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Apparent Rotation: Apparent Movement in Depth Induced by the Alternate Presentation of Disparate Stimuli

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by

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LIFE

The author, Linda Lawler is the daughter of William and Marion Lawler. She was born on April 4, 1951 in Chicago, Illinois.

Her elementary education was obtained in the Chicago parochial schools and secondary education at Queen of Peace High School, where she graduated in 1969. She received a Bachelor of Science degree in Psychology from Loyola University in June, 1973.

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INTRODUCTION

Apparent Movement: An Overview

"Apparent movement" refers to a variety of situations in which stationary stimuli give rise to the perception of motion. This illusion of motion has intrigued psychologists for decades and has been the topic of literally hundreds of empirical studies. It was generally believed that a full explanation of illusory motion would point the way to an overall theory of movement perception and, in general, lead to a greater understanding of brain functioning (cf. Rock, 1975). Yet, despite this voluminous amount of research, there is still no satisfactory nor agreed upon explanation of illusory motion.

The most familiar type of apparent movement, Beta motion, was originally exploited by Exner (cited by Neff, 1936) in 1875, but was not studied extensively until Wertheimer in 1912. Wertheimer's classic studies established the paradigm within which most subsequent research on apparent movement was carried out. He used the tachistoscope to sequentially present two stimuli, usually parallel lines, separated spatially by about 5 cm., so that the lines appeared simultaneous, overlapping in time or successive.

Many variables were found to determine the perceptual response: stimulus duration, intervals between stimuli, stimulus characteristics (e.g., intensity, shape, wavelength distribution), as well as conditions of instructions and subject's attitudes. Wertheimer paid particular attention to the temporal interval separating stimuli. He demonstrated that variations in this variable produced some markedly different visual experiences and referred to them as the three primary stages of apparent movement. With temporal intervals up to about 30 msec. the two stimuli appeared to be simultaneous in time. At somewhat longer temporal separations, approximately 60 msec., observers reported seeing a single line that moved from the spatial location of the first stimulus to that of the second. This latter visual phenomena was termed "optimal movement" and was reportedly so subjectively compelling that it was indistinguishable from veridical movement. When the temporal intervals were even longer, about 200 msec. the stimuli were perceived as two distinct, successive events in time. As Kolers (1972) points out, Wetheimer's stimulus flashes were usually quite brief (under 20 msec.), but his measurements nevertheless confounded variations in stimulus durations with variations in the interstimulus interval, or ISI.

Ever since Wertheimer's studies, much experimentation has been devoted to studying different forms of apparent movement and to the specification of the controlling variables which produce the phenomena (see Hovland, 1935; Neff, 1936; Aarons, 1964; Levy, 1972, for reviews). Graham (1965) states the descriptive breakdown of apparent movement types is arbitrary, but gives the classical description of the main types. Alpha movement is an apparent change in the size of an object after successive presentations. Beta movement is the apparent movement of an object from one position to another, the typical effect indicated by Wertheimer's optimal movement. Gamma movement is the apparent expansion and contraction of an object as luminance is increased and decreased. Finally, delta movement is the reverse of beta movement, where motion is perceived to occur in the direction of the latter stimulus in the former stimulus. The essential requirement is the later stimulus be brighter than the first. Various other apparent movement effects have been reported in the literature, such as movement in metacontrast studies (Kahneman, 1967), movement in backward masking studies (Carlson & Mayzner, 1977) and dynamic sequential displacement (Mayzner & Tresselt, 1970).

During the course of some unpublished experimentation with moving displays the present author serendipitously found what appeared to be a novel apparent motion paradigm. The sequential presentation of a square and a line in the same spatial location led to the perception of a single square rotating in depth. A review of the literature revealed that the display had many interesting characteristics and was apparently worth further examination.

Parameters Influencing the Illusion of Lateral Movement or Movement in Depth

The majority of apparent motion studies have shown that with stimuli consisting of disparate pairs of lines or geometric shapes, beta movement in the two-dimensional plane of the display is the usual perception. Illusory motion was found to occur with a vast number of different figural stimuli and some attention was paid to contour, but it was not until Orlansky's studies (1940) that the role of figure was studied systematically. Orlansky was mainly interested in the way differences in the shapes of the two flashes affected the temporal characteristics of apparent motion. He found that identical shapes are perceived in apparent motion over the widest range of time intervals but that good motion could be perceived with both similar and disparate pairs of stimuli. Orlansky measured onset to onset intervals or SOAs (Stimulus Onset Asynchrony). He indicated that with pairs of stimuli consisting of disparate shapes the perception of motion could have various phenomenal qualities: such as stimuli expanding or contracting while in motion, the two stimuli fusing into a single composite stimulus that is perceived in motion, one stimulus smoothly changing into the other while in motion, and movement in the third dimension. However, Orlansky did not specify the conditions which led to the specific way the diaparity between the stimuli was resolved, and was mainly concerned with the incidence and compellingness of the perception of illusory motion at given temporal conditions.

Apparent movement studies with disparate pairs of stimuli have found that the motion is always seen in the plane of the display and the disparity is often resolved by plastic deformation of shape, whereby one figure undergoes distortion of contour to become the other (Aarons, 1964; Kolers, 1972). However, Wertheimer (1912) and Neuhaus (cited in Kolers, 1972) demonstrated that illusory motion can be seen in depth if the stimuli have a discernably disparate orientation. Neuhaus alternated an upright and an inverted vee-shaped figure. With the proper timing, the perceptual experience was that of a single vee-shaped figure rotating in three dimensional space. Orlansky (1940) also found that under certain temporal conditions, arrows pointing in opposite directions can lead to the perception of an arrow spinning through the third dimension.

Although it was demonstrated that apparent motion could occur in depth with stimuli that varied markedly is orientation, the effect was not studied further for quite some time. Kolers and Pomerantz (1971) investigated the conditions under which perception of plastic deformation or the perception of rigid rotation in depth was chosen by the visual system as a means of resolving the disparity between stimulus presentations.

In the first phase of their experimentation stimuli that differed in contour, but not in orientation (circles, squares, triangles and arrows) were combined to make disparate pairs. The stimuli were sequentially presented in spatially separated locations at varying temporal orders. Their main finding was that disparate pairs of stimuli could be seen in smooth continuous beta motion with the perceived contours changing to accommodate the disparity. This plastic deformation of shape always occurred in the plane of the display and no perceptions of movement in depth were reported..

In the next phase, Kolers and Pomerantz employed stimulus pairs that consisted of right angle trapezoids with identical contours. Each pair of stimuli differed only in respect to orientation, as inversions, mirror reflections, or 180° planar rotations of each other. The stimuli were presented at various durations and ISIs, and were either laterally displaced or spatially superimposed. Observers reported whether they perceived plastic deformation in the plane of the display of a rigid shape changing its orientation in depth. Their data reveal complex interactions between duration, ISI, subjects and spatial placement. Graphical analysis revealed that overall rigid rotation was the more likely perception, and that the temporal ranges at which smooth continuous motion was perceived extended for rigid rotation in depth. Spatial superposition further extended this temporal range, but interpair differences were more marked in this condition than in the laterally displaced condition. From these studies, Kolers and Pomerantz concluded that the visual system needs more time to construct a rigid rotation in depth than a two dimensional change in contour and that the option of either depth change or shape change is influenced by the shapes presented. The stimuli whose orientation was not clearly marked, such as circles or squares, were not seen in depth. A strong orientation mark, such as the positioning of trapezoids, created an opportunity and seemed to be required for a perception of depth.

Kolers (1972) further examined the necessity of having a strong orientation mark to perceive apparent motion in depth. He displayed pairs of squares and disparately oriented trapezoids in spatially separated locations. He found that at durations and ISIs of 100 msec. simple beta motion is perceived when only pairs of squares are presented and two dimensional contour change is perceived with pairs of trapezoids. However, with increased durations, the trapezoids appear to rotate around a horizontal axis in three dimensional space while the movement of the squares is still perceived in the plane of the display. When the pairs of squares and trapezoids are both presented, the squares will also sometimes be seen to rotate depending on the locus of fixation. If the observers look at or between the squares, the squares are seen in regular beta motion while the trapezoids are seen peripherally in depth. If the observer looks at or between the trapezoids, both the trapezoids and squares are seen in depth; both shapes are seen rotating around the horizontal axis. Kolers postulated that the center of the eye needs its own discernable cue to a difference in orientation before it will generate a perception of depth. The visual system seems to be insensitive to inductions from the periphery, but when depth is initiated in the fovea this perception may generalize to other figures in the display.

The general conclusions Kolers (1972) has drawn from his study of apparent motion in depth is that this perception is not based on contour, but is primarily dependent on local patterns of excitation in the visual system, as is all apparent motion. It has been demonstrated that motion can be seen between any two shapes having the proper spatial and temporal characteristics, irrespective of their figural indentity. Therefore, Kolers postulates that phenomenal changes involving contour are interpretations, or rationalizations applied to the local interactions; the visual system responds to a compulsory pattern of excitation and transforms visual figures to accommodate the pattern. He goes on to say that in all transformations involving disparate orientations, the visual system must pay attention to something more than an excitatory signal itself, or else it could not accomplish an appropriate transformation. That something else is presumably an aspect of contour, since only disparately oriented shapes give rise to the perception of motion in depth. Yet the minimum definition of the necessary contour stimulus condition remains uncertain. Research has demonstrated that disparity of orientation can lead to rigid rotation in depth, but the visual system seems to require more energy from the stimulus or longer temporal intervals to accomplish this transformation. Kolers (1972) states that figural operations may have distinctive requirements in apparent motion, but the matter is quite complex and at the present time the role of contour remains enigmatic.

Temporal Parameters of Apparent Movement

Wertheimer (1912) demonstrated that the illusion of movement can be divided into three primary stages that are dependent primarily upon variations in temporal values; the stimuli are perceived as simultaneously presented at brief temporal separations; optimal motion is perceived at middle range of temporal variables; and at larger temporal separations the stimuli appear to be displayed successively. Many studies have since confirmed these stages (De Silva, 1926, 1928; Graham, 1963; Kolers, 1972).

In 1915 Korte measured the temporal and spatial requirements for apparent movement and proposed basic rules that govern the phenomena. Boring (1942) summarizes Korte's results as indicating that for a report of optimal movement (1) spatial separation and stimulus intensity are directly related when ISI is held constant, (2) ISI and intensity are inversely related when spatial separation is held constant and (3) ISI and spatial separation are directly related when intensity is held constant. Korte defined stimulus intensity to include everything that added to a figures impressives such as luminous energy, size, or figural detail. Kolers (1972) points out that Korte's rules imply that (1) apparent motion is perceived at very specific intersections of the variables of spatial separation, stimulus intensity and ISI, (2) the illusory object is perceived to be moving at a constant velocity and (3) the visual system requires a fixed amount of time (the interval from the onset of the first flash to the onset of the second) to process the perception of motion over a given distance.

In 1930, Neuhaus (cited in Graham, 1965; Kolers, 1972) challenged these assertions by experimentation in which he varied stimulus condtions over large ranges of relevant variables. It should be noted that Neuhaus used stimulus duration as his only measure of intensity. Neuhaus' main finding was that if spatial separation and stimulus duration were held constant, good motion could be perceived over a wide range of ISIs. If ranges of values for the variables are considered, rather than a single value, Neuhaus' findings are generally in accordance with Korte's rules. Korte's formulations are now generally viewed as statements of qualitative effects of manipulating various stimulus parameters on apparent movement rather than precise laws of perception (e.g., Kolers, 1972; Kaufman, 1974).

Kolers (1972) replotted Neuhaus' data to show that the velocity of motion is not constant, as Korte implied. Kolers states that from Neuhaus' data alone it is impossible to specify how perceived velocity varies with stimulus conditions, but his data suggest that with spatial separation and intensity held constant, the perceived velocity of apparent movement will decrease when ISIs are increased and vice versa.

There is some support in the literature for the idea of perceived velocity being inversely related to ISI. De Silva (1928) presented parallel line stimuli and varied the ISIs between them. He qualitatively measured the perceived velocity of the movement by having his subjects report whether the motion on any given trial was "faster" or "slower" than the movement observed on the immediately preceding trial. His results showed that when the ISI of a given trial was greater than the ISI of the preceding trial, the velocity of motion was reported as being slower and when the ISI was reduced the motion appeared faster. Very little attention was devoted to the perceived velocity of apparent movement until Carlson (1979) compared numerical measures of perceived velocity of apparent movement with subjectively defined values of velocity. Carlson employed spatially overlapping stimuli consisting of arrays of light-points. Observers rated the relative speed of the motion on a five point ordinal scale. Her results generally showed that with distance and intensity held constant subjective velocity appeared to become slower as the ISI values increased.

Apparent Rotation: Apparent Movement in Depth

It has been demonstrated that an option the visual system has to resolve the disparity between alternated figures is to construct the perception of a single rigid shape rotating in three dimensional space. This perception seems to require that some marked difference in orientation be evident between the members of the stimulus pair (Kolers, 1972). This research presents a novel manner of figurally marking the orientation of a square, by pairing it with a bisecting line, to produce apparent rotation in depth. Rather than displaying shapes of similar contour and providing a disparate orientation by their positioning, as is usually the case, this study employs stimulus pairs whose members differ in contour, but not necessarily in orientation. During preliminary observations squares and bisecting lines were alternately presented in the same spatial location. The most common perceptual experience seemed to be that of a single square rotating around an axis that corresponded to the orientation of the bisecting line. For example, a square paired with a horizontal bisecting line appeared to be in rotation around a horizontal axis, whereas a square paired with a vertical line appeared in rotation around a vertical axis.

The first experiment explores the existence and strength of apparent rotation produced by this novel manner of marking orientation and tests the correspondence between the axis of rotation and the orientation of the bisecting line. The second experiment further explores an aspect of contour and investigates the effect of varying the length of the bisecting line upon the perception of apparent rotation.

The major objectives of the third experiment of the present research was twofold: first to determine if the three classical stages of apparent movement that are dependent on temporal values also exist with apparent rotation and to determine if the subjective velocity of apparent rotation is constant or if it varies predictably with temporal values. Based on preliminary observations with these stimuli an ISI of 0 msec. seemed to produce the most compelling illusion, and it was therefore decided to leave the ISI set at 0 msec. and to manipulate the only other temporal variable, stimulus duration.

At first this decision might seem contradictory to previous research findings that the stages of motion and the perceived velocity are mainly dependent on variations in ISI (e.g., Wertheimer, 1912; De Silva, 1928). Yet research has also shown that stimulus duration and ISI are both important parameters of the phenomena and that they interact in determining the temporal range for apparent movement (e.g., Neuhaus, 1930; Kolers, 1963). In fact many researchers believe that the onset to onset interval, or SOA (Stimulus Onset Asynchrony), is of ultimate importance in governing the phenomena (Korte, 1915; Orlansky, 1940; Kahneman, 1967). The SOA included the duration of the first stimulus plus the ISI. In this research the ISI is always 0 msec., thereby making the SOA and the stimulus duration the same value. Thus, in the present research, manipulating stimulus duration is essentially the same as manipulating SOA. Since stimulus durations are usually quite brief, variations in the ISI and the SOA effect the stages of apparent motion in the same directions, small SOAs lead to simultaneity, large lead to alternation and motion occurs with midrange SOAs. This same relationship is predicted with apparent rotation.

De Silva (1928) and Carlson (1979) both assumed that under the conditions of apparent movement the ISI value corresponded to the time variable in the velocity formulations. The velocity of a moving object is usually calculated by dividing the distance traversed by the time it takes to traverse it. Yet there is some debate as to whether the ISI value is an appropriate definition of time in that formula. Kolers (1972) points out that apparent motion can be perceived when the ISI is 0 msec. or when the flashes overlap in time, which results in a negative ISI value. Both of these conditions would yield uninterpretable values of velocity. Kolers suggests using the onset to onset interval as a measure of time in attempting to calculate the perceived velocity of apparent motion. It is hypothesized that the perceived velocity of apparent rotation will vary consistently and predictably with variations in the SOA interval. More specifically, as SOA values increase the subjective velocity of apparent rotation would decrease.

METHOD: EXPERIMENT I

Apparatus

All stimuli were constructed and displayed by a VR-14 CRT driven by a PDP-8E Computer. A more detailed description of this hardware can be found elsewhere (Mayzner, 1975). The CRT was located in a viewing room adjacent to the one containing the hardware. A constant, low level of illumination was maintained in the viewing room by means of a small reading lamp positioned in a corner of the room. Observers viewed the CRT binocularly with the aid of a chin rest placed approximately 70 cm. from the center of the CRT screen. Each experimental trial was initiated when the observer signaled to the experimenter located in the computer room. The signal was a tone emitted by an intercom.

Subjects

Three male and three female volunteers, ranging in age from 20 to 29 years, participated in this research. All were students of psychology, three graduate students and three undergraduate students. All the subjects had either normal or corrected vision. The same subjects were used throughout the present research.

Stimuli

One member of every stimulus pair was always a square displayed in the same orientation (parallel to the horizon). The second stimulus was a single line, which if superimposed on the square would completely bisect the square into two equal parts. These bisecting lines were displayed in four different orientations; horizontal, vertical, 45° right pointing diagonal (which extends from the bottom left corner of the square to the top right corner) and 45° left pointing diagonal (which extends from bottom left corner of the square to the top right corner).

Ten different stimulus pairs were employed. Two squares of differing size were combined with each of the four bisecting lines and with the single point for both sizes of stimuli. The smaller squares measured 1.25 cm. per side and the larger square measured 5 cm. per side. The stimuli are comprised of points of light which are .025 cm. in diameter and have a display luminance of approximately 1 millilambert. The distance between the points in each stimulus was dependent on the size and shape of the stimulus. It should be noted that each vector or line of the stimuli was constructed with a compliment of "dummy" or null points in order to equate the refresh rate (by the electron gun) for each stimulus point. This resulted in equating the subjective level of brightness for each line of different size and orientation that comprised the stimuli. Each stimulus was displayed in the center of the CRT screen

Procedure

The stimuli were alternately presented in the same spatial location. Each stimulus was presented for 150 msec.; both the ISI and the intercycle interval were 0 msec. On each trial observers reported whether or not they had perceived a square rotating in depth. For these stimuli that were seen to be rotating the perceived axis of rotation was also reported. The cycle was repeated until the observer responded or ten seconds had elapsed.

Each observer was tested in a single experimental session. lasting approximately one hour. This session included a preliminary observation and explanation period, which was followed by Experiment I, a 5 minute break and Experiment II (which will be explained later). Each observer was dark adapted for 10 minutes before any observations were made.

In the preliminary observation session the stimulus pair consisted of the square and the vertical bisecting line. The smaller size stimuli were used and the cycle was set to repeat itself for 3 minutes. The experimenter was in the same room as the observer and asked the observer to verbally describe what was seen on the CRT screen. Desciptions were given until the observer described his perceptual experience to be that of a single square rotating in three-dimensional space. If it was not mentioned, the observer was asked to determine the perceived axis of rotation. The stimuli was stopped at this point and the instructions for Experiment I were given. If the observer did not perceive a single square in rotation the experiment would be terminated and the observer would be dismissed.

The observers were told that on each trial a square with a single point in the center or a bisecting line of various orientations would be presented in the middle of the CRT screen and would remain there until they signaled the experimenter that they had marked their repsonse for that trial and were ready for the next trial. The subjects were asked to first determine if they saw a square in rotation. They were given an answer sheet and were instructed to circle "R" (rotation) if the stimulus appeared to be rotating or to circle "NR" (no rotation) if the sitmulus did not appear to be in rotation. If there was no perception of rotation the observer was asked to signal for the next trial. For those stimuli that appeared to be rotating the subjects were required to determine the axis around which the square seemed to rotate and to compare that to the orientation of the bisecting line. The subjects were then asked to mark the answer sheet "C" (rotation in correspondence with the bisecting line) for those stimuli that are perceived to rotate around the bisecting line, or to mark "NC" (no correspondence between the axis of rotation and the orientation of the bisecting line) for those stimuli that are perceived to rotate along an axis that is different from the bisecting line's orientation. For those stimuli that are marked "NC" and any squares with single points that appear to be rotating, the subjects were asked to write in the axis of rotation on the answer sheet. After the answer sheet was marked the signal for the next trial was given.

Each stimulus pair was presented 5 times, resulting in 50 trials. Each of the stimulus pairs were randomly assigned twice to blocks of 10 stimuli to make two different random orders. The two different blocks were presented alternately until the 50 experimental trials had been given.

RESULTS AND DISCUSSION: EXPERIMENT I

The percentage number of rotation in correspondence with the bisecting line, rotation not in correspondence with the bisecting line, and no rotation responses were computed for each stimulus pair. Three main results are: (1) the stimulus pairs consisting of a square and a single point are never perceived as rotating, (2) the stimulus pairs consisting of a bisecting line and a square are perceived to be in rotation in correspondence with the bisecting line on 215 out of 240 trials, or 89 percent of the time, and (3) the perceived incidence of rotation not in correspondence with the bisecting line is 0.

Thus, with the proper timing, the dominant perceptual experience resulting from a square and a bisecting line being alternately, but continuously displayed in the same spatial location will be that of a single square rotating around the axis of the bisecting line. Further, if rotation is perceived it is *always* in correspondence with the bisecting line since not one incidence of rotation along a different axis was reported. Equally important was the finding that when the bisecting line was replaced by a single point the perception no longer held and rotation was not perceived. As previously discussed, a necessary condition for apparent movement in depth is that stimuli have their orientation marked. This research demonstrates that stimulus pairs consisting of squares and bisecting lines fulfill the definition of marked orientation and give rise to the perception of apparent rotation in depth. This study further indicates that it is the bisecting line that marks the orientation since the single point never produces the perception of rotation and the orientation of the bisecting line determined the axis of rotation.

The percentage number of rotation in correspondence responses given by all subjects and by each student for both size stimuli was computed. These percentages are given in Table 1. The most striking result indicated by this data is the effect of stimulus size on the incidence of apparent rotation. The incidence of perceived rotation for all subjects combined was 100 percent for the small stimuli and was 79 percent for the large stimuli.

Table 1 further shows that the incidence of perceived rotation is less for the larger stimuli than for the smaller stimuli for five of six observers. All subjects perceived the small stimuli in apparent rotation on 100% of the trials while the percentages of perceived rotation for the large stimuli ranged from 65% to 90% for the five observers. Observer number 2 also perceived the large stimuli to be in rotation on 100% of the trials, showing no size effect rather than an effect in an opposite direction.

Table 1

Percentage Rotation in Correspondence Responses by Subject in Experiment I

	Stimulus Size		
Subject	Large	Small	Combined
1	65	100	83
2	100	100	100
3	65	100	83
4	80	100	90
5	75	100	88
6	90	100	95
Total Ss	79	100	89

It should be noted that rotation was still the dominant precept for the larger stimuli, since in every case the incidence of apparent rotation was well over 50% and averaged 79%. Thus, increasing the size of the stimuli tends to decrease the incidence of apparent rotation, at least with the values employed in this research.

On the basis of preliminary observations, both size stimuli were predicted to go into rotation equally well and the appreciable effect of size of stimuli was somewhat surprising to the present author. A thorough review of the literature revealed that very little attention has been given to the parameter of stimulus size, and the role of size in apparent motion is ambiguous. Stimulus size is often confounded with luminence or intensity and with distance, if it is studied at all and many reviews ignore the variable completely (e.g., Neff, 1936; Graham, 1965; Aarons, 1964).

De Silva (1928) discussed some earlier research whose results indicated contradictory effects of stimulus size on the apprehension of apparent motion. These results were not expressed quantitatively, however, and the authors were mainly concerned with the quality of apparent motion, in terms of continuity, similarity to real movement, jerkiness, etc. De Silva (1928) did find that the motion perception was less compelling if the flashes were minute than if they were larger, but the visual angle was not specified.

He further reported that if the flashes were very large, 20° or more of visual angle, the compellingness and vividness of the motion perception again break down. Kolers (1972) states that the quality of motion will necessarily vary as a U-shaped function of stimulus size and postulates that there is an optimal size of stimulus for apparent motion. But what that size is, and how it varies with other variables, such as retinal location, intensity, or even context, has not been measured. At present there is no explanation for the effect of size on apparent motion.

Although the observers' responses to the different sized stimuli were in the same direction (the larger stimuli were seen in rotation less frequently) the magnitude of this size effect varied among the observers. Observer number 2 perceived the large stimuli to be in rotation on 100% of the trials while observers number 1 and 3 perceived them to be rotating only 65% of the time. This is most likely due to differences in thresholds and criterion for reporting apparent rotation for stimuli that lie outside the center of the optimal range of stimulus sizes for a given experimental context.

Observers' attitudes, expectations, familiarity with apparent motion, and frames of reference, etc. have been shown to influence their criterion for reporting optimal motion (see Neff, 1936; De Silva, 1926; Kolers, 1972 for discussions). These variations in criterion lead to individual differences in observers' thresholds and ranges for seeing apparent motion with variables such as spatial separation, ISI, duration, etc. It would seem probable that observers would also exhibit criterion differences for judging apparent motion or apparent rotation when the variable of stimulus size was manipulated.

These criterion differences would not be evident in the middle of the overall optimal range of stimulus size but would become more pronounced towards the ends of the range, where the perception of rotation would start to give way. In the present experiment all the subjects tested in the preliminary observation period spontaneously perceived apparent rotation with the smaller stimuli and the smaller stimuli were perceived to be in rotation on 100% of the experimental trials by every subject. This would indicate that, given these experimental conditions, the small stimuli lie near the middle of the optimal range of stimulus sizes that are perceived in apparent rotation. The incidence of apparent rotation reported for the larger stimuli was less than the 100% reported for the smaller stimuli, but was on the average well above threshold (79%) and the smallest incidence was 65%. Thus, the larger stimuli appear to be moving away from (slowly becoming too large) the optimal size for apparent rotation, but have not yet approached an upper size limit and apparent rotation is still the dominant percept for both size stimuli employed.

Unfortunately, nothing more can be specified about the optimal size range in general, or for these experimental conditions, because only two levels of the size variable were employed in this study. Yet, the results do point to the existence of an optimal size range for stimuli perceived in apparent rotation.

The percentage number of rotation in correspondence responses given for each orientation of the bisecting lines was computed and are presented in Table 2. Overall the specific orientation of the bisecting line does not appear to have much effect on the likelihood of seeing apparent rotation. For both size stimuli combined the incidence of apparent rotation perceived with the different orientations ranges from 87% to 92%. Since the small size stimuli were perceived in apparent roation 100% of the time, regardless of the orientation of the bisecting line, a closer look at only the larger stimuli might reveal an effect of orientation. This was not the case. The incidence of apparent rotation for the various orientations of the large stimuli ranged from 73% to 83%. It should be noted here that due to the small number of the larger stimuli (30) a single response changes the percentage by 3 points. Thus, no specific orientation of the bisecting line appears to be more effective in inducing apparent rotation in depth than is any other orientation of the bisecting lines.

This result is in accordance with previous research

Table 2

Percentage Rotation in Correspondence Responses

by Orientation in Experiment I

	Stimulus Size		
Orientation	Large	Small	Combined
Horizontal	80	100	90
Vertical	83	100	92
Right Pointing	73	100	87
Left Pointing	80	100	90

findings. Frisby (1968) found that similarly oriented and differently oriented lines and contours go equally well into motion. The experiments of Kolers and Pomerantz (1971) similarly found that the transitions between the different orientations were seen in depth with equal facility. All of the trapezoids they used changed equally well into all the others. The results of Carlson's (1977) experimentation with moving grids also demonstrated that the direction of motion had very little influence upon the perceptibility of motion or the perceived velocity of that motion. Thus it appears that aspects of contour, are influential in determining the phenomenol quality of illusory motion, such as plastic deformation, the direction of motion, or the axis of rotation, but it is relatively unimportant in determining the incidence of apparent motion. This is essentially what was postulated by Orlansky in 1940 and Kolers in 1972. The present results are also in accordance with this view. As long as a bisecting line was a member of the stimulus pair, apparent rotation was perceived; the incidence of rotation was similar for each orientation of bisecting line. This is not to say that contour does not enter into the perception of apparent motion, since a bisecting line must be present for the perception of apparent rotation. But it seems that once the condition of a marked orientation is met the influence of orientation is negligible in effecting the incidence or likelihood of apparent rotation.

This study was undertaken to determine if a novel form of apparent motion, apparent rotation in depth, could be induced by the alternate, but continuous, presentation of a square and a bisecting line in the same spatial location. The results indicate that apparent rotation is a stable and predictable percept with stimulus conditions. It was demonstrated that the bisecting line sufficiently marks the orientation of the stimulus pair and determines the perceived axis of rotation; the axis of rotation was always in correspondence with the orientation of the bisecting line.

The combined results suggest that the figural properties of the stimuli employed in this research do enter into the processing of objects in apparent rotation in a complex manner and effect the perception both quantitatively and qualitatively. The effect of stimulus size was rather straight forward and was shown to influence likelihood of perceiving rotation in depth. Specifically, the incidence of perceived rotation was less with the larger stimuli than with the small stimuli, but apparent rotation was still the dominant percept with both size stimuli. The effect of the orientation of the bisecting line and was more complex and was shown to effect the phenomenal quality of the apparent rotation but not the likelihood of perceiving rotation. Each orientation of the bisecting line gave rise to the perception of apparent rotation equally well but phenomenally these perceptions were different in that the perceived axis of rotation varied in accordance with the orientation of the bisecting line.

When the bisecting line was replaced with a single point apparent rotation was no longer perceived. It was thereby demonstrated that the bisecting line marks the orientation and is a necessary requirement for the induction of apparent rotation. A question arises regarding the extent of the bisecting line required for the perception of apparent rotation. Must the bisecting line extend continuously from perimeter to perimeter or will some lesser length of line be sufficient to induce apparent rotation? Experiment II was designed to address this question.

METHOD: EXPERIMENT II

Stimuli

Stimulus pairs consisted of a square combined with a shortened bisecting line. The line was shortened by removing a portion from both ends so that it did not intersect with the perimeter of the square. The remaining section was positioned in the center of the square. Both large and small size squares were studied and the length of the bisecting lines varied accordingly. The length of the remaining section was based on a ratio of 1/3 or 2/3 of the original length of the bisecting line used in the first experiment. Since length was determined by ratio the two lengths of the bisecting lines were different in absolute but not relative length for the large and small stimuli.

The first experiment demonstrated that each orientation of the bisecting line gave rise to the perception of rotation equally well. The second experiment does not manipulate orientation, but uses only the vertical bisecting line for simplicity's sake. Subjects responded to four different stimulus pairs; both sizes of squares were paired with two different lengths of bisecting lines.

Procedure

The paradigm of this experiment is identical to that of the previous experiment. The stimuli are alternately, but continuously presented in the same spatial location. Each stimulus duration is 150 msec.; the ISI and the inter-cycle interval was always 0 msec. The stimuli were presented until the observer signalled his response or ten seconds had elapsed.

The subjects participated in this experiment right after they completed the first experiment and had a five minute break. They were again dark adapted before any experimental trials were given. The subjects were told they would be viewing stimuli that were quite similar to those used in the first experiment, but in this phase the bisecting lines would all be in the vertical orientation, but would be of different lengths and would not extend from one perimeter of the square to the other. They were instructed to report whether or not they perceived a square rotating in depth around the bisecting line. Answer sheets were given to the observers and they had to merely indicate "yes" they perceived a square in rotation, or "no" they did not perceive a rotating square. After marking their response the observers signalled the experimenter they were ready for the next trial.

Each of the four stimulus pairs was presented 20 times. Five different random orders of the four stimulus pairs were randomly assigned to two different blocks of 20 stimulus pairs. These stimulus blocks were alternately presented until a total of 80 experimental trials were given.

RESULTS AND DISCUSSION: EXPERIMENT II

The percentage number of rotation responses given by each subject for each experimental condition was calculated and is presented in Table 3. The data was subjected to a two-way analysis of variance. The results of this analysis clearly showed that Factor A (proportion of bisecting line displayed) was significant ($F = 345.60$, $df = 1/5$, $p < .001$) as was stimulus size, Factor B, ($F = 70.72$, $df = 1/5$, $p < .001$); the interaction of Factors A and B approached significance ($F = 6.664$, $df = 1/5$, $p < .05$).

These findings indicate that the larger squares are perceived to be in rotation significantly less often than are the smaller squares, irregardless of the proportion of the bisecting line that is displayed. The main effect of stimulus size that was found in Experiment II is in accordance with the findings in Experiment I. The analysis also indicated that a bisecting line of 2/3 the possible length was significantly more effective in inducing apparent rotation for both size stimuli than was the bisecting line of only 1/3 the possible length. In general the data indicate that a bisecting line that does not extend the full length of the square will induce apparent rotation, but the longer the line the more likely the perception.

Table 3 shows that the same general results were found with each subject. The longer bisecting line produced greater incidences of apparent rotation than did the shorter bisecting line with both size stimuli and the greatest incidence of rotation occurred with the longer bisecting line and the smaller square. There are some relatively large ranges of percentage of rotation responses between the subjects in three of the four conditions. This could be again due to differences in subject's criteria for reporting apparent rotation.

To determine if these ranges of responses were due to subject's criteria the data from Experiments I and II were looked at to see if subjects who demonstrated stricter or looser criteria in the first experiment also tended to do so in Experiment II. Table 4 presents the incidence of rotation responses from both experiments for each subject. Since no subject differences were evident with the smaller stimuli in the first experiment only the responses to the larger stimuli were presented in Table 4. In order to further simplify the comparison two conditions which had the smallest ranges of percentages and thus less differences among subjects, in this experiment were also left out. Those being the larger square paired with the 1/3 of a bisecting line, where the incidence of rotation was never greater than 15 percent, and the smaller square paired with the 2/3 of a bisecting line, where the incidence of rota-

Table 3

Percentage Rogation Responses by Subject in Experiment II

	Proportion of Bisecting Line			
	1/3		2/3	
Subject	Small	Large	Small	Large
1	5	0	90	15
2	20	15	95	80
3	5	0	90	20
4	10	5	95	55
5	15	10	80	65
6	40	15	100	75
Total Ss	15	7	92	51

Table 4

Percentage Rotation Responses in Selected Conditions from Experiments I and II

	Experiment II		Experiment I
Subject	1/3 Small	2/3 Large	Large
1	5	15	65
2	20	80	100
3	5	20	65
4	10	55	80
5	15	65	75
6	40	75	90

tion responses was never less than 80 percent. Subjecting the data to a correlational analysis yielded the following results. Subjects perception of rotation with the large squares in Experiment II and the large squares in Experiment I were found to be significantly related ($\underline{r}^2 = .91$, $\underline{t} = 4.390$, $\underline{df} = 5$, $\underline{p} < .005$). The relationships between the subjects performance in the other stimulus conditions, between the small and large squares in Experiment II and between the small squares in Experiment II and the large squares in Experiment I, were found to be minimally significant ($\underline{r}^2 = .76$, $\underline{t} = 2.339$, $\underline{df} = 5$, $\underline{p} < .05$; and $\underline{r}^2 = .71$, $\underline{t} = 2.018$, $\underline{df} = 5$, $\underline{p} < .05$, respectively).

Subjects with a strict criteria for judging apparent rotation will have fewer rotation responses than those subjects who use a looser criteria. Table 4 shows that Subjects number 2 and 6 perceived the greatest amount of apparent rotation in the first experiment, 100% and 90% respectively, indicating they had the loosest criteria for reporting rotation. These same subjects seemed to also have the loosest criteria for reporting rotation in the second experiment. The incidence of rotation reported with the large square and the 2/3 of a bisecting line was 80% for Subject 2 and 75% for Subject 6, which were the two highest incidences. These same two subjects also had the greatest incidence of rotation with the small square and the 1/3 of a bisecting line. Subjects number 1 and 3 only perceived the large square in rotation on 65% of the trials in the first experiment and these were the lowest percentages. They also exhibited the strictest criteria for judging rotation in this experiment. Both perceived rotation with the small squares and 1/3 bisecting lines on only 59% of the trials. With the large square and 2/3 of a bisecting line Subject number 1 reported an incidence of rotation equal to only 15% and Subject number 3 reported 20%. The two remaining subjects, numbers 4 and 5, seemed to use a criteria that was in the middle in the previous experiment and their performance was similar in this experiment. It seems that subjects do in their criteria for reporting apparent rotation, especially with stimulus conditions that do not produce optimal rotation. Yet observers tend to be consistent in the degree of strictness of their criteria for judging different stimulus conditions.

The first two experiments dealt mainly with aspects of figure and their effect on apparent rotation. The next experiment will explore the effect of varying temporal parameters on the perception of apparent rotation.

METHOD: EXPERIMENT III

The major purpose of this experiment was twofold: first, to determine if the three classical states of apparent movement also exist with apparent rotation and are likewise dependent on temporal values and second, to determine if the perceived velocity of apparent rotation is constant or if it also varies predictably with temporal values. Some changes in the usual stage labels was necessary to accommodate the fact that with the present paradigm no distanced is apparently traversed and the movement occurs in the same spatial location. The alternation phase of regular apparent movement will also be referred to as alternation, the stage of optimal motion will be termed rotation and the stage of simultaneity will be referred to as flicker, which is defined as occurring when the stimuli appear to be fused into a single stimulus being steadily displayed but having a slightly flickering appearance. The perceived velocity of apparent rotation was measured relatively and each rotating stimulus pair was judged to be in either slow, medium, or fast rotation.

Stimuli

Four of the stimulus pairs from the first expeiment were employed in this experiment; a square paired with either a horizontal or vertical bisecting line was displayed in both sizes.

Procedure

As in the preceding experiments the stimulus duration was the same for both members of the stimulus pair. It should be remembered that in this research the SOA is identical to the stimulus duration, and so the five SOAs are also the five different stimulus durations. As consistently done throughout this research the ISI and intercycle interval were both set at 0 msec. This cycle was repeated until the observer indicated he had responded to that trial or for ten seconds.

Based on preliminary observations with these stimuli the temporal values employed ranged from 20 sec. to 280 msec. as these seemed to be the values where the stages of alternation and flicker consistently occurred. Five SOA values were employed: 20, 100, 150, 200 and 280 msec. Subjects were asked to first determine if the stimuli appeared to be "alternating," "rotating," or "flickering." For those stimuli that appeared to be rotating they were asked to rate the speed of rotation as either "fast," "medium," or "slow."

Each of the four stimulus pairs was presented 20 times at each duration. Four different random orders of the 20 experimental conditions were randomly combined to make a block of 80 experimental trials. This block was presented to the observer 5 times, resulting in 400 experimental trials. The observers were given the following instructions:

> In the experiment today you are going to observe two sizes of squares with either vertical or horizontal bisecting lines. You will be able to perceive three distinct phenomena: (1) Rotation: the stimuli will be rotating as in the previous experiments. (2) Flicker: the stimuli will appear to be almost stationary but have a slight flickering. (3) Alternation: the square and a bisecting line will be alternately displayed, one right after the other. On each trial first determine which of these three phenomena you see. If you perceive "Flicker" or "Alternation" please indicate that on your answer sheet. If the stimuli are seen in rotation I would like you to focus your attention on the relative speed of the rotation. Then rate that speed as "Slow," "Medium," or "Fast" "Rotation" and mark your answer sheet accordingly.

Each observer then participated in a practice session to familiarize himself with the experimental task. One of the four stimulus pairs (small square and vertical bisecting line) was presented in order of increasing stimulus duration and the observer was encouraged to apply the velocity judgments accordingly. The remaining three stimulus pairs were also presented in order of increasing stimulus duration during the practice session.

The observers were tested in two sessions, which lasted approximately 45 minutes, and included a five minute break. The first experimental session consisted of the practice session plus two blocks of experimental trials. The second session was conducted within seven days of the first session. Before data collection on the second day subjects were given half the practice trials to reacquaint themselves with the experimental task.

RESULTS AND DISCUSSION: EXPERIMENT III

For every subject the number of responses in each rating category (alternation to flicker) at the different SOA values was calculated. To determine if these rating categories were dependent on SOA values a Friedman two-way analysis of variance was performed. To compute the Friedman analysis the data must be cast in a two-way table where the rows represent the subjects and the columns represent the various stimulus conditions (SOA values). Then each row gives the scores of one subject under all conditions. The scores in each row are then numerically ranked and the analysis is performed on these ranks. To perform the analysis on these data the rating categories were first given numerical values. A response of "Alternation" scores a 1, "Slow Rotation" a 2, "Medium Rotation" a 3, "Fast Rotation" a 4 and "Flicker" a 5. The sum of these values was computed as a final score for each cell in the table. These final scores were then ranked from 1 to 5 for each subject. The Friedman analysis performed on these ranks was significant ($\underline{Xr}^2 = 318.0$, $\underline{df} = 4$, $\underline{p} < .001$). This indicates that the categorical ratings were dependent on temporal values and each category was significantly different from the others.

Three Stages of Motion

The next step of the data analysis was to determine the percentage number of trials in which alternation, rotation, or flicker responses were given in each experimental condition. At this point velocity discriminations were not taken into account and no distinction was drawn between slow, medium, and fast, rotation responses. These percentages are shown in Table 5. Overall these data show that the three classical stages of apparent motion (succession, optimal motion/rotation, and simultaneity/flicker) are also found with apparent rotation and are similarly dependent on temporal values. The squares are seen to be flickering at small SOAs, rotating at medium values and alternating at the largest SOA value.

A closer inspection of the data reveals that the temporal values employed in this study exceeded the lower temporal limit (point at which rotation gives way to flicker) but were very close to the threshold limit (where alternation gives way to rotation), especially for the smaller stimuli. With an SOA value of 20 msec. both the large and small stimuli were perceived to be flickering on 100% of the trials. While at the next larger SOA (100 msec.) only 1% of the smaller stimuli and 6% of the larger stimuli are seen to be flickering. An SOA of 20 msec. produced stimuli in the "extreme stage" (so termed by Wertheimer, 1912) of flicker and never produced apparent rotation, and the amount of flicker perceived with 100 msec. is negligible. Therefore the lower threshold value must

Table 5

Percentage Alternation, Rotation and Flicker

Responses in Experiemnt III

	Stimulus Size					
	Small			Large		
SOA	A	R	F	A	R	F
20	-	-	100	-	-	100
100	-	99	01	-	94	06
150	-	100	-	-	100	-
200	-	100	-	-	100	-
280	53	47	-	65	35	-

lie somewhere between 20 and 100 msec. Table 5 shows that an SOA value of 200 msec. does not give rise to any instances of alternation for either size stimuli. With the small stimuli SOA values of 280 msec. produced the perception of alternation on 53% of the trials and the perception of rotation on 47% of the trials, which appears to be very close to the upper SOA threshold value. With the larger size stimuli SOAs of 280 msec. gave rise to alternation 65% of the time and to rotation only 35% of the time, which indicates 280 msec. is probably a little longer than the upper limit for the larger stimuli. For both sizes of stimuli SOAs of 280 msec. do not produce extreme stage alternation, but can still induce apparent rotation.

Size is thus seen to have somewhat of an effect on the upper limit of the SOA values lending to apparent rotation. The data indicate that most likely the upper SOA limit is a little shorter for the large stimuli than for the small stimuli. At first glance it might appear that size only has an effect on the upper limit, but it must be remembered that 20 msec. was found to be well below the threshold SOA value for the perception of flicker and 100 msec. was well above that limit. Quite possibly size variables would also effect the lower limit for apparent rotation, but this research does not specify in which way. It appears that stimulus size does not make a difference at temporal values that are beyond the threshold values.

This study was not designed to determine SOA threshold values for the three stages of apparent rotation, but its main purpose was to demonstrate their existence and test their dependence on temporal parameters. Based on preliminary viewing of the stimuli, the present author was relatively confident that both the largest and smallest SOA values chosen were sufficiently beyond threshold values to produce stimuli on the extreme stages. Yet the difficulty in establishing an upper limit encountered in this study has been briefly mentioned in the literature.

Brenner (1953) found greater variance in his data for the distinction between motion and succession than between simultaneity and motion. In his book Kolers (1972) describes a series of experiments that led him to the conclusion that the difference between succession and motion is difficult to measure accurately. He found that subjects were apparently willingly to continue seeing alternation as motion once they had seen motion. In the present study the observers had particiapted in Experiments I and II and were apparently quite familiar with seeing apparent rotation. The finding that they continued to perceive alternation as motion is in accordance with Kolers' and Brenner's findings.

Nevertheless, it was found that variations in the SOA values gave rise to three perceptably distinguishable stages of apparent rotation. At SOA values of 20 msec. the square and the bisecting line appeared to be continuously displayed but seemed to be slightly flickering. With SOA values between 100 and 200 msec. apparent rotation was seen. At an SOA value of 280 msec. some stimuli appeared to be in rotation but the amjority of stimuli were perceived to be alternately displayed. It is predicted that at some SOA value greater than 280 msec. alternation would always be perceived.

Perceived Velocity

For each SOA value the percentage of responses given in each velocity rating category was computed for both size stimuli. These data are presented in Table 6. Overall these data reveal that perceived velocity appeared to become slower as the SOA values increased. This trend was practically identical for both large and small stimuli.

Stimulus size was found to have an influence on the perception of apparent rotation in the first two experiments and on the upper threshold SOA values. The larger squares were perceived less radily in apparent rotation. Yet the data from this experiment indicates that subjectively velocity ratings were given similar velocity ratings. The perceived velocity of apparent rotation seems to be primarily dependent on temporal values and the effect

Table 6

Percentage of Responses in Each Velocity Rating Category in Experiment III

		Rating Category				
Size	SOA	Flicker	Fast	Rotation Med	Slow	Alternation
Large	20	100	-	-	-	-
	100	01	84	15	-	-
	150	-	10	82	08	-
	200	-	01	48	51	-
	280	-	-	-	47	53
Small	20	100	-	-	-	-
	100	06	85	09	-	-
	150	-	22	72	06	-
	200	-	01	48	51	-
	280	-	-	-	35	65

of stimulus size seems negligible, at least past threshold values for rotation.

The first experiemnt found that on only 79 percent of the trials were the large stimuli judged to be rotating. This experiment demonstrated that velocity ratings are assigned with equal predictability and consistency to both large and small stimuli. At first this might sound inconsistent but can be explained by referring to previous research findings. Instructions, expectations and practice etc. have been found to influence the perception of apparent motion (e.g., Wertheimer, 1912; De Silva, 1928; Kolers, 1972). In general these factors can facilitate perceiving apparent motion under the right conditions. In the previous experiments the observers were asked to determine if the stimuli were rotaing or not. In this experiment observers were also asked to determine if stimuli were perceived to be in rotation, but this was in the context of determining the stages of apparent rotation and not in determining the incidence of rotation. Given the conditions of this last experiment, the observers most likely perceived apparent rotation consistently with the large stimuli. If it was not a spontaneous perception the observers could seemingly induce it. This is not to say that suggestion variables are the cause of the perception, but as Koler (1962) states, they merely facilitate it.

Variations in temporal parameters effect apparent rotation in much the same way as they effect regular apparent movements. Smaller SOA values (20 msec.) led to the perception of the stimuli being continuously displayed on the screen but slightly flickering. The middle range of SOA values (100 to 200 msec.) produced stimuli seen in apparent rotation. The largest SOA values (280 msec.) caused stimuli to appear as if they were alternately displayed on the majority of trials. The incidence of the perception of alternation would probably increase as the SOA value increased.

The perceived velocity of apparent rotation was also found to vary predictably and consistently with variations in the SOA values. As the SOA increased the perceived velocity of apparent rotation appeared to decrease. It therefore appears that as SOA values increase from a very small value to a larger value stimuli are seen first to flicker, then in slow rotation and on to faster rotation until the stimuli is rotating so fast that it appears to only be flickering. These changes in perception were found to be primarily dependent on SOA values and not on figural aspects of stimuli.

GENERAL DISCUSSION

The research reported in this paper was conducted to demonstrate a novel form of apparent motion, one in which there is no distance traversed, but the stimuli are seen rotating around a fixed axis in depth. This illusion of apparent rotation is induced by alternately displaying a square and a bisecting line in the same spatial location. With repeated display the usual perception was that of a square rotating around the axis that corresponded to the orientation of the bisecting line. Apparent rotation was found to have many characteristics common to regular beta apparent motion and to be similarly dependent on stimulus parameters. It is proposed that apparent rotation is part of the broader phenomena of illusory motion; while beta apparent motion typically occurs with spatially separated stimuli, apparent rotation will occur with spatially superposed stimuli having the proper figural characteristics. Research on an apparent rotation presents findings, and points to questions that should be included in the general theory of illusory motion perception.

Although there has been much theoretical debate since its discovery there is still no single satisfactory theory to account for apparent motion. Research has shown that the perceptual construction depends critically upon spatial and temporal characteristics and many authors propose a neural mechanism having primarily spatial and temporal components (e.g., Graham, 1965; Orlansky, 1940; Aarons, 1964). Kolers (1963, p. 204) reduces this account further and states that "the mechanism of apparent movement seems to be principally a temporal one with only a limited spatial component." The present findings tend to substantiate Koler's view regarding the primacy of the temporal component, but also suggest that figural characteristics should be looked at more closely.

In this study apparent rotation was found to also depend critically on temporal characteristics. Increasing SOA values led from a perception of flicker to swiftly rotating stimuli on to slowly rotating stimuli and then to the perception of alternately displayed stimuli. What is interesting is that normally the corresponding stages of regular apparent motion are produced by variations in ISI values (e.g., Wertheimer, 1912; Boring, 1941; Kolers, 1972). Some authors have proposed that it is the onset to onset interval, or the SOA, that is the critical temporal value, because stimulus duration has been demonstrated to interact with ISI (e.g., Korte, 1915; Kahneman, 1967). There is no experimental support for stimulus duration producing the different stages of motion and it is highly unlikely that in this study the stages of apparent rotation were solely dependent on the variable of duration. The ISIs were always 0 msec, and the only other temporal variable manipulated was SOA value. This research would support the view that the SOA value is the critical value in the production of apparent motion, or at least in the production of apparent rotation if the two are subsumed by different mechanisms.

It was generally felt that the role of figure was negligent in the production of apparent motion since the phenomena was demonstrated to occur with a vast number of figurally different stimuli (Orlansky, 1940; Aarons, 1964). Kolers (1972) states that figure is not a cause of the perception of apparent motion, but mainly exerts an influence on the interpretation of the motion, i.e., interpreting what is moving. Yet, at certain points in his book, Kolers discusses findings from research with trapezoids which show that contour does enter into the perception of apparent motion. He further states that there appears to be some minimum definition of contour that must be met for the perception to occur,but that as yet not much is known about that minimal definition of to which aspect of contour it applies. Perhaps future research with spatially overlapping stimuli could be useful in which to investigate the role of contour in illusory motion.

In the present research contour was found to play a complex role in the induction of apparent rotation, and affected the perception both qualitatively and quantitatively. It may be important to note that the axis of rotation was always perceived to be in correspondence with the orientation of the bisecting line. This could be considered to be merely a qualitative effect relating to the interpretation of motion or it could have greater significance in understanding the phenomena. Another effect dealing with figural aspects of stimuli was the reduced incidence of rotation seen with shortened bisecting lines. It is possible this result coupled with the lessened incidence of rotation found with the larger stimuli could really be more of a spatial characteristic than a figural characteristic. Since there was no spatial distance traversed by the stimuli and the movement occurred in the same spatial location,it would seem that there was no opportunity for spatial characteristics to be of influence. Yet, the length of the bisecting line and the stimulus size could possibly be analogous to the spatial distance traversed in regular apparent movement since in a way they also define the spatial extent of the movement. This question could be answered in future research with spatially superposed stimuli as could other questions relating to the role of contour. It would be interesting to see if apparent rotation could be produced with other geometric shapes such as circles, triangles etc. combined with some type of bisecting lines.

Although temporal mechanisms appear to be of primary importance in the production of illusory motion, it seems that the system mediating the perception is highly complex and the role of contour could be of importance in producing apparent motion with spatially superposed stimuli. The complicated interweaving of the components in the mechanisms subserving apparent motion remains to be unraveled in future research.

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APPROVAL SHEET

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Arts.

March 1, 1982
Date

Director's Signature