

THE EFFECT OF PRIOR EXPERIENCE
ON APPARENT MOVEMENT

by

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INTRODUCTION

The history of apparent movement begins in the 1820's (Boring, 1942), but its full importance for psychology was not recognized until the publication of Wertheimer's paper, Experimentelle Studien über das Sehen von Bewegung, in 1912 (translated in greater part in Shipley, 1961). Wertheimer saw the significance of the fact that, under certain temporal conditions, the successive presentation of a pair of stationary visual objects "at a considerable spatial distance from one another," evokes the perception of movement. He called this impression of motion in the spatial interval between the two objects the phi-phenomenon.

Wertheimer demonstrated that, in some instances, the phi-phenomenon is perceived solely as motion. The stimulus objects are present in the initial and terminal positions; between the objects there is no perception or imagining of intermediate positions of the objects. There is simply the perception of motion. This is called "pure phi."

In his study of the phi-phenomenon, Wertheimer especially emphasized the importance of the length of the time interval between the presentation of the two stimulus objects. With pauses up to 30 msec. the objects seemed to appear at the same time; optimal movement occurred with pauses near 60 msec.; between 60 and 200 msec. Wertheimer found partial movement of one or both of the stimulus objects; and at approximately 200 msec.

the objects were perceived separately, one after the other.

Wertheimer's work with the phi-phenomenon supplied Gestalt psychology with its fundamental tenet and, perhaps more important, initiated research into a neglected area of perception. Over one hundred papers were published between 1912 and 1936 alone (Neff, 1936). The amount of work done in this area has called forth many surveys of the literature, from Helson (1925) to Aarons (1964).

Following Wertheimer's paper other types of apparent movement were reported. Graham (1965) lists three found by Kenkel in 1913. The apparent change in size of the stimulus object with successive presentations Kenkel called "alpha movement." The apparent movement of an object from one position to another is "beta movement," a term that is today used synonymously with phi. "Gamma movement" is an apparent expansion and contraction of the stimulus object as its luminance is increased or decreased. Korte in 1915 (cited by Neff, 1936) reported that, in certain conditions, a reversal of the phi-phenomenon can be obtained, the second stimulus object moving back toward the first. This reversed movement occurs when the second stimulus object has "a greater 'insistence' than the first⁷, an insistence augmented by increased physical intensity, direction of the attention, fixation, or other factors" (Neff, 1936, p. 14). Higginson (1926b) found "insistent and pronounced" movement when the two objects were presented simultaneously but for different lengths of exposure.

While these investigators were concerned with finding different types of apparent movement, others pursued Wertheimer's study of the

parameters of the perception of the phi-phenomenon. Two factors of importance, however, have not been fully investigated: the effects of past experience, and the effect of a difference in form between the two stimulus objects used to produce apparent movement. The present thesis is concerned to some extent with the second of these factors, but its primary concern is with the role of learning in apparent movement.

The influence of form

In studying the effect of difference in form on apparent movement, Linke in 1918 (cited by Squires, 1959) found that the effect could be obtained with dissimilar objects, such as a circle and an ellipse: the circle changing into an ellipse. When movement occurred with two such stimulus objects differing in form or color the first would change in the course of movement. Linke believed that movement would be perceived only when the two stimulus objects were "identified as referring to...the same stimulus object" in different positions. This "identification" was considered by Linke to be the most important condition for the occurrence of apparent movement.

Wertheimer opposed this view:

the impression of motion need not essentially be connected with the identity of a and b....The...identity of the two stimulus objects was present only in the stage of optimal motion; beyond this (e.g. in the process of shortening the time interval), motion appeared without...identity of the objects...(Shipley, 1961, p. 1074).

Referring to pure phi, Wertheimer concluded that

nothing is to be seen of an intermediate position, a color, an object in motion through the span of separation, and... one does not even think that the object itself moves...(Shipley, p. 1078). There was, simply, motion; without reference to an object (p. 1059).

However, investigators such as Benussi in 1917 and Wittman in 1921 reported that there was "objective" meaning in the phi-phenomenon, and that the movement could not be separated from the object moved. According to these studies, cited by Mibai (1931), this is true even in pure phi.

Dimmick (1920), using a square and an oblique line as stimulus objects, reported that, depending on the order of presentation, either an expanding and contracting square or a shrinking line was perceived. Steinig in 1929 (cited by Orlansky, 1940) reported that circles changed into squares during the course of movement, and von Schiller in 1933 (cited by Toch, 1956) found a tendency for the first form presented to transform itself in every respect into the other form during movement. He called this the "tendency of total assimilation" where the dissimilar form is evolved "phenomenally" from the first. On the other hand, Hartmann (1923, in Ellis, 1938, p. 187) failed to obtain reports of movement when the stimulus objects were a circle and a triangle: "Here the subjects saw a triangle, then a blank, and then a pear-shaped figure; they never saw the circle at all." The experiment was repeated with a line followed by a circle: movement was not obtained, and the circle was again perceived as a deformed figure. Zietz and Werner in 1927 (cited by Werner, 1957) presented an arrow and a point (a dot) to their subjects. Most observers were unable to see apparent movement.

Ternus (1926, in Ellis, 1938) noted that when change in position along with change in size, color, or form was required, apparent movement was impeded. If change in form did take place, the change was by the whole figure and was "not a piecewise process....Instead, the figure itself changes its place and form in one unbroken movement" (Ellis, p. 159). According to Orlansky (1940), Ternus introduced the principle of "demandedness" to account for the importance of stimulus-likeness in apparent movement. When the situation "demanded" that the stimulus object undergo great changes, it was difficult to perceive movement.

An important quantitative study of the influence on apparent movement of similarity and difference in form is that of Orlansky (1940). He refers to Wertheimer's belief that the equality of the figures is "a matter of decisive importance in the determination of apparent movement" (pp. 5-6). Thus, movement is more likely to be perceived with the use of equal forms as stimulus objects than with unequal forms. Using psychophysical methods, Orlansky studied the "range" of apparent movement. He used the threshold value between phenomenal succession and apparent movement as one limit of the range, and the threshold value between apparent movement and phenomenal simultaneity as the other limit. Identical forms were perceived as moving over the widest ranges; as the differences between forms became more pronounced the ranges were smaller. Orlansky had speculated that very unlike forms would not be perceived as moving. When movement did occur with dissimilar forms, Orlansky felt that this was because

the figure combinations for which it was most difficult to perceive motion lost their sharp outlines and became blurred. The

result of this blurring was to make the indistinct masses more like each other, the condition under which movement was perceived (Orlansky, 1940, p. 51).

Orlansky thus used a Gestalt "good-figure" explanation for his finding, supporting Wertheimer's theory of stimulus equality. This study is the most comprehensive and all-encompassing investigation of the influence of form on apparent movement since work began on the problem.

There has apparently been only one study of the apparent movement of dissimilar forms since 1940. Squires (1959) replaced Linke's term "identity" with "invariance," taking the term from topology. The deformed figure is topologically identical to the original when there is no tearing in the new form and so long as there is just one point in the deformed figure for each point of the original form, and vice versa. When Linke found that a disc changed into an ellipse and that a triangle changed into a disc he discovered, according to Squires, "phenomenal topological transformations." The results of Squires's investigation (a continuation of Linke's work) of many different pairs of dissimilar forms showed that there is "a substantial isomorphic relation between topological deformation in the stimulus objects and seen movement..."(p. 11). When the objects were distorted to the point that topological relations were destroyed, movement was more inhibited.

In summary, Wertheimer had stressed the importance of equality in form in the perception of apparent movement. Other investigators, however, found that apparent movement often occurred when the two stimulus objects were different in form. Several theories, such as "identity," "demandedness,"

and "invariance," were used to explain the role of form. A final statement on the role of form in apparent movement has yet to be made.

The role of prior experience

Two methods of studying the effect of prior experience on the perception of apparent movement have been employed: the use of figures that connote movement (such as representations of automobiles), and the use of suggestion and learning methods within the immediate context of the test situation.

The first method has produced contradictory results. Blug in 1932, Jones and Bruner (1954), Toch and Ittelson (1956), and Krampen and Toch (1960) obtained results due to the type of forms used, but Orlansky (1940) and Smith (1951) reported no such effect.

Blug (cited by Neff, 1936, p. 19) found that "figures carrying a suggestion toward movement facilitate a perception of movement...whereas figures carrying no such suggestion do not." Jones and Bruner felt that the perception of movement might be conditioned by "previously established perceptual expectancies." They used stimulus objects, such as drawings of automobiles and rolling balls, which display movement, and also nonsense forms, in order to investigate the influence of expectancy. Jones and Bruner concluded that expectancy affects the path of movement and gives stability to the perception of movement under less than optimal conditions. Toch and Ittelson used a von Schiller paradigm of form presentation in which an arrangement of three stimulus objects is presented. The presentation of the middle object preceded that of the outside forms, which were shown simultaneously. Thus the

middle object might be seen to move in either direction. Among the forms used were airplanes and bombs. Their data showed that the meaning of the symbols determined the direction of movement; airplanes moved forward and bombs moved in a downward direction. Krampen and Toch (1960) investigated "the role of directional connotation in the perception of arrows and arrow-like figures." They found a tendency for the arrow designs to determine the direction of movement more effectively than the other forms.

Part of Orlansky's research on the ranges of movement was conducted with arrows as stimulus objects, raising the question whether "arrows, with their strong 'impulsion to movement' constitute a special case" (Orlansky, 1940, p. 30). He then used parentheses as a second series of stimulus forms in an attempt to corroborate the results of his study with arrows, and found no difference between the two sets of results: that is, the arrow form had no facilitating effect on the perception of movement. Smith (1951), in a paper on apparent movement in depth, investigated the hypothesis that certain forms (e.g., baseballs) with a "property of movement" are more easily perceived as moving than forms usually seen as stationary. He, too, reported that there was no difference between the two classes of objects.

More consistent results with respect to the role of past experience have been obtained by studying the short-term effects caused by verbal suggestion and experimentally-induced set. For example, Wertheimer conducted the following experiment:

I presented a rather long horizontal line $\lceil b \rceil$ as one object

and a line standing on its middle $\angle a$ as the other....When the middle line stood inclined towards the right...under the given conditions of exposure..., a rightward rotation...occurred... in the sense of the acute angle. When the line was inclined towards the left--by 100° to 170° --then, correspondingly, a leftward rotation occurred....

If the exposures were now given one after the other, so that a was successively exposed first inclined to the right at about 30° , then inclined at 40° then at 50° , and so on, one could go far beyond 90° without a reversal occurring in the direction \angle of apparent motion. For example, the setting at 120° still produced a rightward rotation, over the longer stretch, through the obtuse angle...(Shipley, 1961, pp. 1053-1054).

Wertheimer also reported that subjects who had perceived the closing acute angle several times, and were then presented with only one of the lines, saw for two or three exposures

a smaller motion, a rotation into the horizontal. In the first of such exposures this rotation was of about 45° , in the second it was a smaller arc, until, only the third or fourth exposure brought complete rest (p. 1052).

Wertheimer felt that the previous "experiments with the same arrangements" influenced the results.

Krampen and Toch (1960) devised a series of stimulus objects which varied from arrows to "arrow-like" forms. Using a modified von Schiller paradigm, with the presentation of the two outside forms preceding that of the middle form, they found that starting the series with the arrows and progressing to the nonsense forms, instilled in their subjects an expectancy for movement to occur in the direction in which the arrows were perceived to move.

The extent to which the perception of the phi-phenomenon is influenced by instructions from the experimenter was studied by Neuhaus in 1930 (cited

by Neff, 1936, p. 27), who reported that "a formal instruction to see movement will arouse its perception in [subjects] who have hitherto never reported it." Kelly (1935) found that while only 50 per cent of his subjects saw the phi-phenomenon following nonspecific instructions, 94 per cent reported movement following instructions to look for movement. Kelly also reported another experiment in which two patterns of movement might have been seen. Instructions from the experimenter determined which pattern of movement was perceived by 95 per cent of his subjects, but did not prevent them from seeing the other pattern at a later time. Orlansky, in studying the apparent movement of forms, found that suggestion did not increase the type of movement favored, nor did suggestion "reduce the type [of movement] against which it was offered." He did find, however, that the range of movement was slightly increased following suggestion, as were the number of reports of no movement and the number of types of movement observed. Orlansky concluded that suggestion was not a very influential factor in the perception of apparent movement.

In summary, studies of the effects of previously established expectancies have shown that the direction of apparent movement and the stability of the percept are functions of prior experience, but forms connoting movement do not facilitate the perception of apparent movement. Studies concerned with the immediate effects of suggestion and of experimentally-induced set have shown that these variables may also be factors. However, there has apparently not been a systematic study of controlled prior experience nor of the duration of the influence of experience.

The role of the central nervous system

Wertheimer found that the phi-phenomenon is readily produced when one stimulation is presented to one eye and the second to the other eye. Here the interaction is primarily a function of the higher centers of the central nervous system rather than a function of retinal or peripheral structures. Wertheimer believed that the visual cortex was the area involved, and speculated that when a spreading of excitation between the two stimulated cortical points was complete, so that the excitation from one point interacted with that from the other point, movement was perceived.

Later work cast doubt on Wertheimer's theory of the cortical locus and mechanism of the perception. It appears that retinal and subcortical processes, as well as processes at a still higher level than the visual cortex, are involved in the perception of apparent movement.

Smith (1948) found that alternating stimulation of the two nasal retinae produced the perception of apparent movement in 70 per cent of his subjects. At the cortical level, one of the two excitations was in one hemisphere, one in the other hemisphere, which rules out the direct interaction that might occur, according to Wertheimer's proposals, when the two excitations are in the same cortical field (i.e., in the same visual area of one hemisphere). Smith concluded "that in all probability no neural interaction corresponding to horizontal stimulation was in existence." He felt that the ability to perceive apparent movement without this direct neural interaction cast Wertheimer's theory "into considerable doubt."

Smith's research provided evidence against Wertheimer's theory of

direct neural interaction in the visual cortex as the basis for the perception of apparent movement. Later investigators studied the problem from the standpoint of retinal factors, which Wertheimer's theory excluded from a major role in the perception of apparent movement. Ammons and Weitz (1951) concluded that retinal factors are influential in the perception of apparent movement. They found that there were more reports of apparent movement when both of the stimulations were in the periphery of one eye than when both were in the foveal region. Ammons and Weitz felt that the difference in frequency of reports of the phi-phenomenon was the product of the facilitating effect of the spatial summation in the retinal periphery. The number of receptor cells that converge and summate on a single bipolar cell is much greater in the periphery than in the foveal region where there is almost a one-to-one relation between cone receptors, monosynaptic midget bipolar cells, and monosynaptic ganglion cells (Polyak, 1941).

The results of a study by Shipley, Kenney, and King (1945) might appear to be contradictory to those of Ammons and Weitz. Shipley et al. found that binocular stimulation was superior to both monocular and interocular stimulation. When they found no difference between the latter two conditions, these investigators concluded that, since interocular stimulation "precludes the possibility of any direct retinal connection between the stimulated points," the lateral neurones of the retina are not essential in the perception of the phi-phenomenon. However, Shipley et al. failed to control for eye movements by the use of a fixation point. They even seemed

to encourage eye movements by asking their subjects to make direct comparisons of the quality of apparent movement between two pairs of stimulus lights, one above the other. Because of this, it is doubtful whether consistency of the retinal and cortical areas stimulated was obtained. Moreover, their instructions stressed that the study was concerned with apparent movement and emphasized the necessity to choose one of the pairs of lights as exhibiting the better movement. Such instructions would tend to bias the subjects' reports of apparent movement under any conditions.

There is also evidence that subcortical structures, other than retinal, may be important in the perception of apparent movement. Bridgman and Smith (1945) presented one stimulus light in the nasal retinal field and the second stimulus light in the temporal retinal field of the same eye. The two hemiretinae of one eye are represented in opposite cerebral hemispheres which are connected by the corpus callosum. Bridgman and Smith found that subjects with complete sectioning of the corpus callosum were able to perceive apparent movement. They felt that sectioning had eliminated the corpus callosum as the pathway for the direct "bilateral neural integration." Thus they concluded that subcortical levels of the visual system serve prime roles in the perception of apparent movement.

With respect to the role of structures at some point in transmission beyond the visual cortex, whether cortical or not, the most convincing evidence that levels higher than the visual cortex are involved is the data reported by Teuber and Bender (1948, 1950). They found that men with gunshot-caused scotoma of the periphery and men with retinal scars which caused

scotomata experienced the phi-phenomenon even when the movement was across the areas of blindness. This work parallels that of Stern in 1926 (cited by Neff, 1936) who found that stimulus objects presented on both sides of the blind spot may be perceived as moving.

Presumably, then, the locus of the perception is in the association cortex, probably in conjunction with cortical or subcortical motor centers. At this level we are dealing with structures whose functioning always seems to involve learning processes. The effect of learning on the perception of apparent movement is the principal concern of this thesis.

Perceptual learning

In the stimulus-oriented approach to perception, sensory input is the important factor; it "contains within it everything that the percept has" (Gibson and Gibson, 1955a). In a contrasting view, the perceiver adds to the sensory input in creating the percept. In one such approach, associations arising from past experience "enrich" this input by the formation of functional relations between stimuli and responses (Postman, 1955). To others, perception occurs in a "transaction" between assumptions derived from prior experience and active participation in the perceptual world (Kilpatrick, 1954; Ittelson, 1960).

Gibson and Gibson (1955a) define perceptual learning as the improved ability to discriminate or differentiate among stimulus objects so that the percept corresponds "to physical properties and physical objects in the environment...." They propose that emphasis must be placed on the change in the stimulus to which the perceiver responds rather than any change in

the response to an unchanged stimulus (Gibson and Gibson, 1955b). Opposing the view that the perception as such is influenced by traces of the past, Gibson and Gibson (1955a) stress that perceptual learning occurs when the organism discriminates stimulus objects and responds to previously ignored variables of physical stimulation. They take the development of an identifying response as an example. In an experimental study, a specific nonsense form (a "scribble") was not easily distinguished at first from similar nonsense items. Practice enhanced the subject's ability to discriminate this form. Another example of differentiation-type perceptual learning is the increased sensitivity to two-point cutaneous stimulation which follows practice. Mukherjee (1933) reported that limens in his subjects, after prolonged practice, decreased to a third or a sixth of their original values, and that this increased sensitivity transferred to other parts of the body. Perceptual learning in which the percept comes to correspond more closely to the source of stimulation is also shown in the decrease of the Müller-Lyer illusion after repeated trials so that the two segments of line appear equal or nearly so (Judd, 1902; Mountjoy, 1958, 1960, 1961; Newbigging, 1965).

In the differentiation theory of perceptual learning, interest is centered upon the improved performance resulting from practice within a limited experimental period (Newbigging, 1965). The question of the mechanism by which perceptual learning might occur is relegated to a position of secondary importance (Gibson and Gibson, 1955b; Gibson, 1959). The later theory formulated by J. J. Gibson (1963) makes an attempt at proposing a mechanism that would apply to perceptual learning. He makes a distinction between sensation

and sensitivity. Sensations are defined as "conscious impressions induced by certain selected variables of stimulation." They do not create the percept, but may be coincidental with perception. Sensitivity refers to the selected sensory input considered by Gibson to be necessary for perception. In this theory, the senses are assumed to be active exploring and searching systems that have both exteroceptive and proprioceptive functions. Neural feedback from both exploring and performing actions aid the organism in obtaining stimulation and the maximum information from it. Attention, postulated as a part of sensitivity, is peripheral, rather than the action of a mediating process. Its function is to continue the selection and filtration of sensory input already initiated by the sense organs. Learning influences perception by enabling the perceiver to separate internal and external stimulation. According to Gibson, however, the perceiver does not have to learn to change the sensory input into what is perceived.

The differentiation theory thus avoids the idea that mediating processes are involved in perceptual learning. Newbigging (1965) agrees with certain aspects of the differentiation theory, but postulates that attentional responses constitute a mediating mechanism. He suggests that

increased specificity is mediated by the acquisition of attentional responses to cues or stimulus dimensions relevant to the discrimination to be made. That is, as the Gibsons propose, perception is completely determined by the stimulus; but what constitutes the effective stimulus is what is attended to (p. 312).

The intervening attentional process also mediates the transfer effects found in many perceptual tasks, an aspect of perceptual learning not dealt with directly by either the Gibsons or the associationists. Newbigging speculates

that these attentional responses, after fuller exploration, may be useful in understanding a wide variety of perceptual-learning situations.

The associationists hold that the organism may "enrich" the sensory input by linking ideas or memories to it, creating the percept. Postman (1955) formulates this conception in terms of changes in stimulus-response relations. Perceptual learning consists of a change in the frequency of identifying and discriminative responses, or the attachment of new responses to specific patterns or series of stimuli. Postman adds that it is of prime importance to investigate the mechanism which mediates these changes in order to understand how the associations arising from past experience act to modify perception.

Hebb (1966) proposes that perceptual learning includes both a sharpening of perception (as suggested by the Gibsons) and the association of ideas. He hypothesized (Hebb, 1949) that the permanent synaptic changes in the central nervous system, which are assumed to take place in learning, lead to the formation of "cell-assemblies"—closed sets of neural pathways established by the repeated presentation of a specific sensory event. Sharpening is attributed to the organizing effect of synaptic changes occurring within a cell-assembly or set of cell-assemblies with repeated exposure to a specific sensory input. When sets of mediating processes (ideas) become associated or linked through frequent contiguous occurrence, the arousal of one such idea may excite associated ideas. In this way, the percept may be very different from the sensory input. Based on the establishment of these permanent neural connections, perceptual learning is defined by Hebb (1966) as "a

lasting change in the perception of an object or event resulting from earlier perceptions of the same thing or related things" (p. 112).

Several experiments may serve to illustrate the influence on perception of memories or associations acquired by prior experience. Leeper (1935) reported that the way in which an ambiguous picture of a woman was perceived depended upon which of two pictures--either an old lady or a young woman--was presented first. Subjects who had previously seen the former, perceived the ambiguous picture as that of an old woman, and vice versa. In an experiment by Duncker (1939), the color of a form shaped like a leaf was perceived to be greener than that of a donkey-like form, even though both forms were made of the same green cloth. Wallach, O'Connell, and Neisser (1953) reported a learning effect for the three-dimensionality imparted by rotating the shadow of a wire form (the kinetic depth effect). Subjects who had experience with the rotating shadow later perceived the stationary shadow as three-dimensional also. A control group without prior experience with the kinetic depth effect perceived the stationary shadow as two-dimensional. Donderi and Kane (1965) studied response learning to paired-associates with three different-sized luminous circles. A common response was learned for two of the circles. When the three were later viewed simultaneously as dimly lighted forms in a dark room, the two circles identified with the common response tended to disappear or remain visible together. Donderi and Kane interpreted their results as supporting Hebb's association theory of perceptual learning.

The transactional theory of perceptual learning as presented by Kilpatrick (1954) and amplified by Ittelson (1960, 1962) involves two inter-

related processes. Formative learning is the process by which the individual's perceptual world is developed and expanded. New assumptions, weighted averages based on experience that determine the way a situation is perceived (Ittelson, 1960), are formed and new responses are acquired. Reorganizational learning is a "reshuffling" process in which a new organization of existing cue-percept relations takes place and visual cues are unconsciously reweighted. According to Ittelson (1962), reweighting occurs when conflicting cues are present in the individual's perceptual world, and the resulting perceptual experience depends upon the new weights. Kilpatrick considers formative learning more fundamental and more crucial than reorganizational learning. He likens formative learning to placing marbles in a bag, and the reorganizational process to the shaking up and rearranging of the marbles.

The transactionalists have been concerned with the strategies used in perceiving (Drever, 1960). For example, Ittelson studied the use of size as a cue to perceived distance. Objects with familiar sizes (i.e., match boxes, playing cards) were viewed motionless under two size conditions. The larger items were perceived as closer than the smaller ones (Ittelson, 1951b). In another experiment (Ittelson, 1951a), familiar objects were presented as moving or apparently moving to or away from the observer (radial movement). Ittelson found that continuous change in retinal size arising from real or apparent radial movement served as a cue to the distance traversed or apparently traversed. He hypothesized that size operates as a cue to distance when the observer adds information from past experience

concerning the assumed physical size of the object to the retinal size; a perceptual integration is reached enabling the observer to estimate the distance of the object and how far it has moved. Another example is provided by Kilpatrick (1954) in a study of the learning processes by which an observer comes to perceive various parts of the Ames room as distorted in shape rather than normal or almost normal. He emphasized the importance of the use of visual cues ("give-away" cues) that reveal the distortions present in the room. Actions and their consequences are also instrumental in this type of perceptual learning, aiding in the creation of what is seen. Action need not, however, be instigated by the perceiver, but may come from an external source. The appearance of a ball that was thrown in the room was one such give-away cue.

In summary, perceptual learning as viewed by both the transactionalists and the associationists involves mediating processes by which the perceiver acts upon the sensory input to create the percept. Both feel that past experience plays a major role in perception. The associationists stress the importance of understanding the conditions in which the mechanism underlying perceptual learning might be established and how this mechanism functions. The transactionalists stress the active participation of the perceiver in establishing his perceptual world as a framework for action. This approach is, however, a philosophical one that does not attempt to explain the basis of the mediating mechanism. In contrast, the differentiationists assert that there is no evidence that memories from past experience modify sensory input to create the percept. Their contribution has been to show that

perceptual learning may consist of a sharpening process in which the perceiver is able to respond to more and more properties of the stimulus complex.

The experimental work to be presented in this thesis may aid in understanding the way in which perceptual learning occurs and the extent to which prior experience influences perception.

METHOD

For the purposes of the experiment, the various stimulus objects to be presented to the subject were photographed on motion-picture film. A Bolex Paillard, model H16, 16-mm. motion picture camera with an Angenieux-Zoom lens, type 10 x 12B, 12-120 mm., $f/1:2.2$, was used to make the films. This camera permits single-frame exposure. The film was Eastman Plus-X Reversal Safety, type 7276, PXR 449.

When filming, the camera was secured to a table 8 ft. from a stimulus-card holder. Lighting was provided by overhead fluorescent tubes, and by two 100-watt lamps located 18 in. from either side of the card holder at 45° angles.

White stimulus forms were either cut out of cardboard or made from 72-pt. NK Futura Bold "Prestyle" and were fixed upon black cards. The distance between the closest points of the two stimulus forms, if they had been presented simultaneously, would have been equal to the width of the left-hand figure at its widest part.

To film a single presentation of a stimulus pair, 2 frames of the left object were exposed, followed by 2 frames of the right object, and then by 30 frames of a plain black card. This sequence was filmed 10 to 30 times, depending upon the requirements of the experiment.

Testing took place in a darkened room. A Bell and Howell 16-mm. silent

projector, design 273, model A, with a 2-in. f/1.6 lens and a 500-watt lamp, was used. The shutter of this projector opens and closes three times for each frame, actually making three exposures of it (the purpose is to avoid melting the emulsion on the film). Thus, at the projection speed of 24 frames per sec., a single frame is exposed for three periods of 8.5 msec. each. Each exposure period is followed by a dark phase of 5.4 msec. During the third dark phase the film is advanced one frame (Levonian, 1965). The total of the three exposures for each frame is 25.5 msec. Each stimulus object was therefore presented for 51 msec., and the interstimulus interval was 5.4 msec. The blank interval (30 frames) before the appearance of the next repetition of the sequence lasted 1 1/4 sec.

The projector was placed on a table just behind and to the right of the subject, who was seated 12 ft. from the screen (a Radiant Elite Lenticular Vistaglow). At this distance, the projector gave a 20 x 26-in. lighted area on the screen. A black circle, 1 1/2 in. in diameter, was fixed on the screen so that it was located 1/2 in. below the lower left border of the left-hand stimulus object. The experimenter sat behind the projector.

The subjects, between the ages of 16 and 22, were either volunteers from undergraduate courses in psychology at McGill University or were paid participants in a summer research project. None knew the purpose of the experiment. Each subject was used in only one study.

Unless otherwise noted, each subject was given the following typed instructions:

This is an experiment in visual perception. Please keep your eyes on the black circle on the screen while the film is being shown. While keeping your eyes fixated on the black circle you will be able to see what is in the film. Please pay close attention to the contents of the film, and do not say anything while it is on.

After three min. of dark adaptation, each subject was shown the training or test film. The subject was asked to report what he had seen and then to demonstrate with his hands, at the screen. Although subjects occasionally had difficulty giving a verbal description, they rarely had any difficulty demonstrating at the screen. A difference between the verbal report and the demonstrated report sometimes occurred; when it did, priority was given to the latter.

THE INFLUENCE OF FORM

A preliminary study was conducted to ascertain whether, under the conditions just described, apparent movement of dissimilar forms would be perceived.

Fig. 1 shows the seven pairs of forms used in this experiment. Three (pairs 2, 5, and 6) were of equal area, and thus of equal brightness. Four pairs (1, 3, 4, and 7) were composed of forms that were not equal in area. The forms comprising pairs 1 and 6 were topologically identical. In some of the pairs the forms were very different, in others less so.

A group of 12 subjects was used. Each was shown the pairs of forms in random order, each pair presented as an A-B sequence, 10 consecutive times.

Table 1 shows that only one subject saw movement in all seven sequences of forms, including the pairs of forms that were unequal in area. There were more reports of movement in the three sequences of equal-area forms. For pair 2, there were 9 reports of movement, out of 12; for pair 5, 4 out of 12; and for pair 6, 7 out of 12. Those who saw no movement reported either simultaneity (both forms present at the same time) or succession (the appearance of the left, then the right, form).

This preliminary study was to determine how often pairs of dissimilar forms would be perceived as moving under spatial and temporal conditions

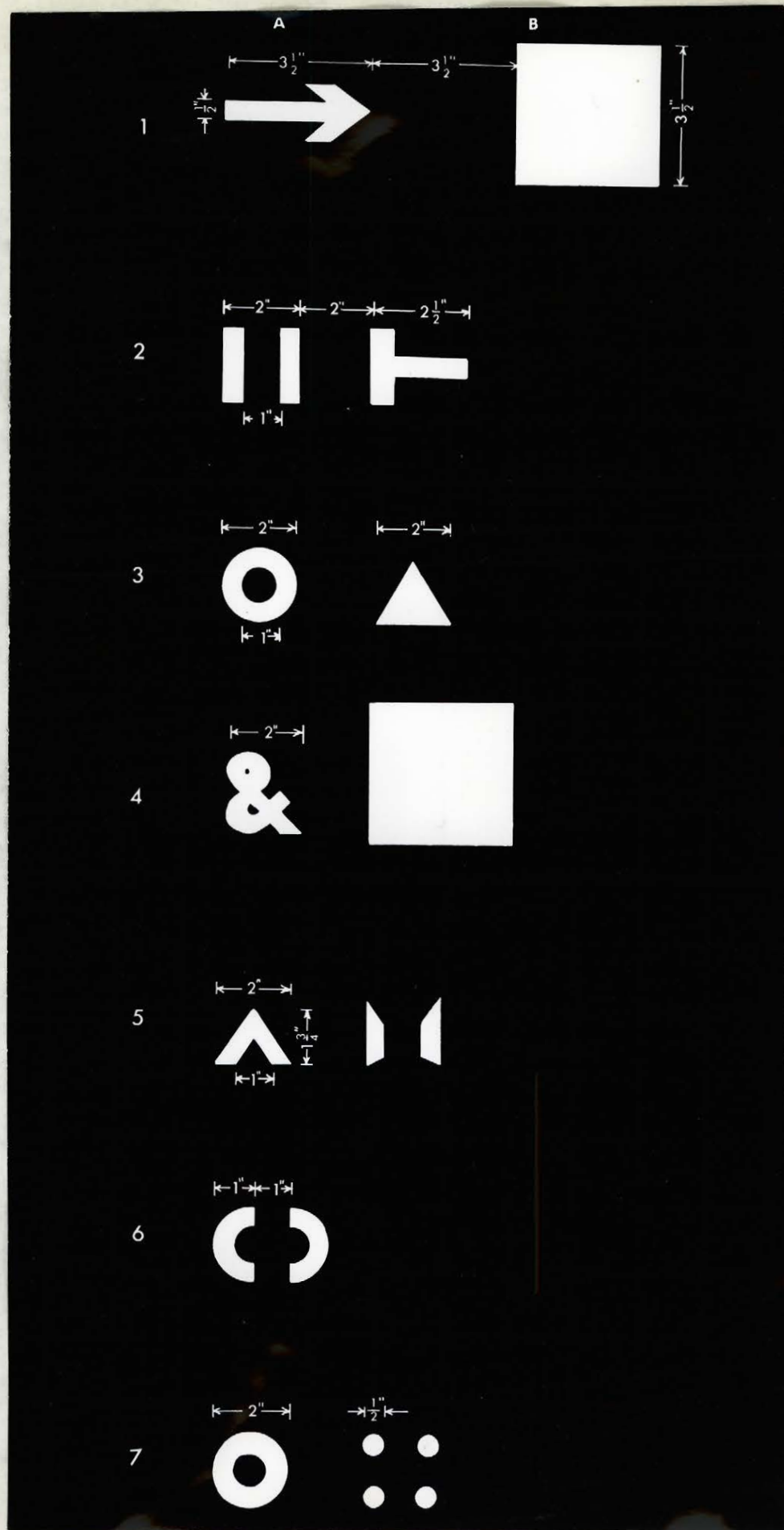


Fig. 1. Pairs of stimulus forms (projected sizes).

Table 1

Number of reports of movement, from 12 subjects,
for the seven pairs of forms (Fig. 1).

Stimulus Pair	Reports of Movement (N = 12)
1. Arrow-Square	1
2. Lines-T	9
3. Circle-Triangle	1
4. Ampersand-Square	1
5. V-Lines	4
6. Semicircles	7
7. Circle-Dots	1

conducive to the perception of apparent movement. Movement was not usually seen with those pairs where the forms differed in shape, area, and brightness. It was more frequently seen with those pairs where the forms were composed of like parts or identical forms in opposing positions. Topological identity did not appear to be a factor.

In the following experiments, pairs of dissimilar forms were used in which the perception of apparent movement was unlikely, as well as pairs of like forms which might easily be seen as moving.

THE EFFECTS OF LEARNING

The main investigation concerned the effect of prior experience with movement upon the perception of movement in situations in which it would not otherwise be expected. An arrow and a square were used as test objects, following preliminary experience with apparent movement of an arrow pair. When it appeared that positive results would be obtained, the duration of the learning as well as the effect of varying the number of exposures to the moving arrow pair were investigated.

The subjects were divided into three experimental and three control groups of 12 each. In preliminary training, each experimental subject was presented with 30 repetitions of a sequence of two identical arrows (Fig. 2, pair 1) and consequently saw, in most cases, the movement of a single arrow from left to right. The test session was given after time intervals of 3 min., 24 hr., and 7 days, for experimental groups A, B, and C respectively. Having seen the arrow-arrow sequence, each subject was now shown 10 repetitions of the arrow-square combination (Fig. 2, pair 2).

Subjects in control groups A, B, and C, on the other hand, were given the 10 repetitions of the arrow-square combination first. Then, following the same interval as the corresponding experimental group, they had the 30 repetitions of the arrow-arrow sequence.

Chi-square with Yates's correction for continuity (Ferguson, 1959) was

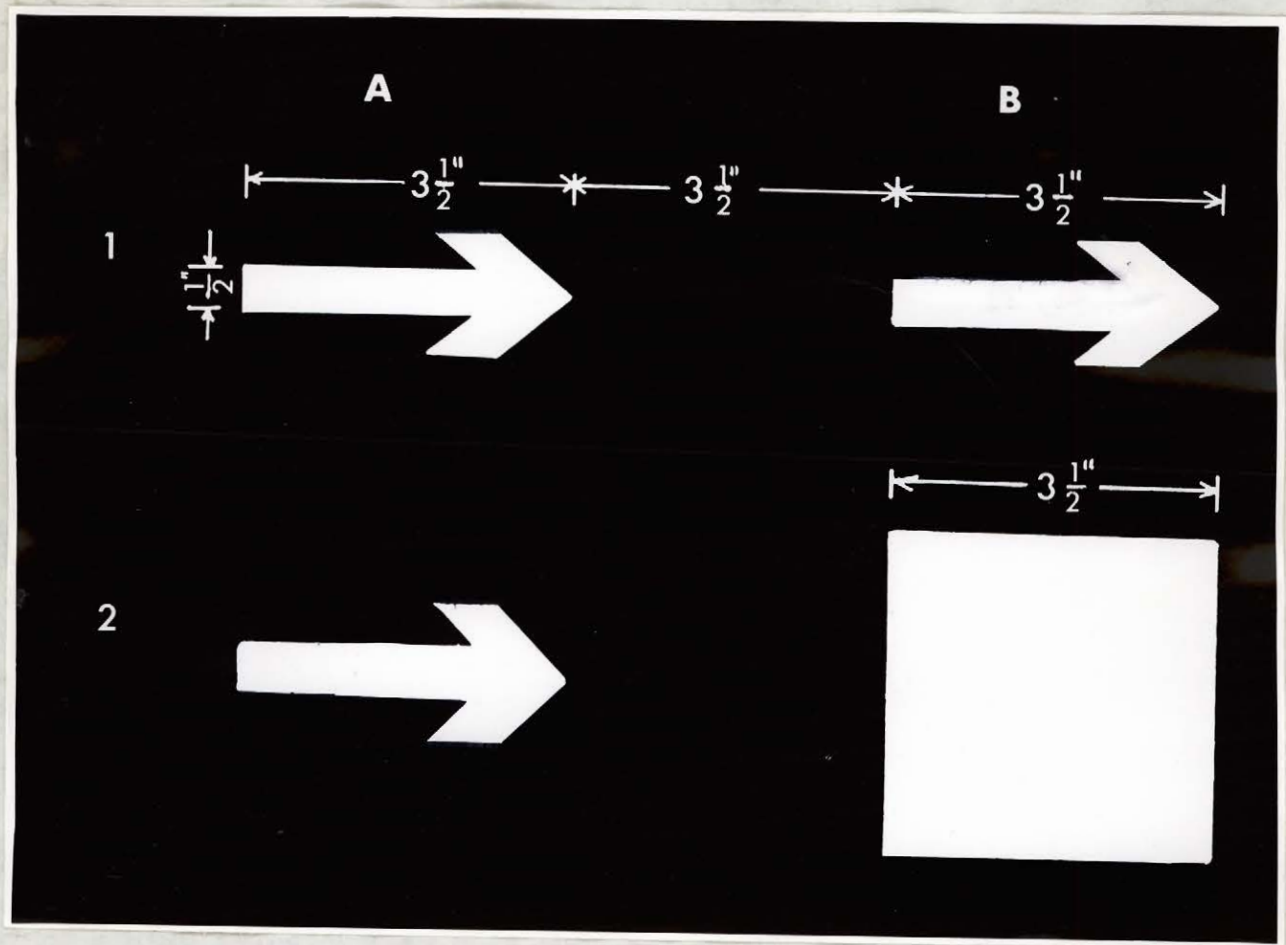


Fig. 2. Projected sizes of the stimulus forms.

used in the analysis of the data. There were large and significant differences between experimental and control groups, shown in Table 2. In the experimental groups, those who had first been exposed to the arrow-arrow film and consequently had seen the arrow move repeatedly, either 9 or 10 of the 12 subjects in each group saw the arrow move to the square. In the control groups, only 1 or 2 of the 12 subjects saw this movement.

The only apparent effect of the length of the interval between prior training and the later perception of arrow-to-square movement was in the completeness of movement. All of the 19 subjects in the 3-min. and 24-hr. groups who saw movement reported that the arrow hit, shot into, or changed into ("exploded into") the square; in the 7-day group, only 2 of the 10 subjects reporting movement saw it with such completeness. The difference in the number of reports of complete movement (Table 3) for the combined results of the two shorter-interval groups and the 7-day group was found to be highly significant ($\chi^2 = 17.18$, $df = 1$, $p < .001$). That is, there is a decrease in the distance that the arrow appears to travel toward the square after an interval of 7 days.

In the preliminary training, 34 of the 36 experimental subjects perceived apparent movement in the arrow-arrow presentation. On the other hand, there was a tendency for those control subjects who had previously seen the arrow as stationary (when shown in combination with the square) not to see movement in the arrow-arrow presentation either; 11 of the 36 control subjects failed to see arrow movement. The failure to see movement--a negative learning effect--will be returned to in the next section.

Table 2

Number of reports of arrow-to-square movement by three time-interval groups.

Group	Interval	Reports		Chi-Square ¹
		Movt.	None	
A	3 min.	$\frac{E}{C}$ 10 1	$\frac{2}{11}$	10.74*
B	24 hr.	$\frac{E}{C}$ 9 2	$\frac{3}{10}$	6.04**
C	7 days	$\frac{E}{C}$ 10 1	$\frac{2}{11}$	10.74*

¹With Yates's Correction for Continuity, $df = 1$

* $p < .01$

** $p < .02$

Table 3

Number of reports of complete and partial arrow-to-square movement by the two shorter time-interval groups (A and B) and the 7-day experimental group (C).

Group	N	Movement		Chi-Square ¹
		Complete	Partial	
A & B	24	19	0	17.18*
C	12	2	8	

¹With Yates's Correction for Continuity, $df = 1$

* $p < .001$

In addition to the preceding study of the effect of different time intervals between the experience with the moving arrow and later exposure to the arrow-square combination, the influence of different amounts of this prior experience was investigated. Subjects were divided into three groups of 24, one for each of the three delay periods (3-min., 24-hr., and 7-days). Each of these time-interval groups was further divided into four equal subgroups. In preliminary training, the subjects had 10, 15, 20, or 25 repetitions of the arrow-arrow combination, according to their subgroup. Only those who saw a single moving arrow in the preliminary training were retained; five subjects who did not see movement and one who saw partial movement of both arrows were replaced. Following the appropriate time interval, the subject was shown the test film containing 10 repetitions of the arrow-square sequence.

There was no significant difference in the results obtained with the subjects who had received 10 repetitions in preliminary training and those who had received 15, so these subgroups were combined; similarly with the 20- and 25-repetition subgroups. Fig. 3 shows that, with a 3-min. interval, all 24 subjects reported arrow-to-square movement (including those with only 10 "practice" trials). With the 24-hr. interval, 23 of the 24 subjects saw movement. After 7 days, 8 of the 12 subjects who had seen 10 or 15 practice trials saw movement, but 11 of the 12 who had been given more exposure saw movement. Though this difference was not significant, 8 is the smallest number of subjects to see arrow-to-square movement following exposure to the arrow-arrow combination.

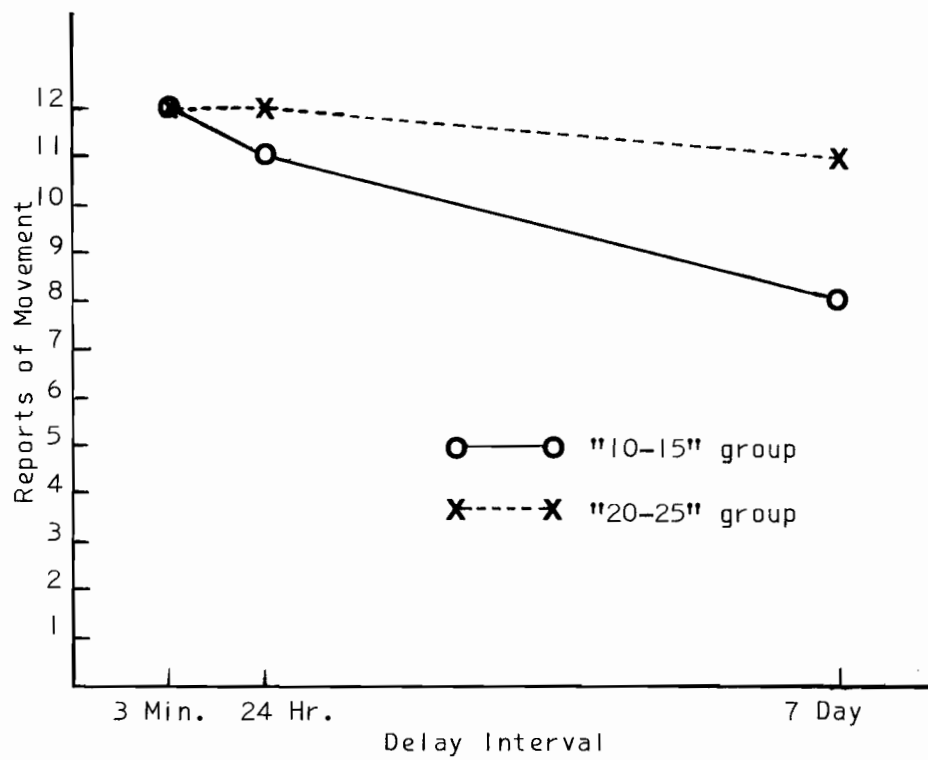


Fig. 3. Reports of arrow-to-square movement by the "10-15" and "20-25" subgroups following each of three delay periods after preliminary training.

More interesting results were obtained when the reports of complete and partial movement were separated (Table 4). Following a 3-min. interval, most of the subjects saw complete arrow-to-square movement. There was a decrease in the influence of the prior experience after a 7-day delay; out of the 19 subjects who saw movement, only 3 (all with 20 or 25 repetitions) reported complete movement. The difference between the 3-min. and the 7-day groups was highly significant ($\chi^2 = 11.13$, $df = 1$, $p < .001$).

Within a time group, the only significant difference with respect to the relation between the amount of practice and the completeness of movement when it was perceived was found after the 24-hr. delay. Of the 12 subjects who had seen 20 or 25 repetitions of arrow movement, 10 reported complete movement. Only 3 of the 11 with 10 or 15 repetitions did so ($\chi^2 = 5.24$, $df = 1$, $p < .05$). Fig. 4 shows that with only 10 or 15 repetitions the influence of the prior experience decays after 24 hr. and tends to disappear completely after a 7-day delay.

The type of movement reported was "unimembral"; the arrow appeared to move to the stationary square. Unimembral movement was reported by Wertheimer in 1912, and by Higginson (1926a) who described it as movement independent of the second form except that it was toward the location of that form.

In summary, prior experience with an apparently moving arrow was found to influence the later perception of that arrow. Most of the subjects who had previously seen the arrow as moving in preliminary training continued to see it as moving to a dissimilar form when later tested. This was in contrast to control subjects who, lacking this prior experience, saw the arrow as

Table 4

Number of reports of complete and partial
arrow-to-square movement.

Interval	Number of Repetitions	Movement		Chi-Square ¹
		Complete	Partial	
3 min.	10-15	6	6	1.69
	20-25	10	2	
24 hr.	10-15	3	8	5.24*
	20-25	10	2	
7 days	10-15	0	8	.90
	20-25	3	8	

¹With Yates's Correction for Continuity, $df = 1$

* $p < .05$

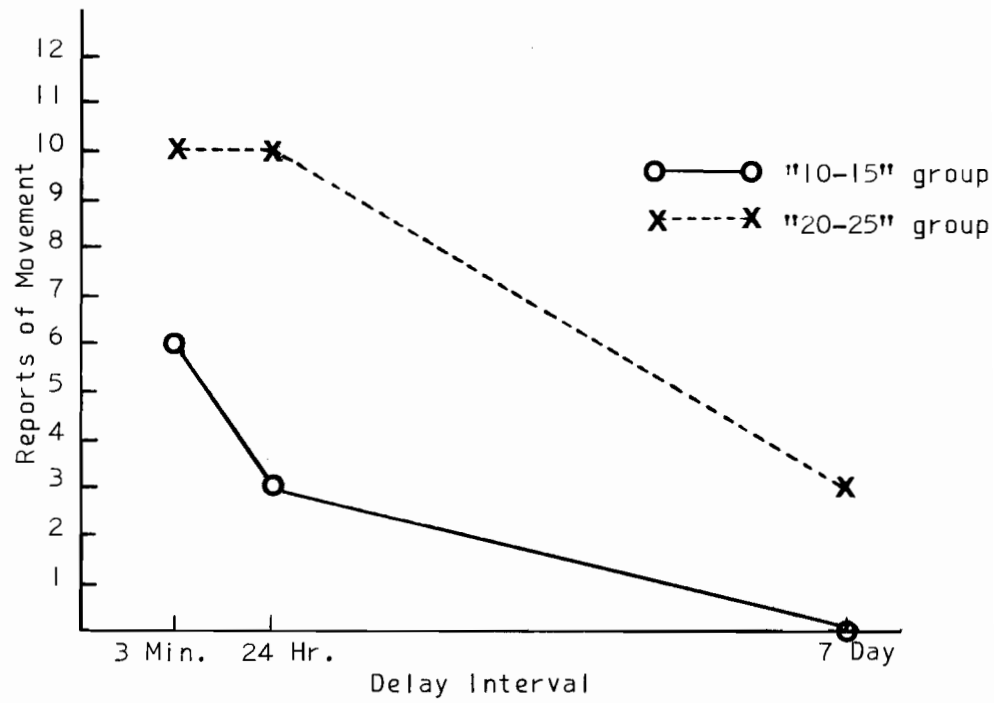


Fig. 4. Reports of complete arrow-to-square movement in the "10-15" and "20-25" subgroups following each of the three delay periods.

stationary. The acquired property of movement was present up to one week after the apparent movement experience, but the influence of the prior experience seemed to diminish. The amount of experience received is an important determinant not only in seeing movement with dissimilar forms, but also in the duration of the influence of the experience.

NEGATIVE LEARNING EFFECTS

It was noted that subjects who had preliminary training with 10 repetitions of the arrow-square combination tended subsequently not to see movement in the arrow-arrow presentation. This apparently negative effect of prior experience was investigated further.

Forty-eight subjects were divided into three experimental groups and one control group of 12 subjects each. As preliminary training, each experimental subject was shown 30 repetitions of the arrow-square combination. The test session--10 repetitions of the arrow-arrow combination--was given following intervals of 3 min., 24 hr., or 7 days for experimental groups A, B, and C respectively. Subjects in the control group viewed approximately 1 min. of blank film in order to provide them with the same amount of exposure to the testing situation as the experimental subjects. The test session was given 3 min. later.

The effect of prior experience with a nonmoving arrow in the arrow-square presentation was clear. Altogether, 22 of the 36 experimental subjects failed to see movement in the arrow-arrow situation. The data for the three groups A, B, and C (with different time intervals before testing) are given in Table 5, together with data for the control group (11 out of 12 reporting movement). The difference between experimental group A and the control group is highly significant ($\chi^2 = 6.40$, $df = 1$, $p < .02$), but no significant difference was

Table 5

Number of reports of nonmovement and movement
in the arrow-arrow combination, following
arrow-square experience.

Group	Interval	Reports		Chi-Square ¹
		Movt.	None	
A	3 min.	$\frac{E}{C}$	$\frac{4}{11}$	8
B	24 hr.		5	7
C	7 days		5	7

¹With Yates's Correction for Continuity, $df = 1$

* $p < .02$

found between the experimental groups, indicating that there was no decay, over a period of one week, in the effect of the prior experience with a nonmoving arrow.

Also, the effect of different amounts of experience with the nonmoving arrow was investigated with numbers of repetitions varying from 10 to 25, and with the same delay periods as above. The groups contained only those who had seen the arrow as stationary. Six subjects who reported seeing arrow-to-square movement in the training session were replaced. As shown in Table 6, 39 of these 72 failed to see movement in the arrow-arrow presentation, confirming the earlier results, and again showing no difference between groups. This indicates that 10 repetitions of the nonmoving arrow had as much effect as 25. There is a suggestion that after 7 days the effect may begin to decrease, but this is not established by the present experiment.

In summary, the perception of arrow apparent movement was hindered by previous experience with a nonmoving arrow. However, it seems to be more difficult to prevent the illusion of apparent movement from being perceived than it is to induce its perception. While almost all subjects who had prior experience with arrow apparent movement saw arrow-to-square movement in later testing, the proportion of subjects who reported no movement in the arrow-arrow presentation following prior experience with the arrow-square combination was noticeably smaller. These results also show that a few repetitions of the nonmoving arrow are as effective as many repetitions in preventing the perception of the apparent movement of similar forms. The inability to see the illusion of arrow apparent movement did not disappear

Table 6

Number of reports of arrow movement following
different amounts of arrow-square experience.

Interval	Number of Repetitions	Reports	
		Movt.	None
3 min.	10-15	5	7
	20-25	5	7
24 hr.	10-15	5	7
	20-25	4	8
7 days	10-15	7	5
	20-25	7	5

with the longer post-experience time interval.

SPECIFIC CONTROL STUDIES

The possibility that some of the results that have been reported here were due to suggestion, or to some inadvertently induced set, was also investigated. This was done by deliberately attempting to produce a set to see or not to see movement. Set was induced in two ways: by the viewing of a single arrow-arrow sequence, and by instructions to see a moving or a stationary form. Neither visually- nor verbally-induced set was found to have a significant effect.

To investigate the possibility that merely seeing a moving arrow induced a set to see movement (as against the idea that repeated exposure had a cumulative effect--that is, caused learning), 24 subjects were divided into an experimental and a control group. Those in the experimental group were shown one trial of the arrow-arrow combination. Each control subject was shown approximately 5 sec. of blank film. After a 3-min. delay, each experimental or control subject was tested with 10 repetitions of the arrow-square combination.

Ten of the 12 experimental subjects reported a single moving arrow in the arrow-arrow presentation, but only 2 of the 12 subsequently saw arrow-to-square movement. Only 1 of the control subjects saw arrow-to-square movement. There is no statistical difference between the two groups ($p > .90$). This may not entirely dispose of the visual-set conception, but it is definitely

more in line with the idea that a learning process is involved, in which the effects of only one trial are minimal.

Verbal suggestion

Experiments concerned with the influence of verbal suggestion on apparent movement have produced divergent results. Neuhaus in 1930 (cited by Neff, 1936) and Kelly (1935) concluded that subjects may be swayed by specific instructions, but Orlansky (1940) found that suggestion was not an influential factor in the apparent movement of dissimilar forms.

The influence of a suggestion to see movement was investigated with 24 subjects divided into an experimental and a control group. Subjects in the experimental group were given the following instructions:

This is a study in visual perception concerned with peripheral vision. Please keep your eyes on the black circle when the film is being shown. An arrow will appear above the black circle, will move toward and hit another figure on the right. I want you to try and identify the figure hit by the arrow while keeping your eyes on the black circle.

Those in the control group were given the instructions used in the preceding experiments. Each subject, experimental or control, was then shown 10 repetitions of the arrow-square sequence.

Of the 12 experimental subjects, 3 reported that the arrow moved, hitting the square. The remaining experimental subjects perceived the arrow as stationary, "flashing" on and off in place. Only 1 of the 12 control subjects saw arrow-to-square movement, giving a report of partial movement.

In order to ascertain whether a suggestion that stationary forms would be shown might prevent the perception of apparent movement, a group of 12

subjects was given the following instructions:

This is a study in visual perception concerned with peripheral vision. Please keep your eyes on the black circle when the film is being shown. An arrow will appear above the black circle and shortly thereafter another form will appear on the right. I want you to try and identify the form that appears on the right.

Each subject was then shown 10 repetitions of the arrow-arrow sequence.

Of the 12, 3 reported seeing two stationary arrows, left followed by right. The other 9 reported that they saw only a single arrow that moved from left to right, and that no other form was presented. They expressed surprise at this; most said that they had expected the appearance of another form and thought that they had failed to see it.

In summary, these studies do indicate that set may slightly influence the perception of apparent movement, but the fact remains that many more subjects saw movement or failed to see movement in the learning studies reported earlier. These results support the conclusion of Orlansky (1940) that factors other than set or expectation are of greater importance in the perception of apparent movement.

Forms lacking movement connotation

The use of forms such as arrows with an "impulsion" to movement raises the question whether these forms constitute a special case in the study of apparent movement. It was seen in the Introduction that there has been no agreement on this matter. In an effort to determine if the results obtained with arrows can also be obtained with other forms, an experiment was conducted using forms that do not connote movement.

Forty-eight subjects were divided into two equal groups, one for learned movement and one for negative learning. The group for learned movement was shown 30 repetitions of a circle-circle sequence as preliminary training. As may be seen in Fig. 5, each circle had a projected outer diameter of 2 in. and an inner diameter of 1 in. If shown simultaneously, they were 2 in. apart. The test was given 3 min. later. For 12 subjects it consisted of the viewing of 30 repetitions of the circle-triangle sequence and for the other 12 the test was the presentation of 30 repetitions of the circle-dots sequence. Both pairs of dissimilar forms, shown in Fig. 5, were used in the preliminary study in this thesis. For training in the negative learning study, 12 subjects of the 24 were shown 30 repetitions of the circle-triangle sequence and the other 12 viewed 30 repetitions of the circle-dots presentation. After a 3-min. delay, all 24 subjects viewed 30 trials of the circle-circle sequence. In this way, the negative learning group served as controls for the effects of learned movement on the perception of movement with both dissimilar pairs, and the other group as the controls for learned nonmovement using the circle-circle combination.

Of the 24 subjects who saw the circle-circle presentation as preliminary training, 19 subsequently perceived the circle as moving and changing into the dissimilar form compared to only 3 of the 24 subjects who viewed the sequences of dissimilar forms as preliminary training. These results are highly significant, showing the importance of prior experience with the moving circle for the later perception of the circle as moving when shown in sequence with a dissimilar form. In Table 7, the reports of movement for each of the

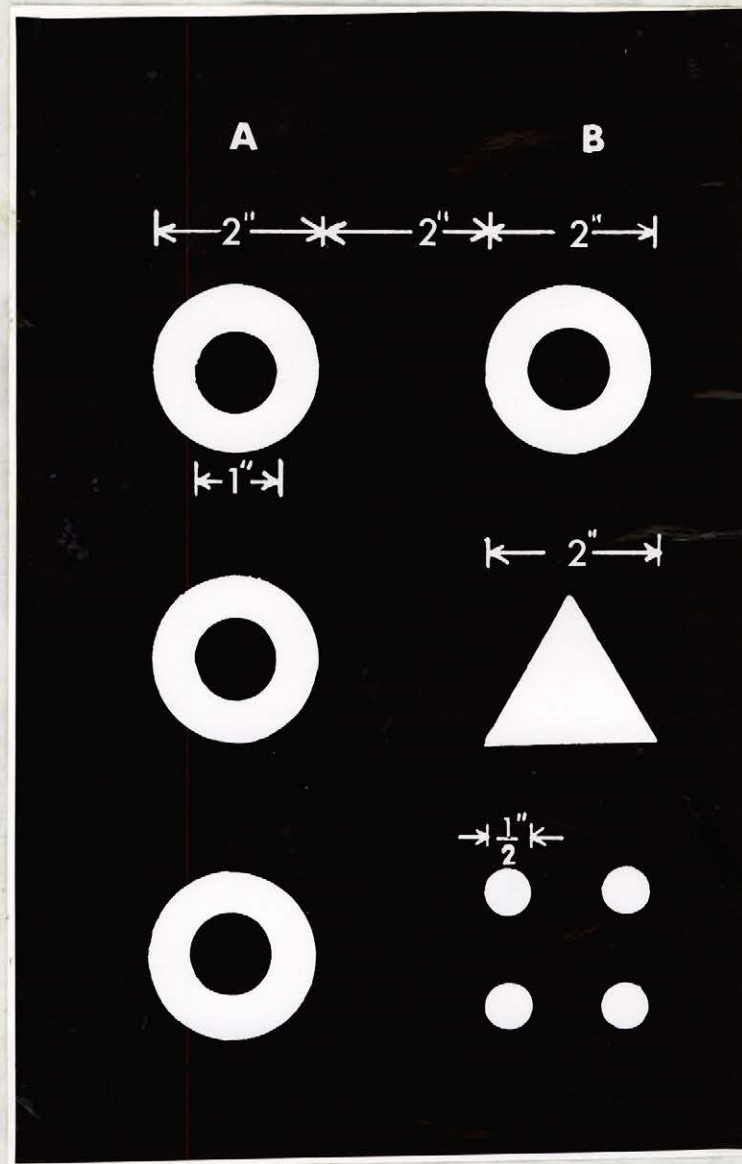


Fig. 5. Pairs of stimulus forms (projected sizes).

Table 7

Number of reports of movement with the sequences
of dissimilar forms.

Group	Circle-Triangle		Chi-Square ¹
	Movt.	None	
Learned movement	10	2	8.17*
Negative learning	2	10	

Group	Circle-Dots		Chi-Square ¹
	Movt.	None	
Learned movement	9	3	8.40*
Negative learning	1	11	

¹With Yates's Correction for Continuity, $df = 1$

* $p < .01$

two pairs of dissimilar forms are shown.

Prior experience with the nonmoving circle paired with a dissimilar form hindered the later perception of circle movement. Of the 24 subjects in the negative learning group, 15 did not see movement when tested with the circle-circle combination. In contrast, only 2 of the 24 subjects in the other group failed to see movement in preliminary training with that presentation. As shown in Table 8, the difference between the two groups is highly significant ($\chi^2 = 15.40$, $df = 1$, $p < .001$).

In summary, these results indicate that the use of movement-connoting forms is not a special case in the perception of apparent movement. This agrees with the conclusions drawn by Orlansky (1940) and Smith (1951). These results also confirm the importance of prior experience on the perception of apparent movement.

Transfer

The aim was to investigate whether the effects of prior experience with the apparently moving arrow would transfer to a very different form.

For preliminary training, a group of 12 subjects was shown 30 repetitions of the arrow-arrow combination. After a 24-hr. interval, the subjects were tested with 10 repetitions of an ampersand-square sequence. These were the same forms used in the preliminary study, but the distance between them was $3 \frac{1}{2}$ in. in order to conform with the dimensions used in the training film.

All of the 12 subjects saw a single moving arrow in the training film, but none saw the ampersand move toward the square in the test film. The ex-

Table 8

Number of reports of no movement with the
circle-circle sequence.

Group	Circle-Circle		Chi-Square ¹
	Movt.	None	
Learned movement	22	2	15.40*
Negative learning	9	15	

¹df = 1

*p < .001

perience with the moving arrow did not influence the subsequent perception of a different form, the ampersand.

This study also indicates that merely presenting the test film under conditions identical to those of the preliminary training will not cause the subject to see apparent movement with dissimilar forms. The influence of the prior experience with the apparently moving arrow is specific to that form and does not transfer. It is probable, however, that a transfer effect would have occurred if a form more like the arrow had been used. The results of Krampen and Toch (1960), referred to earlier, would suggest this.

DISCUSSION AND CONCLUSIONS

The results that have been reported show that learning can play a much greater part in the perception of movement than has been thought. Prior experience causes the subject to perceive apparent movement that he would not otherwise have perceived; it can also determine that he will not see movement that he would otherwise have seen. After two arrows are presented one after another, repeatedly, so that the subject sees one arrow moving from left to right, he tends also to see an arrow move to, and hit or become or "explode into" a different object, a square, when it is substituted for the second arrow. Without the prior exposure to two arrows, the subject tends not to see movement with the dissimilar forms. On the other hand, if the subject is first shown the arrow-square sequence repeatedly, and then shown the arrow-arrow sequence--which normally produces movement for almost all subjects--he sees instead of a moving arrow two successive arrows at different points on the screen. Learning may thus either facilitate or hinder the perception of apparent movement.

Before considering the meaning of these results it should be observed that the classical parameters given for the phi-phenomenon appear to need qualification. They seem to be a function of a particular experimental procedure and may be quite different under other experimental conditions. With the motion-picture method used here, most subjects saw movement when

the two similar stimulus objects were presented within an interval of less than 6 msec., compared with the minimum of 30 msec. for apparent movement reported by Wertheimer. At intervals shorter than 30 msec., according to his data, the simultaneous appearance of the two stimuli would be expected. Further, in the "negative learning" procedure of the present experiments, the same 6-msec. interval was used, and here succession was the most frequent report. According to Wertheimer, the two objects should not be seen in succession with intervals of less than 200 msec.

Historically, the importance of the phi-phenomenon was to show that perception can depart from veridicality, and to demonstrate the integration of two unconnected events into a single organized one. Instead of two unrelated objects, the subject sees a single object that moves from one place to another. He reports seeing the object continuously, even at points in space for which there are no sensory counterparts.

This historical significance of apparent movement remains unchanged. But it may have an even greater contemporary significance as a source of information about the mechanism by which movement, real or apparent, is perceived. The problem of movement perception is complex. Visual movement is perceived when a locus of stimulation moves across the retina--provided the eyes are still. Conversely, if the eyes are moving and the locus of stimulation is unchanged, motion is also perceived; but if the eyes move and the locus of stimulation moves in compensatory fashion, the object is perceived as motionless. Somesthetic feedback from the eye muscles is insufficient to explain these facts, for if the eyes move involuntarily in

nystagmus due to inner-ear stimulation, movement is perceived--the whole environment seems to be rotating--despite the fact that there must be the same muscular feedback as when the eyes are moved voluntarily by the eye-muscles.

The problem of the perception of real motion is beyond the scope of the present thesis, but it is important to note the significance of the study of apparent movement as one approach to that problem. Except for minor differences, apparent movement is indistinguishable from real movement (Wertheimer in 1912; Gibson, 1954; Kolers, 1963; Morinaga, Noguchi, and Yokoi, 1966). In both cases, there is successive stimulation of receptor areas, but in real movement these areas are adjacent while in apparent movement they may be either adjacent or apart. The perception of apparent movement may therefore be an exaggerated case of the perception of real movement, differing from it primarily in that no pattern of stimulation moves across the retina. Seeing it in that light draws attention to certain clinical observations which may help us to understand how learning has its effect on the occurrence of the phi-phenomenon. Hebb (1960), in discussing polyopia, has drawn attention to the possibility that as an object moves across the visual field it excites a series of perceptual structures ("cell-assemblies"). Each one in turn, as it becomes active, extinguishes or inhibits the activity of the preceding one. It is implied that in polyopia, when the subject sees a series of stationary objects, a failure of the inhibitory process leads to a continuation, instead of an extinguishing of the activity of the earlier structures in this sequence.

This line of speculation suggests how learning could affect the perception of movement, which is otherwise hard to understand. In viewing the apparently moving arrow--the subject is not, of course, aware that he is perceiving an illusion--a series of perceptual structures is excited, first for the form as perceived at its initial position, then for the illusion of the form perceived as moving and specific to it, and last for the form at its final locus. With these assumptions, learning can have a role in the total process. Repeated exposure to the illusion of movement strengthens the bonds between these structures creating an integrated unit. When the same form is again presented at the initial position, the total system is activated and the form is seen to move, even though a new and dissimilar form appears at the terminal location. The firing of the second and third components inhibits the activity of the preceding ones and continuous movement, rather than a series of blinking arrows, is perceived. Although long-lasting, however, the system is not permanent; after one week of inactivity decay begins to appear and the left-hand form is not seen to move all the way to the right.

Kolers (1963) hinted at the existence of such a system when he proposed that the temporal sequence of apparent movement has "a unit quality to it." This sequence is presumably activated by the presentation of the first form.

When the learning produces a lack of movement, the system that might be established due to prior experience with the nonmoving form would be composed of components for the perception of two distinct forms separated spatially and temporally. When the left-hand form is later presented in sequence with

an identical form in the apparent movement paradigm, the "no movement" system established for that form is activated, preventing most subjects from seeing movement. They perceive what is presented physically--two distinct forms.

The system established for no-movement perception does not require as much experience as the movement system to become set up strongly enough to resist decay. Whether the influence of this system lasts longer than one week is not known from the study in this thesis.

The experiments concerned with learned movement demonstrate a type of perceptual learning in which the percept may be very different from the sensory input--the perception of apparent movement in a situation where it is not ordinarily seen. When very dissimilar forms are presented, the perceiver enriches the sensory input, creating the percept of movement. Following nonmovement prior experience, however, the perception of two identical but distinct forms, instead of the illusion of apparent movement, demonstrates a type of perceptual learning in which the percept corresponds closely to the physical stimulation. Thus, practice can make the percept either more or less like the sensory input. These results show that perceptual learning may involve both association and sharpening processes, and that the percept may be altered or refined through directed practice.

Since the results show the importance of prior experience in the perception of apparent movement, the work of Orlansky (1940) on the apparent movement of dissimilar forms should be re-examined. Orlansky investigated the apparent movement of dissimilar forms with the same subjects that had

previously taken part in his study of the effect of the spatial orientation of identical forms on apparent movement. The initial form later presented in several of the dissimilar pairs was the same as, or very similar to, the form that had been seen as moving by these same subjects a week earlier (Orlansky, personal communication, 1965). It seems probable that the perception of apparent movement with dissimilar forms reported by Orlansky can be attributed to perceptual learning rather than to the tendency toward form-equality that he suggested.

SUMMARY

It was found that prior experience can either facilitate or hinder the perception of apparent movement. Forms previously seen as moving continued to be seen as moving when later presented in sequence with a dissimilar form, a condition in which apparent movement is not usually seen. Forms previously seen as stationary continued to be seen as stationary when later presented in sequence with an identical form, a condition favoring the perception of apparent movement. The length of the post-experience time interval and the amount of prior experience were found to be important factors in the perception of learned movement, but not in learned nonmovement. The results, relevant to the study of apparent or real movement, show that perceptual learning may involve both association and differentiation processes.

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