the latter in the usual fashion. But these data are sufficient to show the poor psychophysical correspondence involved, insofar as the mean regression coefficient in Experiment IX was only .13 as compared to 1.12 in Experiment VIII in which motion-parallactic cues were available with the identical stimulus situation. The gradient arising from random texture at a slant is an inadequate stimulus for visual slant for the motionless observer.

If texture gradients are not effective stimuli for slant, what other proximal stimuli are available? An earlier experiment (Clark, Smith, & Rabe, 1956) had compared the relative effectiveness of texture gradients and "outline gradient," or perspective. In their report, Condition B was a randomly textured surface slanted at 40° viewed through a 6-centimeter reduction hole, while Condition C was a *textureless* rectangle (with the same solid-angle area as the hole in B) on a black background, also at 40° slant. Judged slant in C was significantly greater than in B. Judged slant in Condition E, which *combined* texture and outline perspective, was *not* significantly greater than in the textureless-rectangle condition. According to the results of Clark et al. (1956), outline perspective has a significantly greater effect on judged slant than texture gradients. And when combined, outline dominates as a visual stimulus. Another experiment (Gruber & Clark, 1956) varied both size and texture density of random-dot patterns as well as the distance of the observer. Observers greatly underestimated the three different surface slants used. Furthermore, both surface texture and observation distance had significant effects on judgments. These results are clearly inconsistent with the concept that "accurate monocular slant perceptions are possible even though . . . the textural elements of a motionless surface are irregular in size, shape, and separation . . . [Flock, 1964a, p. 380]."

Finally, prompted by a finding by Stavrianos (1945) that the judged slant of rectangles of constant shape varies with their size, this writer (Freeman, in press—a) conducted a parametric study to determine whether the size effect could be attributable to outline perspective. Textureless rectangles of sizes ranging from 8–40 centimeters in length were viewed monocularly under complete reduction conditions at a distance of 135 centimeters. With a 24-centimeter reference rectangle, equal-slant contours were obtained for five slants (15°, 30°, 45°, 60°, and 75°), both forwards and backwards. The size effect on judged slant was large and highly significant in most of the curves. Since outline perspective of slanted rectangles varies with the width and probably height, as well as physical slant, of the rectangles, the size effect appears to be a function simply of projective outline shape.

CONTOURS—PRINCIPAL STIMULI FOR SLANT

In addition to the behavioral studies mentioned above, there is mounting evidence that the vertebrate visual system is "tuned" to register contours (abrupt brightness gradients). In addition to the extensive investigations of Hartline and Ratliff (e.g., Ratliff, 1961) on the inhibitory interactions of the lateral eye of the arthropod *limulus*, there are the discoveries of neural boundary detectors in the optic tract of the frog (Maturana, Lettvin, Pitts, & McCulloch, 1960) and in the visual cortex of the cat (Hubel & Wiesel, 1962). The combination of behavioral and electrophysiological evidence cited above makes possible two general postulates which are in disagreement with Flock's optical texture gradient hypothesis:

1. With monocular observation, visual shape and visual slant are a function primarily of linear outline perspective.
2. The greater the numerical value of linear perspective, the greater the judged visual slant and the greater the effect on judged shape.

The second postulate implies that apparent slant will vary with perspective, whether or not perspective is a true function of physical slant, and with or without nonlinear (random) surface texture. Since outline perspective varies with the shape, size, and distance of a plane surface as well as with slant, the apparent slant of stimuli so varied, when viewed monocularly with a motionless head under complete reduction conditions, must also vary, Flock's optical *n* notwithstanding.

The contour hypothesis therefore does not predict veridical judgments of slant, in the sense of judgments which are consistent with physical rotation relative to a fixed observation position. On the contrary, it says that visual slant will vary with variation in the projective character of stimulus contours at a slant to the visual axis, regardless of the environmental source of such variation. It is an explanation based, not on optical ecology, but on retinal stimulation. It is, finally, a theory of perception, not a theory of stimuli.

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