THE PERCEIVED SLANT OF VISUAL SURFACES—OPTICAL AND GEOGRAPHICAL [1]

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One of the properties of a visual surface along with hardness, distance, and color-with-illumination, is that of slant. This term must be understood to include not-slanted as well as slanted; in other words the variable consists of opposite qualities having zero slant as a norm. There is evidence that *optical* slant, so-called, is determined by stimulation. When vision is monocular and the head is motionless, this quality seems to depend on the gradient of the density of the "texture" of the retinal image (1). The experiment which appeared to demonstrate this psychophysical correspondence, however, is defective in that the procedure failed to isolate the quality of optical slant from a congruent quality of *geographical* slant which accompanied it. This failure should be amended if possible. Moreover the two kinds of slant need to be defined and their relevance to space-perception discussed.

Consider first the impression of slant embodied in the face of an object—a bounded surface, or a segment of an array of surfaces. It can be studied in the following situation. The *O* sits in an ordinary room with his gaze horizontally straight ahead and fixates the center of a surface such as a sheet of textured cardboard. This surface is then rotated by *E* around a horizontal axis, either forward or backward. The quality of slant will increase as rotation increases, either ceilingwise or floorwise, until just after reaching the greatest possible slant the surface suddenly becomes an edge (**3**). Putting aside the question of change in shape, this situation provides variation in slant without variation in distance or any of the other qualities of a surface. It also shows that the quality of slant has an upper absolute threshold at the point where the surface becomes parallel to the line of sight. It should be noted, however, that in this experiment the inclination of the surface to the line of sight is so arranged as to have the same value as its inclination to the physical horizontal.

Consider next the impressions of slant embodied in a continuous plane surface filling most of the visual field. Take as an example the visual experience of a man standing on a level desert plain and looking about. This example is particularly significant since it is a kind of minimum perception for any sort of spatial behavior.[2] What he sees is a level ground extending to the horizon with himself standing on it. No impression of slant seems to be evident. But this perception of the earth is almost certainly a product of the integration of successive eye-fixations (**2**, ch. 8). Ordinarily the man is unaware of his saccadic eye-movements, but if he attempts to in-

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[2] The man must confine his gaze to the ground instead of looking upward into the sky if he is to have the kind of space perception with which we are concerned. He must see a surface. This earthbound experience makes a better starting point for psychological theory than the ethereal void of classical space-perception.

trospect, he may discover that every fixation yields a clear momentary impression of a small segment of the ground which *does* have a kind of slant. As he looks downward toward his feet the slant approaches zero, as he looks upward the slant increases, as the center of clear vision approaches the horizon the slant becomes maximal, and at the horizon itself the land ceases to be a surface and becomes an edge.

The varying impressions of slant in this case are somewhat analogous to those obtained with the rotating segment of surface but there are several differences. In this situation increasing slant is accompanied by the impression of increasing distance. In this situation the momentary impressions of slant quickly add up to the experience of a single surface perpendicular to gravity, whereas in the former situation they integrate to the experience of a rotating object. In this situation the total perception is a product not only of successive retinal images but almost certainly of correlated postural-gravitational stimuli as well. Finally, in this situation the optical slant of the surface at the point of regard is not congruent with the geographical slant of the surface in the visual world. The two kinds of slant must obviously be distinguished. Optical slant seems to be a more abstract variable of experience, whose importance probably consists in being determined by fewer variables of stimulation.

The psychophysical experiment on the stimulus for optical slant already referred to (1) utilized in principle the rotating object situation with the line of regard horizontal and straight ahead. The gradient of texture-density of a single retinal image was systematically varied by increasing the density in either an upward or a downward direction and the quality of slant was found to increase in either a floorwise or a ceilingwise sense. The edges and therefore the shape of the surface were eliminated by presenting it behind a circular window in an upright screen, and accommodation for the surface was held constant by substituting for it a projected image on another translucent screen. The objection can be made that *O*s were really judging geographical slant, not optical slant. It is important, therefore, to perform an experiment in which optical slant must be perceived separately and in which the theoretical distinction between the two is verified by two different sets of discriminative judgments.

The ideal test for the theory of two kinds of slant would be to eliminate postural-gravitational stimulation entirely and determine whether the impression of optical slant remained. In the absence of a laboratory outside the earth's gravitational field, an adequate apparatus would be a spherical room falling freely in an elevator shaft, but this also presents difficulties. All the experimenter can do, therefore, is to arrange matters to produce an *incongruency* between the reference-axes of the eye itself and the reference-axes of the experimental room. He can then discover whether (*a*) the two kinds of slant are separately perceived and whether (*b*) the retinal density gradient will determine the impression of optical slant but not the impression of geographical slant.

Slant may be said to vary along one dimension from floorwise to ceilingwise and along another dimension from right-wallward to left-wallward. Although these terms are geographical, they may also be used to describe the dimensions of optical slant, which has reference only to the up-down and right-left directions of the retinal anatomy. In this terminology, slant must not be confused with what the writers prefer to call *tilt.* This is a third and different kind of phenomenal inclination—a clockwise or counterclockwise rotation of a surface with respect either to the up-and-down axis of the retina or to the gravitational vertical. Although this phenomenon is important and has been much investigated, it is outside the scope of the present paper.

Method

The hypothesis is that an impression of optical slant will be in correspondence with the direction of increasing texture-density in the retinal image when an accompanying impression of discrepant geographical slant is not in correspondence with it. Each *S* sat squarely in the experimental room with his head turned 45° to the left and fixed in a headrest set at a 45° angle to the walls of the room. He faced a vertical gray cardboard screen in which a circular window 17.5 cm. in diameter had been cut at eye-height. The plane of this screen was parallel to the back wall of the room, and at 45° to the line of sight. The center of the window was 50 cm. distant from the eye used for observation, which yielded an elliptical field of view 20° in height and somewhat less in width. Vision was monocular.

Through the window, at a further distance of 73 cm., *S* saw a textured surface mounted on a panel which could be rotated around a vertical axis over a considerable range without the edges of the panel becoming visible. The surface could be set either perpendicular to the line of sight (but at 45° to the screen and to the far wall of the room) or parallel to the screen and room (but at 45° to the line of sight). The task of *S* was to judge when the surface reached one of these two normal positions as the panel was slowly rotated by *E*, using a modified method of limits.

In the former position, perpendicular to the line of sight, he was discriminating optical slant. In the latter position, perpendicular to the axis of the body and room, he was discriminating geographical slant. In order to set the variable surface at its optical norm, *S* had to detect and eliminate any gradient of texture-density in the retinal image, either from right to left or from left to right. In order to set the surface at its geographical norm there had to be a strong gradient of density in the retinal image. Whatever the stimulus complex for this impression may be, if he has it, it is not a zero gradient of density.

As a control, each *S* was also required to judge the position of zero slant when the window and the center of the variable surface were straight ahead of the eye and the setup was square with the room. The norms were then congruent instead of discrepant. In the latter condition the window made a 20° circular projection in the visual field whereas in the former condition it made an elliptical projection.

TABLE 1

Accuracy of Judgments of Slant in Degrees with Surfaces of Irregular and Regular Textures

Condition	Irregular Texture (N = 10)		Regular Texture (N = 10)	
	Mean *SD*	Mean CE	Mean *SD*	Mean CE
Optical norm	5.8	3.9 R	4.4	4.4 R
Geographical norm	10.6	4.3 L	3.6	2.1 L
Congruent norms	6.1	.01 R	2.2	0.9 R

Ten judgments were obtained from each *S* on the norm of optical slant, ten on the norm of geographical slant, and ten more on the normal position when the two were congruent. Half of each set were ascending and half descending judgments, beginning from five randomly selected starting points on either side of the norm. The *E* rotated the panel until told to stop by *S*, but then permitted the rotation to be reversed or advanced until *S* was satisfied. Ten college student *S*s were used, the conditions of the experiment being counterbalanced among them.

The texture of the variable surface in this experiment consisted of a mottled black-and-white bookbinder's paper, without regular pattern or alignment of the elements. This was the *irregular* texture. The entire experiment was then repeated with ten new *S*s using a wallpaper composed of a complex plaid pattern having wholly linear and rectangular elements. This was the *regular* texture.

Results

The consistency and accuracy of the perceptions of slant are given by the standard deviations and constant errors of the judgments, the former being the better measure. As may be seen from Table 1, the mean *SD* of the judgments of ten subjects was about 6° for optical slant and about 10° for geographical slant. These values might be considered as rough absolute thresholds for the detection of the two kinds of slant in this situation. It is evident in the first place that the two can be perceived independently. The constant errors do reflect a tendency for the optical norm to be somewhat deflected toward the geographical norm and vice versa, but since the two are 45° apart the conclusion is nevertheless safe. When the norms are congruent, it may be noted, the threshold for slant does not greatly decrease (it is significantly lower than the geographical threshold but not lower than the optical threshold) but the constant error vanishes.

These data refer to the irregular texture. For the regular texture the results are also given in Table 1. In the case of this surface all judgments tend to be somewhat more accurate. Both optical slant and geographical slant are here significantly more consistent when their norms are congruent than when they are discrepant. The superiority of the optical over the geographical perceptions fails to appear in this experiment and they are not significantly different. The constant errors, as before, suggest that the two norms mutually attract one another when they are discrepant but that nevertheless they can be clearly distinguished and that deviations from them can be separately discriminated.

Conclusions

The experiment shows that the two kinds of slant with which we are concerned can be distinguished by an ordinary observer in the situation described. There seems to exist a purely visual impression of slant for the segment of surface fixated which is dependent on its geometrical relation to the eye, not on its relation to other parts of the world or to gravity. The hypothesis that this quality corresponds to the gradient of density of "texture" at the fovea becomes reasonably certain. It has been demonstrated that when the head and eye are turned to one side a zero gradient of density yields a zero optical slant but a 45° geographical slant. It was already known (and confirmed here) that when the eye is pointed straight ahead a zero gradient of density will yield a zero optical slant and a zero geographical slant. It is therefore shown that optical slant corresponds to the gradient of density but that geographical slant does not. The implication of the earlier experiment on slant-perception (1) is upheld.

To what complex of stimuli, then, *does* geographical slant correspond? The impressions of geographical slant obtained were definite rather than ambiguous and hence probably determined by stimulation. This experiment does not give the answer, but it suggests that the angular rotation of the head and eye relative to the body has something to do with the question. A reasonable hypothesis would be that the postural-kinesthetic stimulation which goes with the turning of the head and eye is correlated with the retinal stimulation which yields optical slant, and that the two jointly determine geographical slant.

The question is, once we accept the density-gradient formula for optical slant, why does the perception of the geographical slant of a surface remain constant when the line of regard intersects it at varying angles? Why does a wall have the same slant when one looks 45° to the left as when one looks straight ahead? Why does the earth appear level as we lift our eyes from our feet all the way out to the horizon? The question is not simple, but the key to the answer may prove to be this: when there is a *compensatory relation* between the angular rotation of the eye and the angular optical slant, the perception of geographical slant remains constant. This would mean that when the eye rotates to the left and the density-gradient toward the right-hand side of the retina becomes steeper (and if the product of these two variables is invariant), the perception of objective slant will be constant. Conceivably, this is why we see a level terrain as such.

According to this theory the situation of a man who stands on a physically *sloping* terrain is a special case. If he looks up or down the slope he perceives *slant* in our terminology; if he looks athwart the slope he perceives *tilt*. In this case the geographical perception is subject to illusions. The ordinary correspondence between the posture of the eye and the density gradient (or tilt) of the image has here been altered; there is a discrepancy or conflict of cues. The situation is important to understand, but it should not be confused with the basic one in which the covariance of postural and retinal stimulation seems to yield a stable and upright visual world.

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References

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