Psychological Review
1965, Vol. 72, No. 2, 117-127

APPARENT REVERSAL (OSCILLATION) OF ROTARY MOTION IN DEPTH:

AN INVESTIGATION AND A GENERAL THEORY

R. H. DAY[1] AND R. P. POWER

University of Sydney

3 explanations of apparent reversals (oscillation) of rotary motion in depth attribute this effect to misjudgment of orientation. These explanations are based mainly on observations of a trapezoidal "window" in rotation. The experiments reported here show that perspective effects in a trapezoidal window do not increase reversal frequencies and that other shapes in addition to a trapezoid exhibit the effect with similar frequencies. The experiments also failed to confirm that misjudgments of orientation are a causal condition of apparent reversals. A general theory in terms of an identity of projected (retinal) motion characteristics for clockwise and anticlockwise motion is proposed with supporting evidence. Apparent orientation is held to be a consequence of rather than a necessary condition for apparent reversal. This theory is sufficiently general to explain apparent reversals ("fluctuations") in the orientation in depth of static figures and objects and to explain also the kinetic depth effect. All these phenomena are held to derive from an identity of retinal projections for 2 or more motions or orientations of an object in space.

Objects rotating in depth relative to an observer are frequently judged, usually with monocular vision, as apparently reversing their directions of rotary motion. Recession of a point or edge is sometimes reported as approach and vice versa. This effect, as far as is known, was first reported by Kenyon (1898) in the following terms:

> A curious illusion connected with an ordinary two-winged pendant fan . . . consists in the fan appearing to rotate in the opposite direction. . . . Two other illusions . . . may be noted. In one the vanes, instead of rotating, seem to flap together; in the other the two arms appear to be continually withdrawing into and pushing out from the hanging rod [p. 371].

The effect was later mentioned by Miles (1929) and, more recently, extensively investigated by Ames (1951) who explained it in terms of assumptions consequent upon past experience with certain shapes. Alternative explanations have since been proposed by Pastore (1952) and Graham (1963). All three explanations are based largely on observations of a rotating isosceles trapezoid[2] cut and painted to resemble a mullioned window in perspective. Quantitative data from a series of recent experiments (Day & Power, 1963), however, failed to support any of these explanations and a more general theory is presented here with supporting evidence.

It is intended to review briefly earlier explanations, to present experimental

---

[1] Now at Monash University.

[2] In an earlier paper (Day & Power, 1963) the term trapezium was used instead of trapezoid. This inconsistency is clarified by reference to the McGraw-Hill *Encyclopedia of Science and Technology,* Vol. 14, 1960: "Trapezoid: a term used in the United States for a quadrilateral with two sides parallel. In Great Britain such a figure is often called a trapezium, a term used in the United States for a general quadrilateral."

data which render them questionable, and then to describe the more general theory. It will also be shown that the present theory can be extended to explain a variety of apparent reversing phenomena associated with stationary and moving "ambiguous" figures of two and three dimensions.

CURRENT EXPLANATIONS OF APPARENT REVERSAL

Ames' Explanation

The explanation proposed by Ames (1951) derives from qualitative data and rests upon two basic assumptions. First, an isosceles trapezoid cut and painted to resemble a mullioned window in perspective is seen as slanted to the frontoparallel plane when, in fact, it lies in that plane. The longer vertical edge is seen as closer than the shorter irrespective of the degree of slant. Second, a cue for rotary motion in depth is held to be a continuous variation in the total horizontal angle subtended at the eye. Thus, when the window, actually in the frontoparallel plane, but seen as slanted to it, begins to rotate, an observer would expect the total horizontal angle to increase as the apparently further edge approaches. Since, however, the horizontal subtense *decreases,* and, since this is a cue for recession, the window's direction of motion is seen as opposite to its true direction. Ames (1951) argued that the windowlike properties of the shape enhanced the effect since a window is commonly rectangular. A trapezoidal shape, therefore, would tend to be seen as a slanted window. Presumably a door or book-cover pattern or some such would serve as well to emphasize the reversal effect.

Pastore's Explanation

Pastore (1952) demonstrated and Canestrari (1956) and Mulholland (1956, 1958) confirmed that reversals of rotary motion were not confined to trapezoidal shapes. It was found by the former that the effect occurred with a variety of forms including a circle, an ellipse, a "lopsided" elipse, a triangle, and a solid object. Pastore's explanation is based on a difference between true and apparent slant. When there is a discrepancy between these, apparent direction of motion is opposite to true direction. Contrariwise, when apparent slant conforms to true slant, perceived motion direction is the same as true direction. This principle was demonstrated by slanting a trapezoidal window at 45 degrees from the frontoparallel with the longer vertical edge furthest, obtaining a judgment of slant, and then rotating it through about 90 degrees to obtain a judgment of motion direction. Kilpatrick (1953) has pointed out that there is little to choose between the explanation proposed by Ames and that put forward by Pastore. Both stress the role of apparent slant in determining apparent reversals in rotary motion.

Graham's Explanation

Graham (1963) has explained apparent reversals in terms of an identity of differential angular velocities of points on the surface of the object for clockwise and anticlockwise movement, and the resolution of direction by perspective cues. It is argued that such ambiguity of movement parallax deriving from identical differential angular velocities is resolved by the use of perspective cues provided by the trapezoidal window. Thus, the short vertical edge, no matter in which quadrant of the circle it lies, is judged as being in one of the two far quadrants. When the short edge actually lies in one of these quadrants, movement direction is correctly judged, but when it lies in one of the two near quadrants, reversed rotation seems to occur. The similarity between this explanation and that proposed by Pastore (1952) is recognized by its author.

TESTS OF CURRENT EXPLANATIONS

Although the three explanations reviewed above derive from different theoretical positions, they have two features in common. First, they are based almost entirely on data obtained from observations of a rotating trapezoidal shape. Pastore (1952) demonstrated reversals with a variety of shapes, but he argues from observations of a trapezoidal window slanted at 45 degrees from the frontoparallel. Second, all three explanations treat misjudgment of slant as a critical determinant of apparent reversal. That is, misjudgment of the frontal orientation of the object is regarded as a necessary condition for the oscillatory effect. The greater apparent distance of the short vertical edge of the trapezoid regardless of its true orientation, and the enhancement of this effect by window characteristics, is regarded as the basis of the apparent reversal phenomenon. In the following experiments, therefore, these stimulus properties have been examined.

Throughout what follows the term apparent reversal will be used to refer to the subject's report of the approach of an edge or part of the object when in fact it is receding and vice versa. The alternation of apparent reversals with reports of true motion direction is referred to as oscillation. The term (apparent) orientation will be used throughout to refer to the angle that the shape makes with the subject's frontoparallel plane when it is mounted on a vertical axis.

Experiment 1: Effects of Stimulus Shape and Pattern

In a series of recent experiments (Day & Power, 1963), six stimulus conditions were derived from two shapes (isosceles trapezoid and rectangle) and three surface patterns (plain white, vertical black and white bars, and an Ames window). The vertical edges of the trapezoids were 11.75 and 6.25 inches, and their nonparallel edges 9.625 inches. The rectangular shapes were 11.625 × 9.25 inches. The trapezoidal window was mullioned and painted to resemble a window with thickness slanted to the line of regard. The objects, which were mounted in an enclosed chamber, rotated clockwise at 8 rpm and were viewed monocularly from 52 inches through a viewing tube. Six independent groups of 12 subjects drawn from undergraduate classes in psychology signaled apparent reversals in the direction of rotation by operating a press-switch during two 20-revolution trials. Reversals were recorded on an automatic counter.

Mean frequencies of reversals for each of the six shapes and patterns based on two trials are shown in Figure 1a. Although there were large and significant differences between reversal frequencies for the two shapes ($p < .001$), there was none between patterns ($p > .10$). The surface characteristics of a mullioned window in perspective failed to increase significantly the frequency of apparent reversals, a finding contrary to the generally held view that resemblance to a commonly rectangular object contributes to the effect. Identical results were obtained in a repetition of this experiment using subjects quite unfamiliar with the effect. In the case of the rectangular shapes only a small proportion of subjects in each group reported apparent reversals, whereas all subjects reported reversals with the trapezoidal shapes.

In a second experiment under the same viewing and responding conditions three shapes (circular, elliptical,

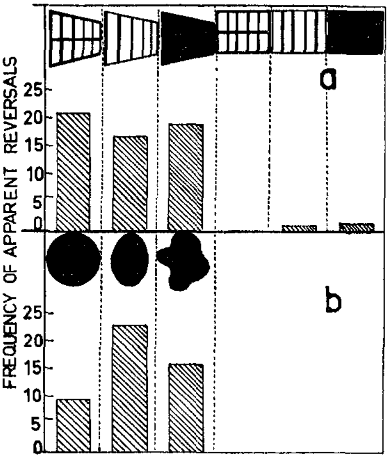

FIG. 1. Part a: Frequencies of apparent reversal of rotary motion for two shapes (trapezoidal and rectangular) and three surface patterns (plain white, vertical bars, and "window"). Part b: Frequencies of reversal of rotary motion for a circular, elliptical, and irregular shape. (In this and subsequent figures the plain white shapes are shown in black for convenience.)

and irregular) with a vertical length of 10 inches were observed during two 20-revolution clockwise trials by independent groups of 15 subjects. The histograms in Figure 1b show that whereas the elliptical and irregular shapes exhibited similar frequencies of reversal ($p > .05$), the circular shape did so less frequently. The apparent reversal frequency of the latter shape differed significantly from that of both ellipse and irregular shape ($p < .01$).

Experiment 2: Apparent Orientation

Since there are no quantitative data on the apparent orientation of a trapezoidal window and other shapes when stationary, Experiment 2 (Power, 1964) was designed to obtain such data for two orientations of six shapes. Using the same monocular viewing conditions as in Experiment 1, six groups of 10 subjects matched the orientation of a trapezoidal window, an ellipse, a rectangular window, and three irregular shapes while they were stationary. One group was assigned to one shape and was required to match its orientation when it was slanted at 60 and 120 degrees from the sagittal (0 degree) plane. The shapes were suspended from the top of the viewing chamber, and the subject matched their orientation by means of a rectangular shape with a lattice pattern on its surface. The axes of the standard and comparison shapes were coextensive, and preliminary observations had shown that the comparison rectangle could be accurately oriented into the frontoparallel plane. Adjustment of the slant of the lower comparison rectangle was made by means of a hand

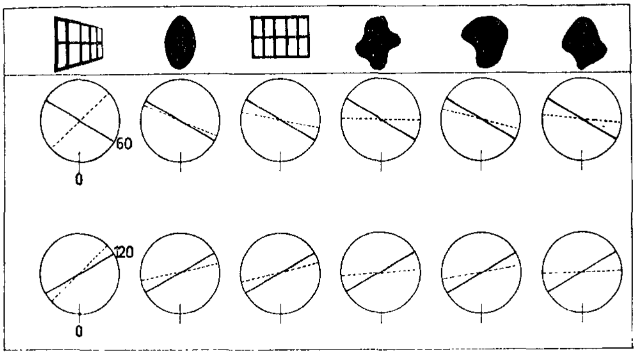

FIG. 2. Apparent orientation (dotted lines) of four shapes (trapezoidal window, rectangular window, ellipse, and irregular) at two angles (60 and 120 degrees) from sagittal (0 degree) plane.

wheel in front of the subject which was connected by means of a pulley and belt to the axis of the shape. The task assigned the subject involved adjusting the slant of the lower comparison shape so that it lay in the same apparent plane as the upper standard shape.

The mean angular matches for the six shapes at 60 and 120 degrees from the sagittal plane are shown in Figure 2 as dotted lines. The 60- and 120-degree true orientations are shown as heavy continuous lines, and the shapes themselves are shown accompanying each diagram. While the ellipse, the rectangular window, and the three irregular shapes were judged as oriented in the correct quadrants at both angles, the trapezoidal window was judged as being oriented with its shorter vertical edge in one of the two far quadrants regardless of its true orientation. Whereas this judgment was correct for the 60-degree position, it was incorrect for the 120-degree position.

Thus the trapezoidal window, whose mean apparent reversal frequency in Experiment 1 was 21, was misjudged as to its quadrants of orientation in one of its two positions. On the other hand, the orientation quadrants of the elliptical and irregular shapes whose mean reversal frequencies were 24 and 17, respectively, were correctly judged.[8] These data suggest that misperception of orientation is not a necessary condition for the occurrence of apparent reversals of direction in rotary motion.

Experiment 3: Relationships between Apparent Orientation, Initial Movement Direction, and Reversals

The purpose of the third experiment (Power, 1964) was to investigate under the same conditions the relationships between judgments of orientation, of initial direction of movement, and of reversals. The second of these (initial direction of movement) was included since Graham (1963) and Pastore (1952) argue that, in the case of the trapezoidal window, apparent orientation determines perceived direction of movement.

The apparatus and viewing conditions were similar to those of Experiment 2. The standard shapes were a trapezoidal window, an ellipse, an irregular shape, and a rectangular window all of which had been used in Experiment 1. For judgments of orientation the four shapes were placed in the subject's frontoparallel plane and the two asymmetrical objects (trapezoid and irregular) were positioned with one edge both left and right. Thus there were six conditions. Indedependent groups of 10 subjects drawn from introductory classes in psychology observed one shape during all three phases. In the first phase the subject adjusted the lower latticed rectangle so that it appeared in the same plane as the upper standard. Immediately this match was made the standard was rotated anticlockwise at 4.5 rpm and the subject indicated apparent direction of movement (Phase 2). In the third phase the subject indicated apparent reversals during a 20-revolution trial as in Experiment 1.

The results are shown in Table 1 for the four shapes and the two positions of the trapezoidal and irregular shapes.

Pastore's (1952) explanation states that, when the longer vertical edge of the trapezoid is judged nearer when in fact it is farther, rotation direction appears opposite to true direction. Judgments of initial motion direction immediately following orientation judgments (Table 1, fifth row) show that when the longer edge of the trapezoid

---

[8] For the order in which they occur in Figure 2, the mean apparent reversal frequencies of the two irregular shapes which were not used in Experiment 1 were found to be 17 and 18 in a separate experiment.

TABLE 1

Means and Standard Deviations of Orientation Matches and Reversal Frequencies with Number of Subjects Judging Initial Movement as Clockwise (C) and Anticlockwise (AC): Experiment 3

		Shapes					
		Irregular (protuberance right)	Irregular (protuberance left)	Trapezoidal window (short side right)	Trapezoidal window (short side left)	Ellipse	Rectangular window
Orientation (Degrees from sagittal plane)	$\bar{X}$	94.6	91.1	320.9	38.3	103.5	92.4
	SD	5.06	5.63	10.3	12.66	32.35	3.67
Reversal frequency	$\bar{X}$	16.4	22.0	28.9	25.5	23.9	.2
	SD	9.1	12.65	9.33	7.17	8.07	.01
Initial movement direction	C	4	5	0	10	2	1
	AC	6	5	10	0	8	9

was judged nearer on the left, all judgments of direction were correct (i.e., anticlockwise). When, however, the longer edge was judged nearer on the right, all judgments of rotation direction were incorrect (clockwise). Thus, Pastore's (1952) statement is valid for the trapezoidal window. The phi coefficients between judged quadrants of orientation and judged initial direction of motion (clockwise or anticlockwise) have been computed for the four shapes, the two positions of the irregular and trapezoidal shapes being combined for this purpose. These coefficients are .297 for the irregular shape, .900 for the trapezoid, .234 for the ellipse, and .250 for the rectangle. The relationship between judged orientation and judgments of initial direction of motion achieves significance only in the case of the trapezoidal window and for all other shapes fails to reach significance. Thus, whereas this relationship holds for one shape (trapezoid) which manifests 29 and 25 apparent reversals during rotation, it does not do so for two other shapes which manifest reversal frequencies of 16 and 22 (irregular) and 24 (ellipse).

Summary of Experimental Data

The data from the first experiment show that the apparent reversal frequency of a trapezoidal window is no different from the reversal frequencies of the same shape with alternative surface patterns. These data show also that, with the exception of rectangular and circular shapes, other shapes exhibit apparent reversals with about the same frequency as a trapezoid. The results from Experiment 2 demonstrate that, whereas the quadrants of orientation of a trapezoidal window are misjudged when the short vertical edge is near, the orientation quadrants of other reversing shapes are not. In the third experiment no evidence was found for a causal relationship between apparent orientation and apparent reversals, nor was there evidence for a relationship between apparent orientation and initial apparent direction of movement. Although the trapezoidal window is misjudged as to its orientation and also exhibits apparent reversals during rotation, the former is not necessary for the latter with the other shapes. In brief, the hypothesis that apparent orientation deriving from perspective cues is necessary for apparent reversals has not been sustained.

AN ALTERNATIVE EXPLANATION

In this and the following section a theory of apparent reversals of rotary motion in depth will be proposed. It will be further argued that the theory applies also to cases of reversal in static figures and objects.

When a plane shape rotates in depth relative to an observer, the retinal projection of its motion is a repeated expansion and contraction as the object moves from the frontoparallel to the sagittal plane of the observer. If the retina is considered as a plane surface then the motion of projected points follows a sine function. The retinal projection expands rapidly as the object moves from the sagittal plane ("edge-on" position) and slows, and finally ceases as it approaches and reaches the frontoparallel ("full-on" position).

Now, when the shape rotates clockwise from the sagittal to the frontoparallel plane, the retinal projection expands from its minimum width determined by the thickness of the object, to its maximum width determined by its horizontal extent. But when the shape moves anticlockwise between these planes an identical expansion of its retinal projection occurs. That is, there is an identity of retinal motion characteristics for clockwise and anticlockwise rotation. The same applies to the contraction phase as the object moves from the frontoparallel to the sagittal plane.

Graham (1963) has shown in a detailed analysis the identity of differential angular velocities for points on the surface of a rotating plane during the approach and recession phases of rotary movement. It is clear from this treatment that the subject cannot judge whether these points are approaching in a near quadrant or receding in a far quadrant, since the same sign and quantity of differential angular velocity apply in each.

Apparent reversals in rotation direction can be explained in the following terms. Since there is an identity of retinal motion for the two directions of rotation, then, in the absence of cues to direction in depth such as retinal disparity, the object will occasionally be judged as moving clockwise and occasionally as rotating anticlockwise.

The data from these experiments indicate that the identity of retinal motion characteristics for approach and recession of the rotating shape is a necessary condition for the occurrence of apparent reversals. When this condition obtains, therefore, it would be expected that judgments of approach or of recession would be equally probable. That is, when the retinal projection of the shape changes from expansion to contraction (and vice versa), the subject will judge it as either approaching or receding, and there is no reason to suppose that other than chance factors determine this judgment. In support of this is the observation that the rotating shapes are not reported as reversing during every revolution. Reversals are reported along with complete revolutions and, as will be seen below (Experiment 4), about half the possible number of apparent reversals occur during a trial. Although the retinal identity of clockwise and anticlockwise motion is clearly recognized by Graham (1963), he nevertheless attributes the apparent reversing effect to apparent orientation determined by cues to perspective. It is pertinent, however, to raise the issue concerning this relationship between apparent orientation in depth and apparent reversals. If the object appears to rotate, say, anticlockwise, then it would be expected that apparent orientation at any one moment would be in accord with that direction and vice versa. That is, apparent orientation can be regarded as a consequence rather than as a cause of apparent direction of movement. The data from Experiments 2 and 3 are convincing in showing that apparent orientation does not determine either reversals or initial direction of movement. This relationship is further discussed below.

The principle involved in this explanation is simply that an identity of retinal motion for two directions of rotation leads to an ambiguity resulting in two possible judgments of direction. It would be expected, however, that if cues to motion direction were available, then apparent reversals would either be reduced in frequency or eliminated. One such cue is that provided by retinal disparity which gives information about the true orientation of the object in depth from moment to moment. Apparent reversals are not reported with binocular viewing unless the viewing distance is greater than that within which retinal disparity is normally operative (Ames, 1951).

Further cues to motion direction are probably provided by certain shapes which exhibit few or no reversals. Although the role of these cues has yet to be confirmed, it is reasonable to discuss their possible modes of operation here. If, as with rectangles, at some stage during rotation the vertical edges project equal visual angles, then decrease of one angle with recession, and increase of the other with approach, could provide directional cues. That is, equality of retinal projections when frontoparallel provides information for direction discrimination; information not available when the two vertical edges are unequal so that at no stage of rotation are "base-line" conditions for comparison available. Support for the role of this cue is provided by Mulholland's (1956) data showing that apparent reversals occur predominantly with asymmetrical objects. It is not possible, however, to speculate with conviction on the directional cues responsible for the reduced frequency of reversal of the circular shape (Experiment 1). Although this shape reversed with a relatively high frequency, it did so less than the trapezoidal, elliptical, and irregular shapes.

ANGLES OF APPARENT REVERSAL

The theory of apparent reversal which has been set out here states that the effect derives from an identity of horizontal retinal motion projections for the approach and recession of an object rotating in depth. It follows that if an edge or point is judged as receding when in fact it is approaching, then the orientation of the object will also be misjudged. That is, the apparent orientation of the object will be determined by the apparent direction of motion. Thus, the theory is in this regard opposite to those of Ames (1951), Graham (1963), and Pastore (1952) insofar as apparent orientation is held to be a consequence of, rather than a necessary condition for, apparent reversals. In brief, it is contended that whichever direction of rotation is judged, both being equally probable, then orientation will be judged accordingly.

It also follows that apparent reversals would be expected to occur when the object is nearly frontoparallel or nearly sagittal. As the object passes through the frontoparallel the retinal projection commences to decrease in horizontal extent, and as it passes through the sagittal plane retinal expansion occurs. At these points of change an observer can make one of two judgments of rotation direction. At all other orientations reversals would not be expected since these would necessarily result in abrupt changes in apparent orientation. For example, if the right edge of a shape is judged as approaching when about 45 degrees from the frontoparallel, an apparent reversal would require a sudden jump of the edge to 135 degrees (the opposite orientation). If a reversal were to occur at this point without such an abrupt reorientation, then the object would necessarily appear to expand as the edge receded. There is no evidence for such sudden changes in apparent orientation. Thus, as the object passes through the frontoparallel and sagittal planes of the observer, changing phase from expansion to contraction, apparent direction of rotation may be judged as clockwise or anticlockwise.

Experiment 4: Angles of Orientation at Which Apparent Reversals Occur

The fourth experiment was conducted to test the prediction that apparent reversals occur when the object is in either the sagittal or frontoparallel planes of the observer.

Using the same apparatus and viewing conditions as in Experiment 1, the subjects were required to press the switch when apparent reversals occurred. These responses were recorded on a constant speed paper recorder. Also recorded were the occasions when one edge of the shape was near and exactly sagittal (0 degree). The distance between these latter signals represented 360 degrees, and it was therefore possible to establish the angular positions of the shapes at which apparent reversals occurred.

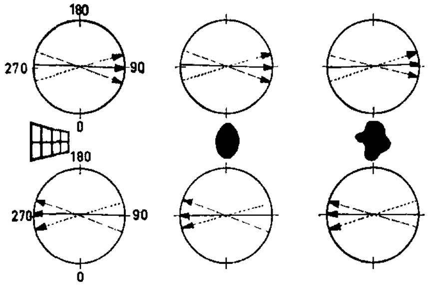

FIG. 3. Mean angles of apparent reversal for three shapes (trapezoidal window, ellipse, and irregular) rotating clockwise (dotted and dashed lines) and anticlockwise (dotted lines). (The mean reversal angles for the two directions of rotation combined are also shown, continuous lines. The apparent reversal angles are shown separately for those occurring near 90 degrees, upper row, and near 270 degrees, lower row.)

Three groups of five subjects each underwent 10 10-revolution trials, 5 in which rotation was clockwise and the other 5 in which it was anticlockwise. One group observed the ellipse, another the trapezoidal window, and the third the irregular shape. All shapes were those used in Experiment 1, and the viewing and responding conditions were also the same.

The mean angles of reversal are shown in Figure 3 for clockwise and anticlockwise rotation and for the two directions taken together. It can be observed that the mean reversal angles for the two directions combined approximate closely to the true frontoparallel (90 and 270 degrees), while those for the two directions considered singly occur beyond and before the frontoparallel. Of the 15 subjects, there were only 2 who signaled reversals near the sagittal position. These are not shown in Figure 3.

In view of the ambiguity of the stimulus conditions and the minimum velocity of the retinal projection when the object is frontoparallel, it is reasonable to attribute the difference between apparent reversal angle and frontoparallel for the clockwise and counterclockwise conditions to the decision time involved. That is, when the retinal projection changes from the expansion to the contraction phase (and vice versa) the retinal velocity is minimal and the stimulus conditions ambiguous because of the identity of retinal projections for approach and recession. It would be expected, therefore, that the subject would take some time to make a judgment of motion direction by which time the shape would have moved beyond or in front of the frontoparallel depending on direction of rotation. The significant finding, however, is that the mean reversal angle for the two directions of rotation approximates closely to the frontoparallel. The relative rarity of apparent reversals in the sagittal plane is difficult to explain on the basis of these data. It could conceivably be due to an interposition cue as one edge appears from behind the other or to the maximum retinal velocity when the object is nearly sagittal. Both hypotheses require further investigation.

A GENERAL THEORY OF APPARENT REVERSAL

Changes in apparent orientation occur with a variety of well-known two-dimensional line figures such as the Necker cube, the Mach book, and the Schroeder staircase. Although these fluctuations of apparent orientation are usually demonstrated with two-dimensional representations, they occur also with three-dimensional models (Adams, 1954; Ulrich & Ammons, 1959). It can be shown using projective drawings that two (or more) orientations of an object may cast identical projections so that apparent changes in orientation can be explained in essentially similar terms to apparent changes in direction of movement. In the first case there is an identity of retinal projections for two orientations in depth, and in the second case an identity of retinal projections for two directions of movement in depth. In the absence of cues to either true orientation or true direction apparent reversals would be expected to occur.

It would also be expected that, for both orientation and movement, instructions and motivational factors would affect apparent reversal frequencies. Since with identities of retinal projections the stimulus conditions are highly ambiguous, both instructions and motivation could be expected to determine apparent orientation and apparent direction of motion. Apparent reversals in the direction of rotary movement have been shown to occur as a function of instructions by Cappone (1963), McGee (1963), and Mulholland (1963). Ulrich and Ammons (1959) have also shown that reversals in the apparent orientation of a three-dimensional cube occur as a function of motivation. It is also of interest to note that in Experiment 1 above, either two or three 20-revolution trials were undertaken with a variety of rotating shapes, and that in every instance the frequencies of apparent reversals increased significantly from trial to trial. Since the subjects were instructed to signal *reversals,* it can be argued that there would have been a readiness to do so. It would be of interest to observe whether a trial-to-trial reduction in frequencies of apparent reversals occurs with instructions to signal complete rotations. This result would be expected from the present theory.

In terms of the theory outlined here a relationship is suggested between apparent reversals of rotary motion and the kinetic depth effect recently reviewed by Braunstein (1962). This latter effect occurs when motion in three dimensions is projected on to a plane and an observer reports three-dimensional motion with apparent reversals. Lissajou's figures, shadowgraphs, and Sinsteden's windmill are classical examples. Apparent reversals in the direction of movement with rotating planes, and with projections of these on to a plane surface (kinetic depth effect), are clearly similar. In the latter instance motion in depth is projected on to a plane prior to its projection on the retina. In this regard it is of interest to note that Kenyon (1898), who is quoted above, recognized three "illusory" effects: one in which rotation appeared to reverse direction, another in which the arms flapped together, and a third in which the arms appeared to move in and out. The last of these effects is the simple projection of three-dimensional motion onto the retina.

Finally, the apparent reversals in depth orientation of a two-dimensional figure stands in the same relation to reversals of a three-dimensional model as the kinetic depth effect does to apparent reversals in rotary (and other) motion. All four effects which have hitherto been treated separately represent instances of the same basic phenomenon. When there is an identity of retinal projections for two or more static orientations in depth, or for two or more directions of movement in depth, apparent reversals will occur providing cues to true orientation or movement are absent. For this necessary condition for apparent reversal the term "projective identity" is suggested.

REFERENCES

ADAMS, P. A. The effect of past experience on the perspective reversal of a tridimensional figure. *American Journal of Psychology,* 1954, **67**, 708-710.

AMES, A. Visual perception and the rotating trapezoidal window. *Psychological Monographs,* 1951, **65**(7, Whole No. 324).

BRAUNSTEIN, M. L. The perception of depth through motion. *Psychological Bulletin,* 1962, **59**, 422-433.

CANESTRARI, R. Ossenazioni sul fenomeno del trapezio ruotante. *Rivista di Psicologica,* 1956, **50**, 1-20.

CAPPONE, M. K. The effect of verbal suggestion on the reversal rate of the Ames trapezoidal illusion. Unpublished master's thesis, Fordham University, 1963.

DAY, R. H., & POWER, R. P. Frequency of apparent reversal of rotary motion in depth as a function of shape and pattern. *Australian Journal of Psychology,* 1963, **15**, 162-174.

GRAHAM, C. H. On some aspects of real and apparent visual movement. *Journal of the Optical Society of America,* 1963, **53**, 1019-1025.

KENYON, F. C. A curious optical illusion connected with an electric fan. *Science,* 1898, **8**, 371-372.

KILPATRICK, F. P. The Ames oscillatory effect: A reply to Pastore. *Psychological Review,* 1953, **60**, 76-79.

MCGEE, J. M. The effect of group verbal suggestion and age on the perception of the Ames trapezoidal illusion. *Journal of Psychology,* 1963, **56**, 447-453.

MILES, W. Visual illusions of motion during train travel. *Journal of General Psychology,* 1929, **2**, 141-143.

MULHOLLAND, T. Motion perceived while viewing rotating stimulus objects. *American Journal of Psychology,* 1956, **69**, 96-99.

MULHOLLAND, T. The "swinging disk" illusion. *American Journal of Psychology,* 1958, **71**, 375-382.

MULHOLLAND, T. Instructional sets and motion perceived while viewing rotating stimulus objects. *Journal of Psychology,* 1963, **56**, 233-237.

PASTORE, N. Some remarks on the Ames oscillatory effect. *Psychological Review,* 1952, **59**, 319-323.

POWER, R. P. Apparent reversal of rotary motion in depth. Unpublished master's thesis, University of Sydney, 1964.

ULRICH, P., & AMMONS, R. B. Voluntary control over perceived dimentionality (perspective) of three-dimensional objects. *Proceedings of the Montana Academy of Sciences,* 1959, **19**, 169-173.

(Received February 18, 1964)