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Dynamic occlusion in the perception of rotation in depth

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Occlusion of more distant texture elements by nearer elements can provide relative distance information in parallel projections of rotating objects, according to Braunstein, Andersen, and Riefer (1982). In that study, occlusion was present in static views in the form of contour interruptions or interposition. In the present study, all visible contours were eliminated. Dots were located within implicit pentagonal texture elements on a transparent sphere. The proportion of the sphere's surface covered by pentagons and dot density within the pentagons was varied. Accuracy of direction of rotation judgments was significantly affected by area, but not by dot density. Accuracy levels with purely kinetic occlusion were as high as in the earlier study, which included static interposition. Judgments of depth and shape were not affected significantly by occlusion, suggesting that occlusion is a specialized source of information for depth order. Levels of texture and the separability of depth and relative distance judgments are discussed.

It is now well established that transforming two-dimensional projections can convey information about depth relationships (see Braunstein, 1976, for a review). The depth information available in such transformations can be conveniently described in terms of three categories: (1) nonperspective transformations (parallel projections), (2) perspective transformations (polar projections), and (3) dynamic occlusion (the covering and uncovering of more distant objects by nearer objects). Some specific relationships have been established between these categories of available information and two types of depth judgments: (1) the depth relationships within an object or pattern (whether it appears two- or three-dimensional and its approximate shape), and (2) the relative distances from the observer of parts of the object or pattern (which parts are closer, which are more distant).[1] Depth discriminations can be made on the basis of nonperspective transformations, at least for objects or patterns rigidly rotating in depth (i.e., about any axis that is not parallel to the line of sight) (Braunstein, 1966). Perspective transformations can provide relative distance information (Braunstein, 1966) and also add to depth information provided in parallel projections (Braunstein, 1962, 1977). Dynamic occlusion provides relative distance information (Braunstein, Andersen, & Riefer, 1982; Kaplan, 1969) but may not add to the information about depth relationships within the projected pattern. Braunstein et al. (1982) considered two types of occlusion in parallel projections of pentagonal texture elements on the surface of a sphere rotating about a vertical axis: (1) edge occlusion—represented by an opaque sphere with texture elements occluded as they rounded the edge, and (2) element occlusion—represented by a transparent sphere with the nearer elements occluding the more distant elements as the sphere rotated. The number of element occlusions was determined by element size. Element density on the surface was constant. Accuracy of direction-of-rotation judgments was consistently high for all edge-occlusion displays, exceeding 90% for the largest element sizes. For element occlusion, accuracy increased from chance at the smallest size to over 80% at the largest size.

In the displays used by Braunstein et al., the texture elements defining the sphere had clearly drawn contours. The overlap of these contours in an instantaneous view of an element-occlusion display (Figure 1a) can provide static-occlusion (interposition)

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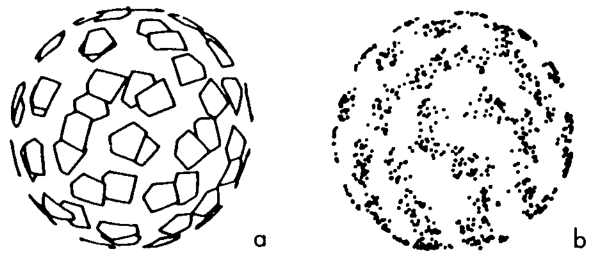

Figure 1. Single frames from the displays with the largest size pentagons, (a) from Braunstein et al., 1982, and (b) from the present study (with the highest dot density). (The stimulus film showed white figures on a black background.)

information as well as dynamic-occlusion information. The present study generalizes the previous results to stimuli that do not have explicitly drawn contours. Instead, dots were randomly positioned within the borders of implicit pentagons. When the projections of two implicit pentagons overlapped, any dot in the more distant pentagon that fell within the projected borders of the nearer pentagon was deleted from the display. This is shown in Figure 2. The pentagon on the left in A moves in front of the other pentagon, in B. With the contours of the pentagons drawn, the relative distance of the pentagons can be determined from static interposition. With only the dots drawn, as in C and D, the static view of the overlapping pentagons (D) does not provide information about which pentagon is in front. These contourless displays provide the type of purely kinetic occlusion studied with translating planes (Kaplan, 1969; Rhodes, 1980; Yonas & Granrud, 1982). Those studies considered the perception of depth order among two or three planar surfaces. In the present study, this type of occlusion will be considered for a simulated three-dimensional object.

The present displays consist essentially of two levels of texture—the pentagons are texture elements on the surface of an implicit sphere and the dots are texture elements on the surface of the implicit pentagons. An instantaneous view of one of these displays (Figure 1b) may provide some indication of the spherical shape and even of the borders of the pentagonal texture elements, but there is no information available in this view concerning which of two overlapping pentagons is occluding the other. These displays were used in the present study to test the hypothesis that purely kinetic occlusion can provide information in parallel projections of objects rotating in depth.

Two possible factors in the effectiveness of occlusion in these displays were considered. The size of the larger texture elements—the pentagons—determined the accuracy of direction-of-rotation judgments with contoured figures (Braunstein et al., 1982) and was varied in the present study. In addition, the number of dots in each pentagon was varied. A comparison of the effects of these two variables on direction judgments will provide a preliminary indication of how these two texture levels interact to determine the effectiveness of kinetic occlusion.

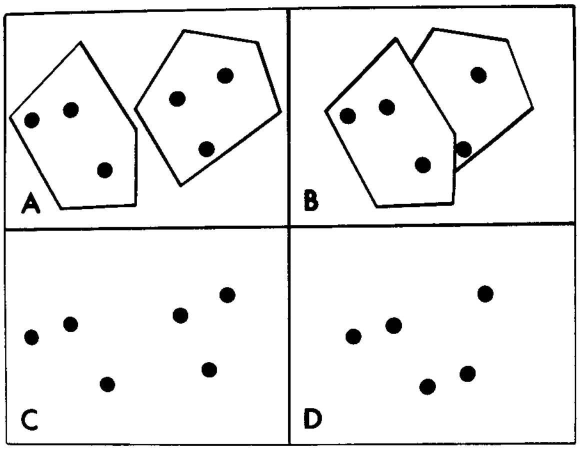

Figure 2. One pentagon moving in front of another, with the contours drawn (A and B) and the contours implicit (C and D).

EXPERIMENT 1

Methods

Subjects. The subjects were 21 students in lower division psychology courses at the University of California, Irvine, who received extra credit for their participation. Acuity of at least 20/40 (Snellen eye chart) was required in the eye used in the experiment. Data from one subject were not used because of failure to follow instructions.

Design. Four independent variables were examined: size of the implicit pentagons (3 levels), number of dots in a pentagon (3 levels), rotation speed (2 levels), and direction of rotation. Rotation speed was run between subjects with 10 subjects run at each level. The remaining variables were run within subjects.

Stimuli. The stimuli were 27 180-frame computer-generated motion-picture sequences. The sequences were plotted one frame at a time on a Tektronix 4020 display scope, recorded on Kodak Plus-X film using an Automax camera, and printed on high-contrast film. Each sequence displayed a parallel projection of dots located on the surface of a sphere rotating 180 deg about a vertical axis. The dots were randomly located on the surface of the sphere in the following manner: First, 50 points were selected arbitrarily on the surface of a sphere so as to appear approximately evenly distributed when the sphere was viewed from various angles. For each of the 27 displays, a pentagon was computed (but not drawn) at each of the 50 locations by a random procedure with the constraint that an angle formed by connecting the center of the pentagon to two adjacent vertices would be between .35 and 2.09 radians (to avoid extreme shapes). The total proportion of the surface area covered by the 50 pentagons was .035, .105, or .245. Three, 9, or 21 dots were randomly located within each pentagon.

The surface of the sphere was treated as transparent in the computation of all displays. In the experimental (occlusion) displays, the implicit pentagons were treated as opaque. When the projections of a pentagon on the front surface of the sphere in these displays overlapped any portion of the projection of a pentagon on the back surface, any dots in the covered portion of the back pentagon were not plotted. Two experimental displays were generated at each of the nine size-density combinations—one with a clockwise direction of rotation and one with a counterclockwise direction of rotation used in the occlusion computations.

The number of pentagons in which any dot was occluded and the total number of occluded dots was computed for each frame of each of the 18 occlusion displays. The mean pentagon and dot occlusions for each combination of pentagon size and dot density are given in Table 1. The number of pentagon occlusions was determined almost entirely by pentagon size, whereas the number of dot occlusions was determined equally by size and density.

A control display was generated at each of the nine size-density combinations in which the pentagons as well as the sphere were treated as transparent. As these displays carried no occlusion information (and, like all other displays in this experiment, were parallel projections), no direction of rotation could be assigned. The 27 displays were arranged randomly on the film with a 120-frame ISI. The film projection speed was 18 fps for half of the subjects and 24 fps for half of the subjects. The rotation speed,

Table 1
Mean Number of Occluded Pentagons and Dots on a Display Frame

Proportion of Surface Covered by Pentagons	Number of Dots in Each Pentagon					
	3		9		21	
	Pentagons	Dots	Pentagons	Dots	Pentagons	Dots
.035	1.4	2.2	2.2	6.8	2.4	15.5
.105	4.2	6.6	6.2	19.7	7.5	47.35
.245	10.0	15.8	14.3	46.4	17.0	110.8

display duration, and ISI were 3 rpm, 10 sec, and 6.7 sec at the slower projection speed or 4 rpm, 7.5 sec, and 5 sec at the faster projection speed.

Apparatus. The film was rear-projected onto a translucent screen (Polacoat) in a separate room by a 16-mm projector (Bell and Howell Model 1592). The dot and background luminances at the screen were 7.3 and .18 cd/m^2, respectively. A .4 neutral-density filter was located in the viewing tube to enhance the perception of the background as totally dark. Subjects viewed the screen monocularly at a distance of 1.8 m through a tube that restricted the field of view to a circular region 17 deg in diameter. The diameter of the projected sphere was also 17 deg.

A 15-cm-diam glass sphere with white dots positioned on the surface served as a demonstration model. An 8-rpm reversible motor was attached to a vertical stem at the bottom of the sphere. The response device consisted of a 50-mm-diam spherical knob on a vertical shaft. Turning the knob clockwise or counterclockwise triggered one of two microswitches, which turned on one of two lights at the experimenter's console.

Procedure. The subjects were run individually. They were instructed to indicate the direction of rotation of the sphere viewed through the tube by turning the response device clockwise or counterclockwise as soon as the display disappeared. The two directions of rotation were demonstrated using the glass model, and the subject practiced the response procedure. The room was then made totally dark and the film was started.

A different order of display presentation was obtained for each subject by running the film in either the forward or reverse direction with 10 different starting positions, spaced at approximately equal intervals, in each direction. The subject gave direction of rotation responses to 59 displays. The first 5 were treated as practice trials. The remaining 54 displays consisted of two repetitions of the 27 stimulus displays (the last 5 of which were the same as the practice trials). The subject was then instructed to judge the coherence or rigidity of each display on a 4-point scale. A rating of 1 was to be used for nonrigid displays, for example, displays that appeared to consist of two or more independently moving surfaces. A rating of 4 was to be used for completely rigid displays. Ratings of 2 and 3 were to represent somewhat rigid displays and mostly rigid displays, respectively. The subjects were told to give their coherence ratings verbally as soon as each display disappeared. The 27 displays were presented in the same order as in the previous blocks of 27 trials. At the end of the session, the subject was asked a series of questions about the displays, beginning with, "What did you think you were looking at?"

Results and Discussion

Accuracy. Each subject made two direction-of-rotation responses to each stimulus sequence. Accuracy was defined as the frequency (0, 1, or 2) with which these responses matched the simulated direction of rotation. As there was no simulated direction of rotation for the control stimuli, the accuracy analysis was conducted for only the 18 occlusion stimuli. The effects of the four independent variables (rotation speed, rotation direction, dot density, and pentagon size) were examined in an analysis of variance. The main effect of pentagon size [$F(2,36) = 4.45$] was significant ($p < .05$). Post hoc comparisons (Tukey's HSD test) showed only the two extreme sizes to differ significantly ($p < .05$). The main effect of speed [$F(1,18) = 3.36$], direction [$F(1,18) < 1$], and density [$F(2,36) = 2.47$] were not significant and there were no significant interactions.[2]

The mean accuracy levels for the three pentagon sizes are shown in Figure 3. These levels are comparable to those found by Braunstein et al. for contoured pentagons of approximately the same three sizes (the three largest sizes in that study). The accuracy levels were approximately the same (.83 and .82, respectively) for the two displays contrasted in Figure 1—the contoured pentagon display with the largest size pentagons and the dot display with the largest size of implicit pentagons and largest number of

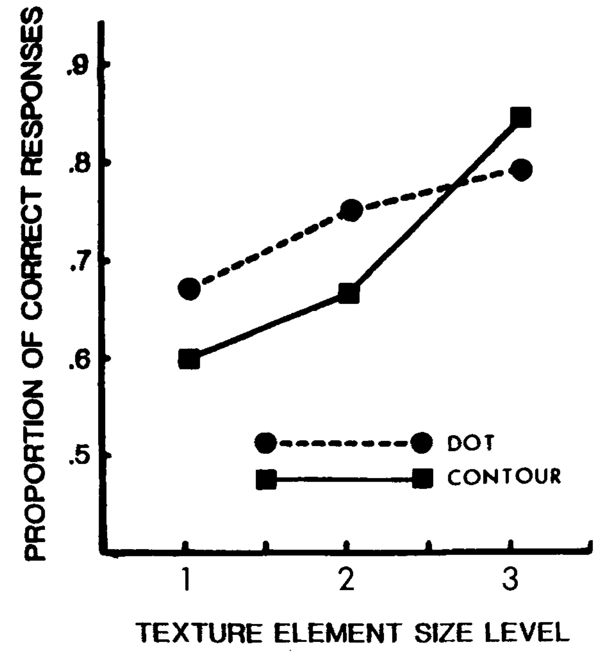

Figure 3. A comparison of the accuracy of direction of rotation judgments for the three pentagon sizes in the present study and the element occlusion displays with the three largest sizes in Braunstein et al. (1982).

dots. These comparisons indicate that the same high levels of accuracy can be obtained whether or not explicit contours are present. The accuracy levels obtained for element occlusion in the previous study do not require the presence of static interposition in instantaneous views of the displays.

The present results provide some suggestions as to how occlusion information is carried in displays that have multiple levels of texture (as would most natural scenes). The two levels of texture in the present study functioned differently: A pentagon was an opaque surface and could occlude another pentagon by passing in front of it. A dot was a texture element on an opaque surface and could not by itself occlude another dot, but a dot would be deleted from a display when it occupied an occluded region of a pentagon. There are two aspects of occlusion that can be measured on each frame of a display: the number of pentagons that have any portion of their surfaces occluded by another pentagon, and the number of dots deleted as a result of occlusion. These measures were correlated ($r = .85$) in the present experiment, so it is difficult to distinguish between the effects of the two types of occlusion. There are some suggestive trends, however. The linear correlations of number of dots, pentagon size, dot occlusions, and pentagon occlusions with accuracy were .32, .70, .72, and .79, respectively. The multiple correlation of these four variables with accuracy was .80. These values suggest that the accuracy of the direction of rotation judgments was based almost entirely on the number of pentagons occluded. The role of the dots may be to define the contours of the pentagons, with the effectiveness of occlusion based on unitary perceptions of one pentagon moving in front of another, rather than on the number of dots that are deleted when this occurs. This is consistent with informal reports of the appearance of the displays. An alternative explanation of these results is that the salience of the dynamic-occlusion information was determined by an interaction of dot density with relative occlusion duration. As the occlusion duration for the dots in the element-occlusion displays was a function of pentagon size, the interaction of density and occlusion duration would not be distinguishable from an effect of number of occluded pentagons, which was also dependent on pentagon size and dot density. Further research in which both the number and size of the larger texture elements (pentagons) is varied would be useful in distinguishing between these explanations.

Coherence. The coherence rating (1-4) given by each subject to each of the 27 displays was subjected to an analysis of variance, with speed, density, size, and occlusion as the independent variables. [A separate analysis of the occlusion displays found direction of rotation to be nonsignificant, $F(1,18) < 1$. This variable was dropped from the overall analysis of the coherence ratings so that the control stimuli, which have no simulated direction of rotation, could be included.] There were no significant main effects ($F < 1$ in all cases). The interaction of number of dots with pentagon size was significant [$F(4,72) = 3.42$, $p < .05$]. The combination of the greatest dot density and largest pentagon size yielded the highest mean coherence ratings (3.01). At the two lower density levels, rated coherence was highest for the middle pentagon size. There were no other significant interactions. Informal observations of the stimuli suggested that perceived coherence might be reduced when the direction of rotation indicated by occlusion was in conflict with a subject's individual preference for perceiving a particular direction. Individual preferences for associating a particular direction of horizontal translation with relative distance were found by McConkie and Farber (1979) for random-dot planes translating horizontally. If a subject tended to perceive dots moving to the right as being closer than dots moving to the left, for example, a preference for perceiving counterclockwise rotation might be expected in the present experiment. Direction preference was assessed for each subject in the control stimuli, which displayed no veridical direction information. Six subjects selected a counterclockwise response on more than 50% of the trials, while the remaining 14 selected a clockwise response on at least 50% of the trials. The coherence results for the occlusion stimuli were reanalyzed using preferred vs. nonpreferred direction for the individual subject, rather than clockwise vs. counterclockwise, as an independent variable. The main effect of direction preference was significant [$F(1,18) = 10.1$, $p < .01$]. The mean coherence ratings for the preferred and nonpreferred directions were 2.635 and 2.305, respectively. As in the overall coherence analysis, the interaction of dot density and pentagon size was significant [$F(4,72) = 3.71$, $p < .01$]. There was also a significant interaction of projection speed, preferred vs. nonpreferred direction and dot density [$F(2,36) = 3.45$, $p < .05$].

Debriefing. In response to the first, open-ended, debriefing question, 15 of the 20 subjects stated that they believed they were watching a three-dimensional object through the viewing tube. One subject stated that it looked like a film. The remaining four subjects gave initial descriptions that could not be classified as describing either an object or a projection, but stated, when specifically asked about that possibility, that the displays sometimes looked three-dimensional. The proportions of three-dimensional and of two-dimensional responses were higher in the previous study, in which the contours of the pentagons were drawn (25 and 5 responses, respectively, in the two categories among the 30 subjects), and there were no responses that required clarification in that study. The realism of the displays appears, overall, to have been comparable in the two studies.

EXPERIMENT 2

Perceived depth has been compared for parallel and polar projections in three studies using different types of judgments (Braunstein, 1962, 1977; Petersik, 1980). In each study, judged depth increased with polar perspective. Dynamic occlusion, like polar perspective, can add relative distance information to the depth information in a parallel projection, but there is no evidence that dynamic occlusion also contributes to the impression of depth or to the perception of the three-dimensional shape of the rotating object. If occlusion provides only the order of surfaces in depth, as suggested by Kaplan (1969), it may not affect depth and shape judgments for the type of displays used in Experiment 1.

A second reason for considering depth and shape judgments was the issue of how well the stimuli in Experiment 1 represented, to naive subjects, spheres rotating in depth. The high coherence ratings for most of the stimuli in that experiment, and the high proportion of subjects reporting that they believed the display to be three-dimensional, provide indirect evidence that this representation was satisfactory. However, these findings do not provide specific information about the relative effectiveness of the stimulus parameters in representing depth and spherical shape. A second experiment was therefore conducted in which responses were limited to numerical ratings of depth and of spherical shape.

Methods

Subjects. Eleven naive subjects were obtained from the same source as in Experiment 1. The same vision criterion was employed. Data from one subject were not used in the analysis because of failure to follow instructions.

Stimuli and Apparatus. The stimuli and apparatus were the same as in Experiment 1, except that the response device was not used. Only one projection speed, 18 fps, was used.

Procedure. The subjects were run individually. They were told that they would be judging the depth and shape of a number of displays of moving dots, but first they were to carefully observe the displays without responding. The room was made totally dark, and the subject viewed one block of the 27 displays. As in Experiment 1, different orders of presentation were obtained for each subject by starting the film in different positions and presenting it in a forward direction for five subjects and in a reverse direction for five subjects.

After viewing one block of 27 sequences, the subject was instructed to rate his or her impression of the depth in each display on a 5-point scale. A rating of 1 was to be used for displays that appeared completely flat; a rating of 5 was to be used for a strong impression of depth; a rating of 3 was to be used for some impression of depth. The subjects were instructed to give their ratings verbally as soon as each display disappeared. The 27 displays were then repeated in the same order. The rating procedure was repeated for ratings of spherical shape. A rating of 1 was to be used for displays that did not appear spherical at all; a rating of 5 was to be used for displays that appeared as perfectly round spheres; a rating of 3 was to be used for displays that appeared somewhat spherical. An egg shape was given as an example of a somewhat spherical shape. The debriefing procedure was the same as in Experiment 1.

Results and Discussion

Depth ratings. An analysis of variance of the depth ratings for the occlusion displays found the main effect of direction of rotation to be nonsignificant [$F(1,9) < 1$]. By collapsing over this variable, which applies only to the occlusion stimuli, it was possible to run an analysis of variance for all displays, with number of dots, pentagon size, and occlusion vs. control as the three independent variables. Number of dots was significant [$F(2,18) = 8.76$, $p < .01$]. The mean depth ratings for the three dot densities (3, 9, and 21 dots per pentagon) were 2.73, 3.22, and 3.72. Post hoc comparisons (Tukey's HSD test) showed only the difference between the 3-dot and 21-dot ratings to be significant ($p < .01$). Pentagon size was also significant [$F(2,18) = 5.54$, $p < .05$]. The mean depth ratings were 2.82, 3.33, and 3.52, for the small, medium, and large sizes. Only the difference between the small and large sizes was significant ($p < .05$). The interaction of density and size was also significant [$F(4,36) = 4.95$, $p < .01$]. This interaction is illustrated in Figure 4. There were no other significant interactions.

The increase in depth ratings with increasing dot density is not surprising. Each dot provides an opportunity for a projected sinusoidal velocity to be perceived as the projection of a constant-velocity circular motion in depth. It could also be argued

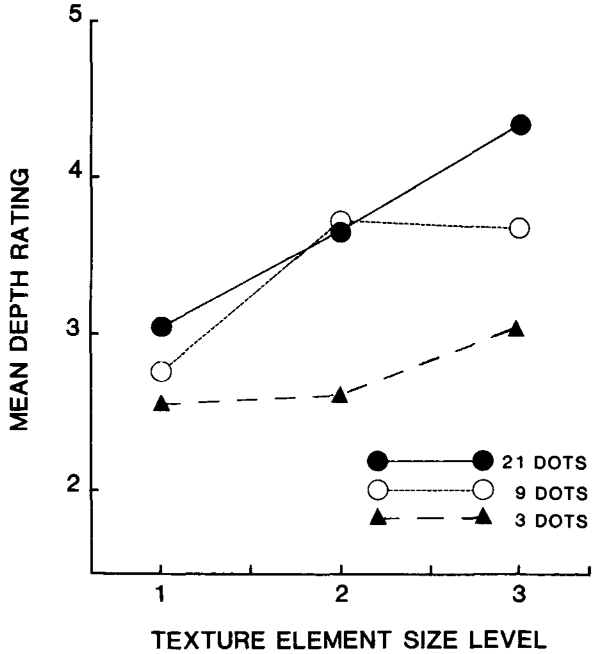

Figure 4. The interaction of pentagon size and dot density in determining depth ratings.

that increasing the number of dots increases the information available for computing a rigid structure, but depth ratings have also been shown to increase with numerosity when each dot is moving at a different velocity and there is thus no rigid configuration indicated (Braunstein, 1961). The main effect of pentagon size, and the density-size interaction, may be related to the uniformity of the dot distribution across the surface of the sphere, which is affected by pentagon size. This possibility could be tested by varying uniformity of the texture distribution in displays that do not have superordinate texture units.

The finding of almost identical ratings for the occlusion and control stimuli is of special interest. While occlusion was the principal variable determining accuracy in Experiment 1, it had no measurable effects on depth ratings in Experiment 2. This supports the concept that occlusion serves the special function in depth perception of removing ambiguities in depth order.

Shape ratings. As in the analysis of the depth ratings, direction of rotation was not significant for the occlusion stimuli [$F(1,9) < 1$], and an overall analysis was run for the occlusion and control stimuli. The main effect of number of dots was significant [$F(2,18) = 14.4$, $p < .01$]. The mean shape ratings for the three dot densities were 3.15, 4.03, and 4.22. Shape ratings were significantly lower for the lowest dot density than for the two higher densities ($p < .01$), but ratings for the two higher densities did not differ significantly. The main effects of pentagon size [$F(2,18) = 2.63$] and of occlusion vs. control [$F(1,9) = 2.32$] were not significant ($p > .05$). There were no significant interactions.

As in the case of the depth ratings, there are two alternative explanations for the effects of number of dots on the shape ratings. Increasing the number of dots increases the number of distance relationships that are maintained in a rigid rotation and this may increase the perceptibility of the overall structure. On the other hand, the sinusoidal waveform and horizontal extent of each projected dot path may provide perceptions of circular cross sections in depth that are integrated into an overall spherical shape. These two possibilities can be distinguished through the use of displays in which the same paths are traversed by dots moving with sinusoidal projected waveforms, but not in a rigid configuration. The separation of these two factors—rigidity vs. the combination of sinusoidal waveform and horizontal extent—in shape judgments will be the subject of future research.

GENERAL DISCUSSION

The study of dynamic occlusion in the perception of direction of rotation in depth brings together two previous findings. Kaplan (1969) showed that purely kinetic occlusion is sufficient for the perception of the depth order of two surfaces translating horizontally. Braunstein, Andersen, and Riefer (1982) found that occlusion of more distant texture elements by nearer elements was sufficient for the perception of direction of rotation for displays that included static as well as kinetic occlusion. It is now clear that depth order from purely kinetic occlusion can be used to resolve ambiguity of direction of rotation in parallel projections.

In order to isolate the effects of kinetic occlusion, the present study used stimuli in which texture was present at two levels: At one level, the texture elements—the pentagons—were large enough to display gradual occlusion and disocclusion of more distant elements by nearer elements; the subordinate-level texture elements—the dots—were the features that actually appeared and disappeared. Multiple levels of texture are a normal feature of the complex visual environment of the human observer, and an analysis of how these levels interact will be required for an understanding of the role of dynamic occlusion in depth and shape perception. The present results provide some suggestions as to how these levels interact in the processing of occlusion information. Pentagon size and the number of occluded pentagons, rather than dot density and the number of occluded dots, appear to determine the effectiveness of occlusion. This suggests that it is the occlusion and disocclusion of forms, rather than the accretion and deletion of texture elements, that is most salient. The process may be as follows: The dots provide the organization of the surface of the sphere into pentagons, with even a small number of dots capable of establishing the approximate subjective contours of a pentagon. These contours appear to be provided, in part, by the groupings of the dots on the surface of the sphere. In the occlusion displays, it is likely that occlusion plays a major role in indicating the contour locations. Once these approximate contours are established, the total surface area covered by the pentagons appears to determine the effectiveness of occlusion. The surface area covered is a function of the number and size of the pentagons, and for a given area there is likely to be an optimum combination of number and size. This should be the combination that provides the maximum number of pentagon occlusions. This analysis remains speculative at this point. It suggests the general hypothesis that when texture elements are organized into larger forms, the salience of occlusion depends not on the number of accretions and deletions of individual texture elements but on the number of forms on which any surface element is accreted or deleted. Factors affecting the organization of texture elements into forms have been studied in relation to perceived similarity (for example, Kimchi & Palmer, 1982) and may also be important in determining how occlusion affects relative distance perception.

The present study provides additional evidence regarding the separability of depth and direction of rotation judgments. This has been discussed for comparisons of parallel and polar projections (Braunstein, 1976) and has been labeled functional dissociation (Petersik, 1980). This issue concerns the well-known, but still remarkable, result that internal depth relationships can be perceived within a pattern when there is no information available concerning the relative distances (depth order) from the observer of parts of the pattern. Different combinations of information appear to be used for judgments of direction of rotation, shape, and depth for objects rotating in depth. Direction of rotation could be judged accurately in parallel projections when occlusion was present. Shape and depth judgments, on the other hand, showed no effects of occlusion. Shape judgments were affected by the number of dots in the rotating pattern. If the sinusoidal waveform of each projected dot suggests that it is the projection of a circle in depth, it is reasonable that ratings of spherical shape will increase with the number of these projections. The grouping of the dots into larger superordinate texture elements appears to contribute to the impression of depth in these displays. This suggests that the organization of the dots, as well as their number, determines this impression. This distinction between the variables underlying shape judgments and those underlying depth judgments may be important in understanding the perception of complex dynamic patterns and is a topic requiring further investigation.

Overall, these results suggest that dynamic occlusion is a specialized source of information for the perception of order in depth that does not provide information about interval depth relationships. It is important for removing ambiguities regarding depth order. Another possible value of occlusion is in establishing the contours of moving patterns. This aspect of occlusion was not directly examined in the present study but has been shown to be important in the perception of dynamic dot patterns representing persons walking (Proffitt & Bertenthal, Note 1). This role of occlusion is also worth further study.

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NOTES

1. This paper will not be concerned with a third type of depth judgment—absolute or egocentric distance (Gogel, 1973)—which requires additional information.

2. It is possible that a larger speed difference would produce a greater effect. The nonsignificant trend favored the slow speed, with a mean accuracy of .77, relative to .68 for the fast speed.

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