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ADJACENCY AND ATTENTION AS DETERMINERS OF PERCEIVED MOTION[1]

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Abstract—Motion induction was investigated as a function of depth adjacency and attention. Moving induction objects producing opposing induction effects in a test object were presented simultaneously at different distances in the visual field with the apparent distance of the test object varied relative to the induction objects. In agreement with the adjacency principle, it was found that separating the test and induction object in apparent depth decreased the induction effect. Instructions to attend to one and to ignore the other induction object while looking at the test object clearly modified the induction effect and accounted for about half of the total effect produced by depth adjacency. The results are discussed in terms of the measurement of attention and the ability to perceptually organize the visual world.

The magnitude and direction of the perceived motion of a point or object can be influenced markedly by the physical motion of adjacent points or objects. Examples of such relative motion effects are provided by research concerning the vector analysis of the perceived motion of moving points (Borjesson and von Hofsten, 1973; Johansson, 1971, 1973, 1974) and by instances of induced motion (Brosgole, 1966; Duncker, 1939; Wallach, 1959). These examples indicate the importance of the relative motion between objects in determining perceived motion, at least in situations in which the objects are not too far separated in the perceptual field. As the perceived distance between the objects or points increases in depth (Gogel and Koslow, 1971, 1972) or in separation in a frontoparallel plane (Gogel, 1974), the perceptual influence of one moving object upon another decreases. This change in the effectiveness of perceptual interactions as a function of object separation supports the "adjacency principle" which states that the effectiveness of cues between objects in determining perceived object characteristics (including that of perceived motion) is inversely related to the perceived separation of the objects (Gogel, 1970).

One possible explanation of the adjacency principle is in terms of attention. Perhaps when objects are adjacent it is difficult for the observer to ignore one while making judgments concerning the other. That attention can somewhat modify the effectiveness of perceptual interactions is indicated by experiments in which it was found that the effectiveness of a relative cue between two objects was greater if the task required the observer to attend directly to those objects (Gogel, 1965, 1967). Although it is unlikely, on the basis of these results that attention can account for the entire adjacency effect, it is possible that the tendency for an observer to notice objects that are near the object being considered can contribute to the adjacency factor. For example, it has been found that the perception of relative motion can be modified in some cases by the observer changing the point upon which his gaze is fixed (Johansson, 1974). Possibly this effect of direction of gaze is mediated by attention rather than by fixation *per se*. The purpose of the present study is to examine the possible effect of attention on the perception of motion in situations in which the perceived motion is influenced by perceptual interactions between the point being considered and other moving points in the visual field.

In the perceptual interaction of two or more objects, the object whose perceptual characteristics are being reported will be called the test object. The other objects which influence the perception of the test object will be called induction objects. As has been discussed previously (Gogel, 1974; Gogel and Newton, 1975) demonstrations of the adjacency principle essentially involve cue conflicts. An example of a three dimensional cue conflict is shown in the perspective drawing of Fig. 1. This figure illustrates two displays, one at a near and the other at a far distance from the observer, with each display subtending the same visual angle. The two horizontally moving points at the near or far distance are called the near or far induction points or the near or far induction object. The vertically moving point at the near or far distance is called the near or far test point or test object. The repetitive motion and the phase of the motion of the test and induction objects are indicated by the arrows. The phase of motion of the induction object is opposite at the near and far distances. As shown in Fig. 1, for the near display, as the induction points move left the test point moves upward. As the induction points move right the test point moves downward. For the far display, as the induction points move right the test point moves upward. As the induction points move left the test point moves downward. The effect of an induction object on the test object is to cause a difference

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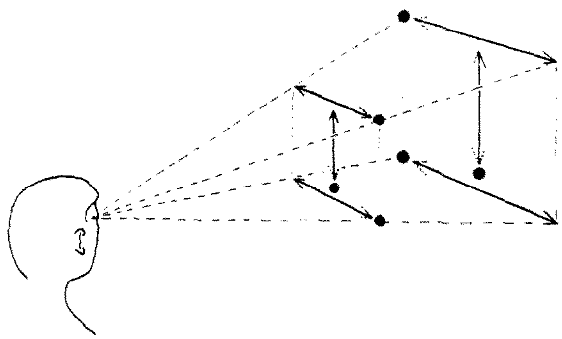

Fig. 1. A perspective drawing of the near and far stimuli used in investigating motion induction for induction objects at two different distances from the observer.

between the physical and apparent path of repetitive motion of the test object. If the apparent path of repetitive motion is from upper right to lower left and returning from lower left to upper right, etc., this will be referred to as motion in an apparent direction between upper right and lower left. If the apparent path of repetitive motion is from upper left to lower right and returning from lower right to upper left, etc., this will be referred to as motion in an apparent direction between upper left and lower right. As will be shown, if the near display is presented alone, the induction effect would cause the test object, despite its physically vertical motion to appear to move in a direction between upper right and lower left. Also, as will be shown, if the far display is presented alone, the induction effect would cause the test object to appear to move in a direction between upper left and lower right. Consider the case in which both induction objects are presented simultaneously with a single test object at either (not both, as in Fig. 1) the near or far distance. In this case, the induction effects from the two induction objects on the single test object will be opposite (a cue conflict will occur). According to the adjacency principle the apparent direction of the path of motion of the test object in this case will be determined more by the perceptually adjacent rather than by the perceptually displaced induction object. Thus if the test object is closer in apparent depth to the near than to the far induction object in Fig. 1, it will appear to move in a direction between upper right and lower left. On the other hand if it is closer in apparent depth to the far induction object in Fig. 1, it will appear to move in a direction between upper left and lower right.

If the effect of depth adjacency occurs as discussed above, the effect of attention can then be investigated. Suppose for example, that the test object is at the near distance in Fig. 1 with both induction objects presented simultaneously. If the attention of the observer is directed to the near induction object, the attention and adjacency factor will be in agreement and the path of apparent motion of the test object will be between upper right and lower left. But, if the attention of the observer in this situation is directed to the far rather than to the near induction object the attention and adjacency factors will be in opposition. If attention is effective under these conditions the path of apparent motion of the test object should be modified toward that expected from the far induction object. Conversely, if the test object is at the far distance, changing the attention from the far to the near induction object should modify the apparent direction of the path of motion of the test object toward that expected from the near induction object. Also, if the factor of voluntary attention is responsible for the entire induction effect, the direction of the apparent motion of the test object should be determined entirely by the attention of the observer, not by the distance position of the test object relative to the induction objects.

EXPERIMENTAL

Apparatus

Figure 1 can be used to consider the stimuli presented to the observer in several portions of this study. The dashed lines in Fig. 1 indicate the visual angles and perspective in the drawing and were not present during the experiment. The near and far induction objects could be presented simultaneously or one at a time. Unlike the situation shown in Fig. 1, two test points were never presented at the same time. Instead, a test point with the same phase of motion was presented at either the near or far distance. As is indicated in Fig. 1, the separations and motions of the moving points at the near and far distances were such as to produce the same stimulus (the same visual angle) on the eye. The induction object or objects and the test object were the only objects visible with the remainder of the visual field totally dark. The objects always were viewed binocularly with the cue of binocular disparity producing a perception of depth between the near and far induction objects when these were presented simultaneously and also determining the apparent depth position of the test object relative to each induction object.

The observer sat inside a light-proof booth and, with his head in a head and chin rest, viewed two TV screens through a nonrestrictive aperture. The aperture contained polaroid material with the orientation of the polaroids opposite for each eye. The viewing aperture could be occluded by a shutter controlled by the experimenter from outside the booth. Inside the booth, to the right of the aperture, was a white metal rod (21 cm long and 4 mm dia) pivoted at its midpoint, which the observer could rotate to indicate the perceived orientation of the path of motion of the test object. The adjustable rod was mounted on a black disc (21 cm dia) which was oriented in the observer's frontal plane when he turned toward it to make his adjustment. A white horizontal and white vertical line painted on the disc served as reference lines for the adjustment. By means of an extension of the pivot shaft attached to the adjustable rod, the setting of the rod could be read by the experimenter from a position outside the booth.

The configurations of moving points on the two TV screens were produced and controlled electronically. The amount of time for each point to complete a cycle of motion was always 6.3 sec (9.5 c/min). During the presentations of the stimuli, the room and booth lights were turned off and nothing was visible from the observation position except the moving points. The distances of the far and near TV screens from the observer were 135 and 94.5 cm, respectively. In order to properly position and present simultaneously the stimuli on the near and far screens, the near screen was seen by reflection from a partially transmitting–partially reflecting mirror and the far screen was seen through this mirror. The test object with a constant visual angle of motion could be generated on either the near or the far screen. If the accommodation of the test point were always the same as that of the induction object at which it appeared, the adjacency effect might possibly be attributed to this factor. It seemed desirable, therefore, for the accommodative difference between the test and induction object to be independent of whether the test object appeared at the distance of the near or far induction object. For this reason, the test object generated on one screen was sometimes modified in convergence so as to appear at the distance of the other screen. This was accomplished by producing two images of the test object with one seen only by the left eye and the other only by the right eye with the use of polaroid material properly oriented at the screen and at the observation position. The result was that a single vertically moving point at the near or far accommodative distance could be made to appear stereoscopically at either the near or far screen. A red filter was placed over the path of motion of the test object so that its color would clearly distinguish it from the bluish induction objects. The apparent brightnesses of all of the points were equated by using strips of neutral density filters on the TV screens where required. At the far position, the physical motion of the test object at the top and bottom of its travel was separated by 1.5 cm from the path of horizontal motion (17.3 cm) of the induction points with the induction points vertically separated by 17.1 cm. The physical motion, distances, and separations at the near screen were reduced appropriately from those at the far screen so that the near and far displays were identical on the eye except that the phase of motion of the induction object (points) was opposite at the two distances.

Procedure

Two kinds of instructions were used. In the first part of the experiment, the observers were asked to note the apparent direction of motion of the red point (the test object) and following the presentation to indicate this apparent direction by their adjustment of the rotatable rod. These are called the neutral instructions. In the second part of the experiment, the observers also indicated the apparent direction of motion of the red point; but they were instructed to note this apparent direction while gazing at the red point and simultaneously paying attention to one of the induction objects and ignoring the other. These are called the attention instructions. Which of the two induction objects (the near or far pair of horizontally moving points) was to receive attention and which was to be ignored was systematically varied. One purpose of the first part of the experiment (the part using the neutral instructions) was to establish that the induction effects in the expected direction would occur from the induction and test motions used in the experiment. For this purpose, one induction object was presented at a time with the test object always stereoscopically in the plane of this single induction object. Another purpose of the portion of the experiment using the neutral instructions was to establish that the expected effect of depth adjacency between a test and induction object would occur when the two induction objects at different stereoscopic distances were presented simultaneously and the single test object was stereoscopically in the plane of one or the other of the induction objects. For this purpose the near and far induction objects were presented simultaneously and the relative effectiveness of each in determining the apparent direction of motion of the test point was evaluated as a function of the near or far position of the test object. Observer reports of the apparent distances of the test and of the induction object or objects were also obtained with the neutral instructions in order to ascertain that the expected distance relations were perceived.

The purpose of the second part of the experiment (the part using attention instructions) was to evaluate the role of voluntary attention in modifying the effect of depth adjacency. For this purpose the induction objects at the different stereoscopic distances always were presented simultaneously with the single test object sometimes at the stereoscopic distance of the one and sometimes at the stereoscopic distance of the other induction object. The induction objects were never presented singly with the attention instructions.

The observers were 16 men and 16 women from an undergraduate course in psychology who partially satisfied a course requirement by participating in the experiment. All had a visual acuity in each eye (corrected if necessary) of at least 20/20 and a stereoscopic threshold of at least 22" as measured on a Keystone Orthoscope. None were informed of the purpose of the experiment prior to serving as observers.

The observers were given general instructions concerning their task before entering the observation booth and more specific instructions thereafter. The general instructions specified that the apparent direction of motion of a red point of light was to be indicated by using the rotatable rod. This task was illustrated with the aid of a model consisting of a bead moveable along a wire to represent the red point and also a small version of the rotatable rod. During the experiment, on each trial following the presentation of a stimulus, the viewing aperture was occluded and the light in the observation booth was turned on. The observer, after removing his head from the head and chin rest and turning to look at the adjustable rod, indicated by his adjustment the apparent direction of motion of the red point he had been viewing. Prior to this adjustment, while still observing the stimuli, and under the neutral instructions only, the observer verbally indicated in feet or inches, or in some combination of both, the apparent distance of the induction object or objects and of the test object from his eyes. The order of reporting the apparent distances of the several objects was varied between observers.

The stimulus presentations in which no mention was made of attention (the neutral instructions) always preceded those in which the attention was varied by the instructions. The order in which the near and far test object was presented with either the neutral or attention instructions and the order in which the near or far induction object received the observer's attention (while he continued to gaze at the test point) was systematically varied between observers. With the neutral instructions, the simultaneous presentations of the two induction objects always preceded the presentations of the single induction objects.

RESULTS

The average verbal reports of distance (converted to centimeters) obtained with the neutral instructions and the simultaneous presentations of the induction objects were that the test object was at 71 and 134 cm and the induction objects were at 71 and 130 cm for the near and far distances respectively. These results indicate that the apparent depth relations expected from the cues of binocular disparity usually occurred. When only one induction object was present, binocular disparity was available to determine only the perceived equidistance of the test object with respect to the induction object and the only cue available to specify the perceived distance of the display from the observer was the convergence of the eyes. The average verbal reports of distance under these latter conditions were that the test object was at 87 and 102 cm and the induction object was at 93 and 99 cm for the near and far distances, respectively.

The results in degrees from indicating the apparent direction of the motion of the test object from the vertical are shown in Table 1 for both the neutral

Table 1. Deviation in degrees of the direction of the apparent motion of the test point as measured from the vertical as a function of depth adjacency and attention. A positive value indicates that the apparent motion was between upper left and lower right. A negative value indicates that the apparent motion was between upper right and lower left. The physical motion of the test point was always vertical.

	NEUTRAL INSTRUCTIONS				ATTENTION INSTRUCTIONS			
	ONE INDUCT. OBJECT		TWO INDUCT. OBJECTS		TEST OBJ. NEAR		TEST OBJ. FAR	
	INDUCT. & TEST NEAR	INDUCT. & TEST FAR	TEST NEAR	TEST FAR	ATTEN. NEAR	ATTEN. FAR	ATTEN. NEAR	ATTEN. FAR
MEAN	−25.1	+27.1	−15.9	+18.3	−18.9	+3.7	+7.2	+24.2
MEDIAN	−28.0	+27.0	−13.5	+21.0	−21.2	0.0	+7.5	+24.8
S.D.	11.2	12.6	13.6	10.1	12.5	15.4	15.2	10.4

and attention instructions. It will be recalled that the direction of the physical motion of the test object was always vertical and, depending upon the experimental conditions, the induction effect could displace the direction of apparent motion of the test object in one direction or the other from the vertical. A positive value in Table 1 indicates that the average (or median) direction of apparent motion of the test object was between upper left and lower right. A negative value in Table 1 indicates that the average (or median) direction of apparent motion of the test object was between upper right and lower left. Consider first the results using the neutral instructions. The effect of a single induction object on the apparent direction of the path of the stereoscopically equidistant test object was large and differed markedly as a function of the phase of the induction object. This difference of 52.2° (from −25.1° to +27.1°) was significant in the expected direction beyond the 0.01 level ($t = 12.83$, d.f. $= 31$). With the simultaneous presentation of the two induction objects the change in the apparent direction of the motion of the test object as a function of the phase of the stereoscopically equidistant induction object was 34.2° (from −15.9° to +18.3°). This difference also was significant at the 0.01 level ($t = 9.67$, d.f. $= 31$). The difference of 34.2° is in the direction expected from the adjacency principle and clearly indicates that depth adjacency was a highly effective variable. However, although the induction object stereoscopically equidistant with the test object mainly determined the apparent path of motion of the test object, as expected from the adjacency principle, it is also clear that the addition of the second induction object, even though displaced from the test object, modified the induction effect. This change of 18° (52.2° − 34.2°) was significant at the 0.01 level ($F = 41.27$, d.f. $= 1/31$). The influence of the displaced induction object, although considerably less than that of the induction object adjacent in depth to the test object, was not negligible.

The data in the left portion of Table 1 from the simultaneous presentation of the two induction objects provides clear support for the importance of depth adjacency in the induction effect. It is meaningful to inquire therefore, whether this adjacency effect is actually the result of the apparent distance position of the test object relative to the induction objects or whether it is due to the tendency for the observer to pay attention to the induction object closer in apparent distance to the test object and to ignore the induction object more displaced in apparent distance from the test object. This question can be answered by examining the results from the attention instructions shown in the right portion of Table 1. It will be recalled that the two induction objects were presented simultaneously whenever the attention instructions were used. The effect of attention is indicated by the change in the apparent direction of motion of the test point as a function of shifting the attention from the adjacent induction object to the displaced induction object. If attention is effective this should result in a change in the perceived direction of motion of the test point from that expected with the adjacent induction object toward that expected with the displaced induction object. There are two cases to consider. One case is that in which the test object was stereoscopically at the plane of the near induction object. Changing the attention from the near to the far induction object changed the direction of the apparent motion of the test point by 22.6° (from −18.9 to +3.7). The other case is that in which the test object was stereoscopically at the plane of the far induction object. Changing the attention from the far to the near induction object changed the direction of the apparent path of motion of the test point by 17.0° (from +24.2 to +7.2). The magnitude and direction of these changes suggest that attention was a significant factor in the induction changes. A two-way analysis of variance of the results from the attention instructions indicated that both the position of the test object (near or far) and the direction of the attention (near or far) were significant at the 0.01 level ($F = 70.59$, d.f. $= 1/31$ and $F = 47.91$, d.f. $= 1/31$, respectively).

The contribution of adjacency and attention can be assessed independently using the data of Table 1 as is shown in Fig. 2. In Fig. 2, the terms T_n and T_f refer to the near and far positions of the test object, while the terms A_n and A_f refer to the near and far distances of attention. Thus, T_nA_n, T_nA_f, T_fA_n and T_fA_f refer to the four combinations of test object position and attention distance. As shown in Fig. 2, the effect of adjacency and attention together is indicated by the difference in the direction of the apparent path of motion of the test point that occurs between the T_nA_n and T_fA_f conditions. The effect of attention with adjacency held constant is shown by the difference in results between either the T_nA_n and T_nA_f conditions or the T_fA_n and T_fA_f conditions. Similarly, between either the T_nA_n and T_fA_n conditions or the T_nA_f and T_fA_f conditions, only the adjacency is

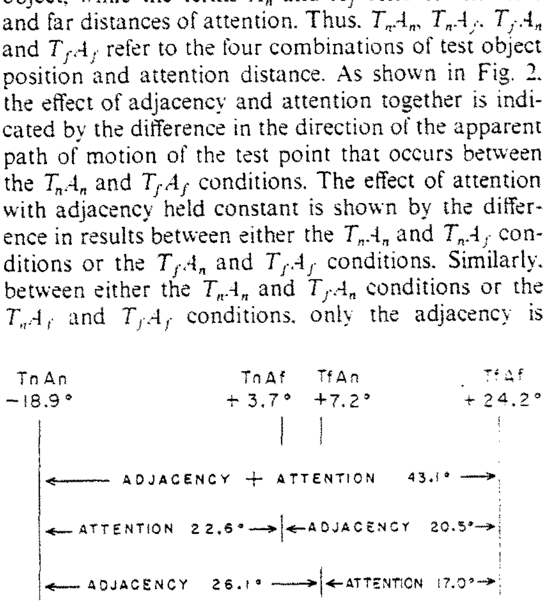

Fig. 2. Method of determining the magnitude of the induction effect attributable to adjacency and to attention.

being modified with the attention constant. The changes in the perceived direction of motion of the test point attributable to attention and depth adjacency independently are shown in Fig. 2. Two estimates of the relative contribution of these factors are available, with one of these calculated by using the results from the T_nA_f condition and the other by using the results from the T_fA_n condition. In the former case, attention accounts for 52% of the total change between T_nA_n and T_fA_f (adjacency 48%) and in the latter case attention accounts for 39% of the total change between T_nA_n and T_fA_f (adjacency 61%). It seems that attention to the displaced induction object was somewhat less effective in modifying a depth adjacency when the test object was at the far rather than at the near distance. This difference was significant at the 0.05 level ($t = 2.29$, d.f. $= 31$). It can be concluded that both depth adjacency and voluntary attention contributed independently to the induction effect, that the effects of both factors were large and somewhat similar in magnitude, and that changing the attention from the adjacent to the displaced induction object had more effect when the test object was at the distance of the near rather than the far induction object.

DISCUSSION

It is clear from the situations involving the neutral instructions that a large induction effect occurred when the test object was at the same apparent distance as the single induction object. Although adding a second induction object of opposite phase at a different distance decreased the induction effect from the first induction object, the contribution of the displaced induction object was much less than that of the induction object adjacent to the test object. This latter result is a clear demonstration of the adjacency principle. The contribution of attention to this depth adjacency effect was examined by considering the results from the attention instructions. Shifting attention from the adjacent to the displaced induction object reduced the contribution of the adjacent induction object in determining the apparent direction of motion of the test object. This modification in the induction effect by attention, although large, was not sufficiently large to account for the total adjacency effect.

Although voluntary attention in this experiment did not account for the total change in induction as a function of the distance position of the test object, it might be suggested that the adjacent induction object continued to command some of the attention of the observer even though the observer attempted to direct his attention to the displaced induction object. In other words, perhaps attention is not completely under the control of the observer and involuntary attention to the adjacent object may account for the adjacency effects not accounted for by the voluntary changes in attention. But, there is evidence against this possibility. If involuntary attention were sufficient to account for the remaining adjacency effect, it would be expected that the near induction object would produce a greater induction than the far induction object when both induction objects were presented simultaneously. The reason for this is that the near induction object is interposed between the observer and the far stimuli, and, therefore, it ought to be easier to ignore the far than the near induction object when both of these are presented simultaneously. But, contrary to this, it will be seen from the data of Table 1 that the deviation in the apparent direction of motion of the test object from the vertical was no greater when the test object was at the near than the far distance for either type of instructions.

The large effect of voluntary attention upon the direction of the apparent path of motion of the test point in this experiment provides the clearest visual example known to the authors of the effect of attention on perception. This effect is both obvious and clearly perceptual (non-cognitive). Conversely, the three-dimensional display of Fig. 1 can be used to measure the observer's ability to direct attention to different parts of the visual field.[2] The ability to distribute attention voluntarily in visual fields possibly is an important dimension for the evaluation of perceptual development (Haber and Hershenson, 1973) and for the diagnosis of disturbed mental states (Silverman, 1964; McGhie, 1970). By providing a sensitive objective measure of visual attention, the display used in the present experiment is likely to be useful in investigating the observer and stimulus conditions that affect the attentional processes.

The adjacency and attention effects obtained in this study reflect a differential weighing by the observer of information contained in the proximal stimulus. The question occurs as to whether the conclusions from the present study are limited to the configurations used or whether the results reflect perceptual processes of considerable generality. The modification of the apparent motion of the test object in the present study was labeled an induction effect. But the configurations of moving points involved in the present study more nearly resemble the configurations used in studies of the vector analysis of motion (Johansson, 1964), than configurations used to illustrate induced motion (Brosgole, 1966). If the induction and attention effects occurring in the present study are to be regarded as applying to the range of situations that includes both visual vector analysis and induced movement, it is necessary to show, as has been proposed by Wallach (1965, 1968), that the same perceptual processes are involved in responding to these two kinds of situations. There are experimental and logical reasons to support this possibility. It has been found experimentally that the adjacency principle applies to the induced motion involving a moving frame and stationary point (Gogel and Koslow, 1971, 1972) as well as to the configurations of the present study. The logical reasons can be discussed with the aid of Fig. 3 which represents a number of instances of perceived motion (indicated on the right) resulting from the physical motions (indicated on the left). It is assumed that no objects are visible except those

[2] It is likely that attention instructions have less effect in situations in which the objects are separated in a frontoparallel plane than in depth. This is suggested by an experiment completed following the present study in which adjacency but not attention was significant under conditions of frontoparallel separation similar to those used in a previous study (Gogel, 1974).

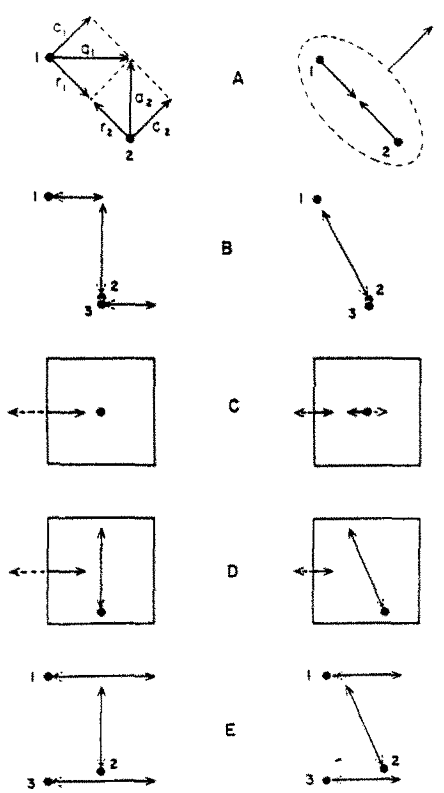

Fig. 3. A series of drawings indicating the relation between the vector analysis of perceived motion and the induced motion obtained with a moving frame.

shown in the diagrams. In Fig. 3A, two points are physically moving at right angles to each other as is indicated by arrows labeled a_1 and a_2. As point 1 moves horizontally to the right, point 2 moves vertically upward. Upon meeting, the two points reverse their direction of motion with point 1 now moving left and point 2 now moving down, etc. The motion of point 1 or point 2 can be specified by a_1 or a_2 (absolute motions) or by pairs of equivalent vectors. The pair of vectors labeled $\mathbf{r}_1$ and $\mathbf{c}_1$ are equivalent to a_1, and the pair labeled $\mathbf{r}_2$ and $\mathbf{c}_2$ are equivalent to a_2. The motion of point 1 with respect to point 2 (relative motion) is specified by $\mathbf{r}_1$ and the relative motion of point 2 with respect to point 1 is specified by $\mathbf{r}_2$. Vectors $\mathbf{c}_1$ and $\mathbf{c}_2$ are equal in magnitude and direction and are common to the two points (common motions). As is shown on the right of Fig. 3A, the two points appear to move toward and away from each other as determined by the relative motions and also appear to move as a pair or group diagonally as determined by the common motions (see Johansson, 1971).

Figure 3B is similar to Fig. 3A with regard to the physical motion between points 1 and 2. It differs mainly from Fig. 3A in that point 3 is present which physically moves in phase with and parallel to point 1. The solid and dashed arrowheads indicate the repetitive motion of the objects. Relative motions of point 2 with respect to points 1 and 3 in Fig. 3B are such that point 2 will appear to move diagonally between upper left and lower right as shown on the right drawing. Probably the apparent direction of the path of motion of point 2 is inversely related to the amount of motion (absolute motion) perceived in points 1 and 3 and the right diagram of Fig. 3B illustrates the case in which, despite their physical motions, points 1 and 3 are perceived as stationary.[3]

In the induced motion situation, it is found that the physical motion of one object or point (the induction object) can produce an apparent motion of another object or point (the test object) even though the test object is physically stationary. A situation that is often used to demonstrate induced motion is shown in Fig. 3C. The induction object is a luminous frame and the test object is a small luminous disc or point of light. As is indicated by solid and dashed arrows, the physical absolute motion of the frame is right and left whereas the point is physically stationary. As shown at the right of Fig. 3C, the absolute motion of the frame is perceptually underestimated and the physically stationary point appears to be moving horizontally with a phase opposite to the phase of the physical motion of the frame. Another example of induced motion is diagramed in Fig. 3D, in which the physical and perceived motion of the frame is identical to that in Fig. 3C. Unlike Fig. 3C, however, in Fig. 3D, the point moves physically up and down (vertically) with a phase such that the point is at the bottom and top of its path of motion as the frame moves from the left to right position, respectively. It is expected that adding the physically vertical motion to the point will add a perceived vertical component to the point. This perceived vertical component, when combined with the induced (perceived) horizontal component will result in the point appearing to move in a path that deviates from the apparent vertical. Depending upon the phase of the physically vertical motion of the point and the physically horizontal motion of the frame, the direction of the perceived path of motion of the point will be either between upper right and lower left or between upper left and lower right.

The induced motion shown in Fig. 3D does not require the entire frame to be present. The simplest example of induced motion is that in which a point moving directly toward or away from a physically stationary point causes the stationary point to appear to move with a phase opposite to that of the physically moving point (Duncker, 1939; Mack, Fisher and Fendrich, 1975). A somewhat more complicated situation producing induced motion is shown in Fig. 3E. In Fig. 3E, all of the frame is removed except two of the corner points (points 1 and 3) and as in Fig. 3D, the test object (point 2) is moving vertically. The physical motion is such that when point 2 reaches the center of its path of motion, points 1, 2 and 3 are vertically aligned. It will be noted that unlike the situation in which the entire frame was present, the induction points (points 1 and 3) move to the right of point 2. The direction of the apparent path of motion of point 2 is shown in the right hand portion of Fig. 3E and, as in the case of Fig. 3D, the perceived

[3] Perhaps for a constant physical motion, when induction occurs, the sum of the perceived motion of the test and induction object is constant. This, however, would not be consistent with Duncker's hypothesis regarding the separation of systems (Duncker, 1938).

direction will be between upper left and lower right or between upper right and lower left depending upon the phase of the motion of the test point relative to the induction points. The basic stimulus configuration represented by Fig. 3E was used in the present study.

It is clear that similar perceptual processes are involved in determining the apparent motion of the test object in all of the situations illustrated by Fig. 3. The similarity is in terms of the importance of relative motion between the test object and the other objects of the display in specifying the perceived motion of the test object. It is likely that the adjacency and attention effects demonstrated in the present study by using the situation illustrated by Fig. 3E, also could have been demonstrated with any of the situations illustrated in Fig. 3.

The perception of absolute motion is the perception of the motion of one object or point independently of other objects or points. To the extent that absolute motion is perceived in a configuration of moving points, the parts of the visual field are perceptually fragmented. The perception of relative motion is the perception of the motion of one object or point relative to another object or point. To the extent that relative motion is perceived in a configuration of moving points, the parts of the visual field are grouped or organized. The present study clearly supports the conclusion that relative motion cues decrease in effectiveness with increasing separation in perceived depth. It is likely that the rapidity with which the effectiveness of relative motion cues or other relative cues decreases with increasing separation is an inverse measure of the amount of perceptual interrelation between objects or points that occurs across the visual field. It is also likely that the ability to perceptually interrelate displaced portions of the visual field will vary as a function of development and personality variables. It was mentioned previously that the substantial attention effects obtained in the present study with the opposed induction objects at different distances suggest that such displays can provide a sensitive way of measuring attention. Perhaps observer differences in the effect of either or both adjacency and attention in this kind of display can indicate the differing perceptual abilities of individuals to organize and to modify the organization of their visual world.

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