Notes and Comment

The priority of perceived distance for perceiving motion has not been demonstrated: Critical comments on Gogel's "The sensing of retinal motion"

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In a recent article in this journal, Gogel (1980) argued from two experiments that motion parallax is a result of perceptual underestimation of depth between objects. Gogel also made the more far-reaching assertion that, without some perception of distance, the perception of motion would be impossible. In the present paper, we (1) challenge Gogel's conclusions about motion parallax, (2) criticize his assumption that distance perception is required in perceiving motions, and (3) consider implications for his previous attempts to infer apparent distance from measures of apparent motion (e.g., Gogel, 1977).

Why Motion Parallax?

Motion parallax is a set of apparent motions of stationary objects that results from a change in viewing position. You can see it by holding your index fingers at distances of 6 and 12 in. while swinging your head back and forth. When you look at the far finger, the near finger will appear to move against the direction of head movement; when you look at the near finger, the far finger will appear to move with the direction of head movement. Ordinarily, this apparent relative motion is consistent with a concomitant optical pattern of differential angular velocity existing between the line of sight to a fixated object and the line of sight to any other object in the visual field. Shebilske (1977) suggested, therefore, that motion parallax might be caused by sensing retinal motion. Gogel (1980) argued, instead, that we see motion parallax because we underestimate the separation between the objects that appear to move. He supported his position with two experiments suggesting that induced changes in apparent object separation lead to predicted changes in motion parallax. His experiments seem to contradict an explanation based on

sensing retinal motion, because, in several conditions, subjects allegedly saw motion in a direction opposite to retinal motion.

We think that Gogel's results were an artifact related to the paradoxical nature of motion parallax. When one watches one's fingers in the preceding demonstration, they appear to move without going anywhere. That is, one sees one's fingers in the same spatial location before and after one's head moves. If wooden dowels are substituted for fingers, one can point to them accurately before and after one's head moves, even though one sees apparent relative motion during the head movement. The paradoxical nature of motion parallax creates a pitfall that must be avoided in valid experiments. This pitfall is demonstrated by a hypothetical experiment. Imagine moving your head from side to side while viewing the farther of two wooden dowels. Suppose the nearer dowel moved from one spatial location, A, to another spatial location, B, during your head movement. The dowel's objective movement path would be distorted because objective motion and apparent motion combine vectorially (Hay & Goldsmith, 1973; Wallach & Frey, 1972). You would see the dowel's position accurately, however, before and after your head movement. What would you say, then, if we asked you to describe the dowel's movement? Unless we gave you special instructions to describe the *apparent motion path*, you might simply say that the dowel moved from A to B. Gogel's procedure brought his subjects to the brink of this pitfall, and we think they fell headlong into it.

Gogel used a line stimulus, and he induced an error in the perceived separation of the line's endpoints by stereoscopically changing the line's apparent slant. Gogel's subjects moved their heads back and forth along a track in the frontal plane, and they viewed the stimulus line continuously as their heads moved from one side of the track to the other, stopped, reversed directions, and returned to the other side. They traversed the track several times. Then, to describe what they saw, they turned to another line, mounted on a plate. In the first experiment, Gogel described his response procedure as follows:

In making a response, the observer first oriented the plate on which the response rod was mounted to the depth slant perceived in the line stimulus on the immediately preceding experimental trial. The observer then indicated the angle through which the line had appeared to rotate in the plane of this slant by adjusting the response to one extreme (limit) of this angle and then to the other, pausing so that the experimenter could record each extreme of

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adjustment. The observer repeated the rotation adjustments several times before the extreme rotational positions were recorded. (pp. 158-159)

This response procedure may have caused subjects to attend, not to the motion path (the motion parallax), but to the line's appearance at the extreme positions. With this set, subjects may not have even noticed the motion path itself. If they did, they may have seen an extremely complex motion path, especially when the induced rotation between the extremes was in the direction opposite to the motion parallax.

In a second experiment, subject's attention may have been drawn even farther away from the motion path itself: "In Experiment 2, the instructions made a distinction between the amount of perceived motion of the ends of the line and direct judgments of the angle of apparent rotation. This distinction was illustrated by means of a drawing and the observer was instructed explicitly to avoid using the magnitude of the perceived motion of the ends of the line in indicating the rotation perceived in the stimulus" (Gogel, 1980, p. 161). We think it is quite likely that subjects following these instructions would attend to the stimulus line's apparent orientation at the extreme head positions and ignore the stimulus line's apparent motion path during head movements.

One would do better to focus attention on the motion path itself by having subjects report the moment to moment velocity and direction. However, such measures would have to be taken with extreme caution because subjects are not used to describing paradoxical motions. We think such an experiment will support the hypothesis that motion parallax is a paradoxical sensation of retinal image motions.

Motion parallax is similar to an apparent motion that sometimes is seen during eye movements. A luminous stimulus viewed against a background of darkness appears to streak, smear, or jump in the direction opposite to eye rotation during voluntary saccades (Hill, 1972; Matin, Clyner, & Matin, 1972). This apparent motion is paradoxical in the sense that the stimulus appears to move without going anywhere. A stationary stimulus is accurately localized before and after an eye movement, even when it appears to move during the eye movement (Shebilske, 1977). Processes determining whether or not we see motion during eye movements are unrelated to processes determining our ability to see direction (cf. Shebilske, 1977). Similarly, processes underlying motion parallax may be different from processes underlying the ability to see an object's position in space.

We disavow any connection between our retinal motion hypothesis and the core-context theory (Boring, 1952). Gogel's attempt to tie retinal motion hypotheses to the more general core-context theory is misleading. Core-context theory suggests that motion parallax should increase as distance cues are reduced. We know of no advocate of a retinal motion hy-

pothesis who has ever suggested that motion parallax depends in any way on distance information. We certainly do not think it does. The next section presents our views on distance information.

Is Distance Perception Required for Perceiving Motions?

Gogel argued from his experiments that, without some perception of distance, the perception of motion would be impossible. Gogel's bold proposal is flawed in two respects: First, his testing procedures were inadequate and, second, even if we did not hold reservations about the testing procedures, the results do not support the theoretical claim that distance must be taken into account in perceiving motions. We address each of these problems, dealing first with the methodological issue.

Gogel failed to measure important parameters of what observers saw. A line viewed by a moving observer will be seen to have numerous parameters, and among these will be its pitch (slant in the median plane), roll (rotation or object-relative motion in the plane of the pitch), translation (common observer-relative motion), size (separation between endpoints), and distance (from observer to the centroid of the line). It may seem odd that we have included translation as one of the parameters; however, recognizing that the proximal information does not define a unique percept but, rather, specifies an indefinite set of possibilities, it can be determined that all but one of the possible descriptions of the event will appear to move laterally relative to the observer, as well as rotate. Gogel measured only two of the five parameters: perceived slant and rotation. Ideally, he should have measured the other three. We have already argued that Gogel's procedures did not provide adequate measures of the perceived motion path of the stimulus line. Measures of translation would have to be included in any satisfactory measure of apparent motion. Measures of perceived size would have tested Gogel's claim that subjects underestimated the apparent separation between endpoints of the line. Measures of perceived distance would have tested his implicit assumption that subjects saw the stimulus line at its actual distance of 100 cm.

However, even if Gogel had taken all the appropriate measures and had found that they agreed with his assumptions, we still would not accept his assertion that "perceived distance always is an essential component in the perception of motion" (Gogel, 1980, p. 155). Surely, if the perceptual system had taken distance into account, as Gogel asserts, then the perceived events would have had the motions that Gogel reported. However, *the motions reported could also have been based solely on motion information and principles of perceptual organization that make no use of distance information.* A likely candidate for such a rule of operation in perceptual organization is the minimum principle (Köhler, 1920/1938). Of the min-

imum principles reviewed by Cutting and Proffitt (Note 1), the one proposed by Restle (1979) seems to best address Gogel's situation. Restle suggests that people select the set of motions for an event that minimizes the parameters of perceived motion. Recall that all but one of the possible descriptions of the event will appear to have two motion parameters: translation and rotation. Restle's minimum principle would select the one perception with the least number of motion parameters, causing observers to see rotations compatible with this nontranslating alternative. These rotations would be exactly the same as those that Gogel determined would be seen if distance information had been taken into account.

Our point is that the motions seen by Gogel's observers may have been based on a minimum principle operating solely on motion information. It is, of course, also possible that Gogel's assertions are correct and distance had been taken into account in selecting the perceptual alternative; however, his experiments provide no means for determining whether a minimum principle or distance information had been the primary selecting factor.

Under the assumption that a minimum principle is primary, one might argue that distance information was a derivative of motion information in Gogel's experiment. Such an argument could be based on the fact that one can consciously compute distance from motion, given Restle's minimum principle and given the proximal pattern in Gogel's experiment. We caution against the assumption, however, that the perceptual system makes these computations as well. Even if the perceptual system does compute distance as a derivative of motion, we leave open the possibility that such derived information is not utilized by other perceptual subsystems. Observers, for example, might select the appropriate perceptual alternatives based on motion information without being able to point accurately at the stimulus. Similarly, derived distance information may not be utilized by the processes that underlie size perception. This possibility calls into question earlier work by Gogel, which we examine in the next section.

Is Apparent Motion of a Stimulus During Head Movements a Valid Measure of Apparent Distance?

The significance of our criticisms goes beyond Gogel's experiments on retinal motions. Our arguments imply that Gogel may have been on the wrong track in his earlier attempts to infer perceived distance from measures of perceived motion. Gogel (1977)

argued that measures of apparent object translation during head movement provide "a 'pure' measure of the apparent distance of the object; that is, a measure that will not be modified by cognitive factors" (p. 148). He went on to test important hypotheses about the relationship between apparent size and apparent distance, using his derived measure. Gogel addressed a serious problem when he called into question the role of cognitive factors in measures of apparent size and distance. Observers sometimes develop special cognitive strategies to meet specific task demands. Gogel's proposed solution, however, should be regarded critically, in light of the fact that his assumptions about the relationship between perceived motion and perceived distance are at odds with other current theories of motion perception (cf. Proffitt & Cutting, 1980). Gogel's "pure" measure may not be a valid measure.

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