INFANTS' VISUAL FIXATION RESPONSES

STIMULUS MOVEMENT AND COMPLEXITY AS DETERMINANTS OF INFANTS' VISUAL FIXATION RESPONSES

By

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This thesis is concerned with the systematic variation of stimulus movement and complexity in order to investigate developmental changes in visual fixation. It was shown that there is a developmental transition in the way in which infants extract visual information from the environment, with younger infants responding primarily through length of fixation, and older infants through the number of fixations. It was demonstrated that the faster a stimulus moves, the more fixation it elicits from infants; that older infants appear to be more responsive to differences in speed than younger infants; and that the more complex the stimulus, the greater the visual response to it. Percent measures were found to be more reliable than absolute measures in making age comparisons.

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CHAPTER 1

Introduction

This thesis is concerned with the collection of normative data on the roles of movement, complexity, and their interaction on the visual fixation preferences of 8-week-old, 16-week-old, and 24-week-old infants. At present, the literature contains no systematic investigations of the development of movement perception in the human infant. The existing paucity of data may be attributed to the fact that there has been a hiatus in methodology which has hindered any serious attempts to investigate developmental trends in perception. Recently, there has been a renewed interest in the collection of data on abilities of infants. This interest has arisen from the awareness that "indicator" responses, such as visual fixation, can be applied to the study of perceptual development. This new awareness has enabled psychologists to study a wide variety of behaviors heretofore relegated to the realms of the unapproachable.

The collection of normative data on movement and complexity is potentially important because there is evidence that the perception of moving detail may form a basis for other types of discrimination. Hunt (1961) and Fiske and Maddi (1961) have proposed that there is a strong interdependence between early sensory stimulation and the development of the organism's capacity to respond adaptively to its environment. Data on the ability to perceive movement and complexity could be used in the study of the critical effects of early environmental stimulation on the development of perceptual discrimination and intelligence. Spitz (1946), Rheingold (1961), Wolff (1963), and Walters and Parke (1965) have proposed that movement and complexity may be important for certain types of social responsiveness. The investigations of Walk and Gibson (1961) and Walk and Dodge (1963) indicate that the movement of textured surfaces may well form a basis for the perception of depth by young organisms. In addition, Dember and Earl (1957) have proposed a theory of perception and motivation which maintains that the development of perception is closely related to the developmental stage of the perceiving organism. Movement and textural complexity are stimulus dimensions which could readily be used to test this theory.

A secondary purpose of the thesis is to obtain data on the ways in which looking behavior changes during infancy. The findings of earlier studies have indicated that there are differences in patterns of looking behavior at different stages of development (Silfen and Ames, 1964; Ames and Silfen, 1965; Stechler, 1965; and Karmel, 1966). In order to investigate these differences more fully and to study their implications for the comparison of subjects of different ages, the research to be presented compares results obtained from analysis of six different measures of looking behavior: total looking time, percent looking time, average span of looking time, total number of looks, percent average span of looking time, and percent total number of looks.

CHAPTER 2

Historical Review

In reviewing the literature relevant to this research topic, it became apparent that the material on the perception of movement and of complexity is extensive and, since most of it is concerned with adult subjects, often is of only indirect relevance to the present thesis. Nonetheless a general review is warranted to provide historical perspective to the experiments subsequently described. The range of literature to be covered will include adult and developmental studies on movement perception and on complexity. In addition, there will be a brief review of the use of the visual fixation preference method in studies of visual preference in infants.

Studies on Movement Perception

Concepts and Issues in the Study of Movement Perception

The literature on the perception of movement is quite extensive, and includes studies of both real and apparent movement. Motion is a quality conferred upon objects by an observer, when there is a displacement of such objects in both time and space. Since the perception of movement results from the successive stimulation of different retinal receptors, it is possible to produce a sensation of movement by manipulating stationary events in a temporal sequence. This type of movement is known as apparent movement. The perception of apparent movement depends on several variable conditions: the length of the time interval between the presentation of the first and the second stimulus, the luminance of the stimuli, the distance between them, the exposure time of each, the magnitude of the stimuli, and the conditions of instruction. Since this thesis is concerned with the perception of real movement, a discussion of apparent movement will be omitted. Excellent coverage of this material may be found in Wertheimer (1912), Korte (1915), and Graham (1963).

Real movement occurs when the physical (distal) stimulus undergoes displacement in space within some sufficient interval of time. As the stimulus moves, there is successive displacement of luminous energy across the retina. If the successive stimulation of the receptors is rapid enough, a continuity of movement will be perceived. If the speed is decreased sufficiently, a velocity is reached below which the discrimination ceases (the lower threshold). Similarly, by increasing the speed of the stimulus, a velocity is reached above which movement is no longer perceived and the stimulus pattern appears fused (the upper threshold).

Gottsdanker (1956) discusses other types of movement threshold. Among these are the difference threshold, or the measure of how well the subject distinguishes between two motions of different velocities; the threshold of acceleration, which is the sensitivity of the subject to a smooth change in velocity; and the difference threshold of acceleration ("jerk"), which is the measure of accuracy with which the subject is able to distinguish a sufficiently rapid change in the rate of change. Since very little research has been done on acceleration and "jerk", they will be excluded from consideration in this paper. Treatment of these topics may be found in Hick (1950) and Hick and Bates (1950).

Studies in Adults' Perception of Real Movement

Studies in the perception of real movement by adults are fairly extensive, cover a wide range of variables, and have reached a fairly high level of sophistication. Starting with the now classic work of J. F. Brown (1931 a,b), a large number of variables affecting phenomenal velocity and/or movement thresholds have been investigated. The review that follows includes the findings of early (pre-Brown) studies, Brown's classic studies on field determinants of phenomenal velocity, later work arising from Brown's description of the "velocity transposition phenomenon", studies of the roles of fixation and eye movements on movement perception, and an account of variables that have been demonstrated to affect movement thresholds.

Early studies of movement perception. According to J. F. Brown (1931b), there were many experiments performed on the perception of velocity during the late 1800's and early 1900's. In this period, Czermak showed that movement observed in the periphery of the visual field is phenomenally slower than the same movement observed in the center of the visual field. Aubert and Fleischl, in separate studies, observed that movement seen while fixating a stationary point is phenomenally faster than the same movement followed by the eye. Bourdon observed that the threshold for movement with large objects was greater than that with small. These and other early studies have been reviewed and summarized in some detail by DeSilva (1929), Fröbes (1923), Kennedy (1936), and more recently by Graham (1963) and Whiteside (1963).

Brown's classic experiments. J. F. Brown (1931a) performed what is now considered a classic series of experiments, specifically designed to investigate the influence of a variety of objective factors on the perceived rate of movement. Brown had subjects compare speeds in two fields, which differed in various respects from experiment to experiment. Each movement field consisted of an opening in a black cardboard screen, with black dots of equal size moving vertically through this opening on a white background. The dots were pasted on a roll of white paper running over two moving drums, which were hidden from view by the screen. Only a uniformly illuminated, flat surface was visible through the opening. The subject compared successively the speeds with which the dots in the two fields passed through their respective openings. The velocity of the variable field was controlled by the experimenter, and could be decreased or increased under the subject's direction until the speeds in the two fields appeared to be the same. The physical velocities of both fields were measured, and the ratio between them was computed.

Brown's major finding was that, by varying the size and the structure of the visual field in which a given stimulus velocity occurred, the resulting phenomenal velocity varied over a large continuous range. In other words, phenomenal velocity was not produced by the physical velocity of the stimulus alone, but was dependent upon other properties of the field surrounding the movement. The major results of this series of experiments may be summarized as follows:

1. Phenomenal velocity diminishes as the distance of the movement from the observer increases.
2. Either an increase in width and length of the moving field or an increase in the size of the moving object result in a decrease in phenomenal velocity. Variation in the size of the field causes a greater difference than does variation in the size of the moving objects.
3. If two moving fields are compared successively in a homogeneous surround, and one of the fields is changed in all its linear dimensions, the stimulus velocity of that field must undergo a corresponding change to retain the same

phenomenal velocity in both fields. For example, suppose that two stimuli, A and B, are presented at equal distances from the subject in a darkened room. If A consists of circles 1 cm. in diameter placed regularly at 4 cm. intervals on a belt moving behind an aperture measuring 18 cm. x 6 cm., while B consists of circles .5 cm. in diameter placed regularly at 2 cm. intervals on a belt moving behind an aperture measuring 9 cm. x 3 cm. -- i.e., if all of A's dimensions are double the size of B's -- then the physical velocity of A must be doubled in order for the phenomenal velocity to be the same in both fields. Since judgments are made in a darkened room so that cues to distance are omitted, no general frame of reference is available to the subject, and his judgment of speed depends on the relationships between dimensions in the field in which it is observed.

Brown's data show that this velocity transposition phenomenon cannot be completely accounted for by adding the phenomenal difference caused by variation in the size of the field to the phenomenal difference caused by variation in the size of the moving objects. That is, one cannot simply add the two factors discussed as Result #2 above to obtain the velocity transposition phenomenon described here as Result #3.

4. If the structure of the larger field surrounding the moving field is heterogeneous, the phenomenal velocity is faster

than it would be for the same physical velocity surrounded by a homogeneous field.

5. Objects oriented in the direction of movement move phenomenally faster.
6. Relative to the observer, vertical movement is phenomenally faster than horizontal, and movement diagonally between the vertical and horizontal falls phenomenally between the two in velocity.
7. Phenomenal velocity increases as the illumination of the field in which the movement occurs decreases.
8. Movements observed while fixating a stationary point are phenomenally faster than when the eye follows the moving object. This upholds the findings of Aubert and of Fleischl (Brown, 1931b).
9. Movements projected on the fovea of the retina are phenomenally faster than those projected on the periphery. This agrees with the previous findings of Czermak (Brown, 1931b).

Brown (1931a) performed a second series of experiments to investigate the question of whether or not the thresholds for movement were also conditioned by the same factors as the phenomenal velocity itself. From the results of his earlier experiments, Brown hypothesized that all the factors which increase the phenomenal velocity by fixed amounts, should decrease the thresholds for movement by equivalent amounts, and vice versa. The basic procedure was to measure the threshold for a given field A, and on the basis of the ratios already calculated in the previous experiments, to predict what thresholds for variations in field structure would be. If his predicted values for thresholds could be verified by experimental evidence, his hypothesis could be considered proven.

Brown used five variations in field structure, involving changes in the size of the diaphragm aperture, size and spacing of the moving figures, and illumination, each of which was varied separately. He then predicted values for several different types of threshold in each of these field variations. The data confirmed Brown's hypothesis -- namely, that the same factors which influence phenomenal velocity also influence the lower threshold for movement, the difference threshold for movement, the threshold of apparent reversed movement, the threshold for the appearance of increase in number of moving objects, and the threshold for fusion.

The experiments also demonstrated that the circular velocities are phenomenally faster than linear velocities, but that the two may be phenomenally equated with a comparatively high degree of accuracy. In addition, it was shown that Brown's general conclusions about field structure held for circular velocity as well as linear velocity.

Later studies on the velocity transposition phenomenon. Brown's discovery of the velocity transposition phenomenon stimulated other researchers to explain its occurrence in terms of other known perceptual phenomena. Wallach (1939) attempted to show that the transposition phenomenon could be explained by the same principle he employed to explain constancy of visual speed. Wallach stated that, from the viewpoint of the perceiver, the transposition phenomenon is analogous to what one experiences in cases of speed constancy. In speed constancy, identical moving fields are presented at different distances from the eye, which produces corresponding retinal images of different sizes. The subject experiences equal phenomenal speeds when the retinal velocity of the nearer (larger) field is greater than that of the farther (smaller) field. The judgment of speed is made on the basis of displacements relative to the size of the retinal image. If one retinal image is twice the size of another, then displacements in the former must be twice as great as in the latter for phenomenal speeds to be judged equal.

In the case of the velocity transposition phenomenon, one movement field is twice as large in all dimensions as the second field, and since both are presented at the same distance from the eye, the retinal image in the case of the first is twice as large as in the case of the second. According to the transposition principle, the phenomenal speed in both fields is the same when the objective velocity in the larger field is twice as great as in the smaller. This being the case, the velocity of the retinal image of the larger field is also twice as great as that in the retinal image of the smaller. We find then, that the two different experimental situations yield essentially the same processes on the retina. If we apply the principle of transposition to the retinal images of the two movement fields in a constancy experiment, the principle leads to equality of phenomenal speed. Wallach said that the transposition principle alone, if applied to retinal images and retinal displacements, would yield constancy of visual speed, and no further principles would be needed for its explanation.

Another attempt to provide an explanation of the velocity transposition phenomenon was made by Smith and Sherlock (1957). They performed an experiment to test two hypotheses. First, that Brown's transposition phenomenon could be explained on the basis of judgments of frequency, i.e., that judgments of apparent velocity were determined by the frequency at which moving objects left their bounded fields. This type of frequency could be varied independently by changing the density of discriminable objects in the moving field. Second, that retinal matches of velocity would be made when the movement fields were observed in the absence of any cues to distance, external to the fields.

Their stimuli were composed of black and white horizontal stripes pasted across the surfaces of two endless rubber belts which were covered with white paper. The stripes were one inch wide on one belt, and 1/2 inch wide on the other. The velocity of either belt could be varied continuously via remote control by either the experimenter or the subject. The stimuli were viewed through eyepieces with variable rectangular apertures. The one-inch stripes were viewed through an aperture 23 inches x 17 inches, and the 1/2-inch stripes through an aperture 11.5 inches x 8.5 inches. Both stimulus surfaces were six feet from the apertures and were viewed in a homogeneous surround, thereby fulfilling the physical conditions for transposition.

Each subject made three types of judgment in random order. In the first condition (condition A), the subject was asked to match the frequency at which the one-inch lines passed behind a fixed center point by adjusting the velocity of the belt bearing 1/2-inch lines. In condition B, the subject was instructed to adjust the frequency of the 1/2-inch lines to twice the frequency of the one-inch lines. In condition C, the subject was instructed to regard the smaller lines as being twice the distance of the larger lines, and to take this into account in making matches of physical velocity. The physical velocity of the standard (one-inch lines) was constant at 20 feet per minute for all three judgments.

The basic findings supported the hypothesis that Brown's subjects could have been making matches of apparent frequency when they were instructed to make judgments of apparent velocity, and that frequency can be judged independently of physical velocity. Even in condition C, when cues to distance were eliminated but subjects were instructed to assume distances, matches of retinal velocity were not made. Instead, matches seemed to be made on the basis of frequency. Smith and Sherlock concluded that an explanation of transposition based on frequency judgments is preferred, since frequency can be an independent variable when the retinal velocity is held constant.

Fixation as a determinant of phenomenal velocity. As mentioned previously, J. F. Brown (1931 b), in agreement with earlier works by Aubert and by Fleischl (Brown, 1931 b), showed that movement observed while fixating a stationary point is phenomenally faster than when the eye pursues the moving object. In contrast, Gibson, Smith, Steinschneider, and Johnson (1957), studying the relative accuracy of movement perception viewed under these two conditions, found that the mean difference between error for pursuit and error for fixation is not significant. Their findings indicate that discrimination of speed under the two viewing conditions is equally good. However, it is difficult to compare the results of the Gibson, et al. study with that of Brown, since different procedures were used. In Brown's study subjects made judgments by following the velocity in one field with pursuit and then fixating the second field immediately thereafter. Velocity was then changed in the second (fixated) field until the velocities were reported as phenomenally equal. Thus, the judgments were not made simultaneously, and involved constant change in set in turning from one stimulus field to the other. In the study by Gibson _et al._, subjects were presented with a standard and a variable stimulus pattern, and instructed either to fixate _or_ pursue the stimulus patterns and to match the variable to the standard by looking back and forth between them. Here, the subject was concentrating on one task at a time, and performed equally well under the two conditions.

The results obtained by Gibson _et al._ suggest that the differences in phenomenal velocity attributed by earlier investigators to mode of fixation may actually be replicable only in procedures in which subjects are required to make successive judgments while shifting from pursuit to fixation. It appears that there are other experimental procedures in which fixation and pursuit are equally effective.

A further investigation of the role of eye movements in the perception of movement was performed by Mashhour (1964), who attacked the classical view which explains the perception of movement of a pursued object on the basis of the retinal movement of the background image. The classical view assumes that the image of the object remains stationary, because the eyes move with the object. It is the image of the stationary background which moves on the retina and looks blurred. Mashhour has shown, through photographic records of eye movements, that the eye is not able to follow the moving object perfectly and smoothly, which implies that the retinal image cannot remain stationary during pursuit. Furthermore, he concluded that information about the speed of an object is supplied to the higher nervous centers by short, frequently occurring pauses during pursuit, allowing the object to move across the retina. He has demonstrated that the length of the pauses increases, in general, with an increase in velocity, implying that periods of fixation and pursuit are longer at higher speeds than at lower ones.

Variables affecting movement thresholds. There have been several attempts to measure various types of movement thresholds. As is the case for all psycho-physical data, thresholds for movement have been found to be a function of a number of variables, not the least of which are the procedures employed and the measures taken. R. H. Brown (1960; 1961) has reviewed some of these methodological considerations. No attempt will be made to present all of Brown's arguments here; instead, a more focused review including those experiments that have systematically manipulated variables to determine their effect on movement thresholds will be presented.

Since the perception of movement seemed to be related to visual acuity and the resolving power of the retina, Gordon (1947) became concerned with a comparison of the thresholds of form, motion, and displacement using the same type of stimulus throughout. The threshold of form was defined as the smallest separation of two contours which could be recognized as discrete.

The threshold of motion was defined as the slowest perceptible rate of movement of the stimulus. The threshold of displacement was equal to the minimum distance through which the stimulus object moved at a given speed in order to produce the perception of movement.

Gordon found that, within a speed range of 0.8 degrees to 1.8 degrees of visual angle per second, the relationship between the thresholds of form and motion is approximately linear at all retinal points, and that the threshold of form is approximately equal to the threshold of displacement.

In view of Gordon's findings of a relationship between thresholds for form and for movement, it is not surprising that other investigators have shown that movement thresholds may be influenced by some of the same variables that affect form perceptions. Research on these variables -- brightness, exposure time, and spatial and temporal cues will be reviewed in the remainder of this section.

In 1937, Crook determined the brightness level at which the direction of movement could be detected. He presented vertical black gratings of different widths in front of a milk glass screen. The velocity of the stimulus could be varied by the experimenter, as could the brightness of the field. The field was exposed automatically for 1/5 second on each trial. All subjects were dark-adapted prior to experimentation and run through an exploratory series to determine the "doubtful" zone of brightness in which the subject could just detect a moving vs. a non-moving stimulus. A formal series of twenty trials was then given, during which the subject was asked to make judgments of movement in terms of "right" or "left". Direction of movement was varied at random in the series. If the percentage of correct judgments fell below 75 percent, the brightness of the field was raised for a second series of trials; if the percentage was above 75 percent, it was lowered. The threshold was defined as the brightness level at which the direction of movement of a given grating size at a given speed could be correctly judged 75 percent of the time.

Crook's data showed that the log brightness necessary for discrimination is a function of speed. They also demonstrated that intensity thresholds decrease as the width of the grating bars increases.

R. H. Brown and Conklin (1954) investigated the effects of exposure times on the lower threshold of visible movement. They found that the lowest rate of movement required for a judgment of visual movement is a decreasing logarithmic function of exposure time.

More recently, Mandriota, Mintz, and Notterman (1962) studied the effects of spatial and temporal cues on the differential threshold for angular speed. Their stimuli consisted of single spots of light which traversed the field from left to right. A trial consisted of a single traversal of a standard velocity stimulus, followed by a single traversal of a comparison stimulus. The subjects were exposed to three conditions. First, the standard and comparison stimuli traversed equal extents of visual angle, hence the duration of stimulus transit varied inversely with the velocity. Second, the standard and comparison stimuli were in motion for equal duration, so that the extent of the traversal varied directly with the velocity. Third, the stimuli moved over extents and for durations which were randomly changed from presentation to presentation, so that velocity could not be inferred from either the extents or the durations of the comparison stimulus. They found that, within the range examined, discrimination is finest when spatial cues are present, intermediate in the presence of temporal cues, and poorest when neither a spatial nor a temporal cue is related to stimulus velocity. They conclude that the precision of velocity judgments is at least partially dependent upon systematic presence of either spatial or temporal cues.

In summary, it may be noted that many variables have been shown to influence adults' perception of real movement. These include the size and structure of the field, the distance of the field from the subject, the size of the moving objects, the heterogeneity of surround, the direction of movement, illumination, exposure time, the presence of spatial and temporal cues, the use of peripheral vs. central vision, and of fixation vs. pursuit. Any of these factors that are not equated in stimulus fields that are compared may be considered as potentially effective variables. Whether these same variables are effective for infants has never been determined; however, it would seem most parsimonious to suspect their effectiveness until it has been disproven. In the research presented in this thesis, all the variables except three have been controlled. One of these -- size of the moving objects (or, in the terminology of this thesis, complexity) -- is employed as an independent variable. The others -- peripheral vs. central vision, and fixation vs. pursuit -- cannot be controlled through instructions to infants, and could only be investigated in these young subjects through the use of eye movement photography, not employed in the experiment to be reported. Although the role of these variables is not fully agreed upon even in studies using adults as subjects, the possibility of their operating as uncontrolled variables in the present research is acknowledged, and must be considered in interpretation of results obtained.

Developmental Studies on the Perception of Real Movement

If we consider only behavioral data, a survey of the literature reveals few developmental studies which appear to be directly related to the perception of real movement. Most of the early studies were designed to measure the maturation of eye muscle responses, and therefore emphasize the response rather than the stimulus.

<u>The use of real movement in the developmental study of ocular-motor coordination</u>. From the review of earlier studies, it can be concluded that the perception of a moving stimulus was used primarily as a means of studying various developmental aspects of ocular-motor coordination. In other words, the purpose of using moving objects was not to study the perception of movement <u>per se</u>, but to use movement as a tool to study other developmental problems.

In one of the earliest studies of this type, Jones (1926) reported observations on age norms and developmental periods for several early behavior patterns in young children. One of her observations was concerned with eye coordination and the ability to follow a moving light. Each subject was placed on his mother's lap, facing toward the experimenter, who systematically moved a pocket flashlight at an approximate rate of six inches per second in the following manner. First, the light was moved slowly from side to side at the level of the eyes, twelve inches to the right and to the left at a distance of twelve inches from the child's nose. Then the light was moved up and down, and finally in a counterclockwise circular motion of about one foot in diameter. Jones reported that no true fixation or following occurs at birth, but that improvement in the use of the eyes is marked during the first months of life. Horizontal following develops first, at the median age of 58 days; then vertical following, at a median age of 65 days; and finally circular following, at a median age of 78 days. She reported reliable differences in the maturation of these three functions.

Another early study was undertaken by McGinnis (1930). He studied the effects of movement on three aspects of ocular-motor behavior in early infancy: optic nystagmus; the first occurrence of saccadic, pursuit, and coordinate compensatory eye movements; and the development of ocular pursuit. His main experiment consisted of placing the infant in a stationary crib bed located in the interior of a rotating drum cylinder. The cylinder was constructed of wire mesh screening. The interior was lined with white cardboard, to which were attached eleven black cardboard bars, running lengthwise of the cylinder. Each bar subtended an angle of five degrees as measured from the center of the cylinder. Ten of the bars were placed on one side of the cylinder, with twenty degrees between centers, while the eleventh bar was placed at the midpoint of the opposite side of the cylinder. The cylinder could be rotated clockwise at three speed levels, or oscillated in a harmonic fashion. Eye movements were recorded with a motion picture camera. When the infant was placed in the cylinder, an attempt was made to get him to look toward the single bar, which was immediately overhead. The cylinder was oscillated at a slow speed, and then turned over and oscillated at the same speed with the ten bars uppermost. The procedure was repeated for a medium and a fast speed of movement. After this, the cylinder was rotated at these three speeds, with movement occurring in the barred field, Finally, the cylinder was turned so that the single bar was uppermost, and behavior was recorded in response to a stationary stimulus.

The results may be summarized as follows. Optic nystagmus occurs during the first twelve hours after birth, and is characterized by the presence of both large saccadic movements, and slow, gliding pursuit movements. The number of eye movements occurring during nystagmus is directly influenced by the number of bars in the visual field and their speed of movement. Successful ocular pursuit first appears during the third and fourth weeks. With increasing age, there is a gradual increase in the number of eye and head movements corresponding to the direction of the stimulus movement, and a gradual decrease of movement in the opposite direction. The number of ocular adjustments during pursuit is inversely related to the speed of movement, but the proportion of eye movements in the correct direction is usually greater for rapid speeds than for slower speeds.

Beasely (1933) compared visual pursuit in 109 white and 142 negro infants, ranging in age from 2-1/2 hours to twelve days. Three stimulus objects were used -- a fountain pen flashlight, the experimenter's fingers moving in a fluttering manner, and a dark blue cylinder two cm. in diameter and seven inches long. Beasley studied horizontal pursuit by first moving the flashlight to the right (at a rate of one inch per second) at a distance of from six to fourteen inches in front of the infant's eyes, then back to the left, and then again to the right, through short distances of one to two inches. A similar procedure was used for horizontal pursuit with moving fingers and the dark cylinder. The latter was held so that the long axis was parallel to the saggital plane of the subject's head. Beasley repeatedly observed that some of the subjects followed an object better at twelve to fourteen inches, and others from six to eight inches, which would hint at individual variations in the ability to accommodate.

In the vertical pursuit test, an identical procedure was used by simply changing the direction of motion. In this test, the dark cylinder was held so that the long axis was perpendicular to the saggital plane of the subject's head. For circular pursuit, the stimulus objects were moved in a circular motion, with a radius of about ten inches, centering on the subject's nose.

The results showed that for all subjects, at all ages, for all kinds of pursuit, negro infants excelled whites. In white infants there was a slightly greater tendency for pursuit to occur in the tests using moving fingers and the dark cylinder, than for tests using the flashlight. The results for negro infants showed that the frequency of pursuit was greater than for whites, and that the type of stimulus was not influential. Beasley concluded that the visual pursuit of negro babies not only begins at a higher level of excellence, but also shows more rapid improvement. This would indicate that functional development is more advanced in negroes at birth than in whites.

Ling (1942) used a black disk moving in a vertical plane to study sustained visual fixation in infants from birth to six months of age. Her study was important in demonstrating that the development of visual fixation is systematic and gradual, and that fixation on a moving object is primarily monocular in the young infant, with binocular fixation developing at a median age of seven weeks.

More recent studies have sometimes employed moving stimuli to determine the limits of infants' visual acuity. Schwarting (1954) attached wire wands of different thicknesses to a metronome which moved a wand across a lighted visual field. He found that in infants as young as three months, the thickness of wand that had to be present before an infant would pursue the wand could be used as a rough measure of visual acuity. According to this measure, Schwarting found three-month-olds to have acuity of 20/400.

Another measure of acuity is provided by the optokinetic nystagmus response to moving stripes of various widths. Recent studies involving the nystagmus response have mainly been methodological improvements on the basic technique employed by McGinnis (1930). Gorman, Cogan and Gellis (1957) observed the reflex eye and head movements of infants under five days of age to a large field of moving stripes, and decreased the width of the stripes until the optokinetic nystagmus response was no longer present. They found the visual acuity of a large percentage of newborns to be approximately 20/350, and that all of the 100 newborns they tested had acuity at least as good as 20/450.

Fantz, Ordy, and Udelf (1962), employing an apparatus patterned after that of Gorman _et al_. (1957), tested 46 infants between four days and six months of age. Their results on the nystagmus response agreed fairly well with the results of a study of visual fixation responses to non-moving grids of stripes in finding that during the first month of life infants had visual acuity of approximately 20/400, and that acuity increased with age, so that in the sixth month of life acuity was better than 20/150.

Dayton, Jones, Aiu, Rawson, Steele, and Rose (1964) increased the precision of judgment of the presence of nystagmus by using electro-oculography, in which electrodes are placed close to the outer canthus of each eye and on the bridge of the nose to provide horizontal recordings across both eyes. Of 39 infants tested between the ages of one and eight days, 18 had records clear-cut enough to permit interpretation of the level of visual acuity. Dayton _et al_. concluded that visual acuity in some newborn infants is at least 20/150, and may be even better.

In general, it can be concluded that estimates of infants' visual acuity have steadily improved as sophistication in methodology and in instrumentation has increased. The same appears to be true of estimates of visual pursuit ability, which has also recently been studied with electro-oculography by Dayton and his co-workers. Dayton, Jones, Steele, and Rose (1964) showed infants less than ten days old a series of targets each consisting of a black dot moving at an angular speed of about 16 degrees per second. Of thirty infants who were awake for testing, 17 exhibited pursuit of the dot on two or more successive presentations. This finding contradicts McGinnis's (1930) finding that infants less than two weeks old cannot successfully pursue moving objects. In another study employing the same stimulus, Dayton and Jones (1964) found that those infants who pursue show a high degree of conjugation of the two eyes. These results do not uphold earlier contentions (Ling, 1942) that fixation on a moving object is primarily monocular in young infants. Dayton and Jones (1964) also found that the major differences between the pursuit reflexes of infants and those of adults are in amplitude and frequency of refixation. Infants tend to fall behind in tracking the target, and they require more refixations to pursue it. While adults rarely have any measurable refixation movements, newborn infants make one to 1.5 refixations per second. The number of refixations slowly decreases with age.

Recently Wolff and White (1965) have investigated the effect of organismic state on infants' visual pursuit and attention. In their research 43 three- to four-day-old infants were presented with a 7-1/2 inch circle moved horizontally across the visual field at the approximate rate of one foot per second. Wolff and White found that the range of visual pursuit using conjugate eye movements was greater when infants were alert but quiet than when they were active. They also found that pacifier sucking inhibited the infant's head movement. Pursuit performed while the infant was starting to suck employed more eye movement and less head movement than when the infant was not sucking. Infants who sucked on a pacifier for a period of three minutes or more had larger ranges of eye pursuit than infants who had just started to suck.

Developmental studies concerned directly with perception of movement. Several investigators have studied infants' responses to matrixes of blinking lights (Cohen, 1965; Haith, 1966; Kagan and Lewis, 1965; Lewis, Campbell, Kagan, and

Kalafat, 1966). Although many of the stimuli presented in these studies were ones which to an adult might lead to the perception of apparent movement, it is not known, of course, whether infants do perceive movement under these conditions. A start on answering this question would depend on the obtaining of normative data on infants' responses to real movement.

In line with the claims of importance of movement in the human face as a basis for social responsiveness (Rheingold, 1961; Walters and Parke, 1965) there have been several studies of infants' responses to moving faces. In none of these studies has the amount of movement been varied, probably because of the difficulty of measuring the amount of movement in an object as complex as a face. There are, however, several indications that infants do respond to movement vs. non-movement. Recently Morgan (1965) has studied infants' visual fixations to motion pictures of a human face. She found that her five-month-old subjects looked significantly more at movies in which a female adult moved her face than in movies in which the adult held the face and head motionless. Several studies (Ahrens, 1954; Ambrose, 1961; Spitz, 1946; Wolff, 1963) have noted that more smiling is elicited from infants than when the head and face are motionless. The earliest reports of smiling at a moving but silent human face are by Wolff (1963), who noted this during the fourth and fifth weeks of life in his sample of four subjects. It is possible that the use of the visual fixation response rather than the smiling response might allow future investigators to find an even younger interest in moving faces.

To this author's knowledge, there is only one study in the literature which attempts a developmental investigation of the threshold for movement perception. Carpenter and Carpenter (1958) taught two children, ages 81 and 101 months respectively, and two chimpanzees, ages 36 and 39 months, to press a window in front of whichever of two identical striped paper belts was moving. Using operant techniques, the children were reinforced with pennies and the chimps were reinforced with milk whenever they pressed the correct window. Incorrect responses, i.e., pushing the window in front of the non-moving belt, were punished by turning the room lights off for ten seconds. After initial discrimination training, a paper drive was programmed to give a continuous series of two-second intervals. Movement occurred in only thirty percent of these intervals, and its presentation was alternated in an irregular series with intervals during which movement was not present. Not more than four movement intervals occurred consecutively. When the subject's performance became stabilized at a particular rate of movement, the rate was decreased in a modified method-of-limits procedure. Chance level of correct responses was thirty percent, and the threshold was defined as that speed which produced a point halfway between chance and errorless performance, or 65 percent correct responses.

The results showed the children and the chimps to be approximately equal to each other in performance on this task. In both species, the older subjects had a considerably lower threshold than did the younger. In comparing the performance of the children and the chimps to that of two human adults run in the same apparatus, both were markedly inferior. Whereas the thresholds of the adults were between 10' and 17' per second, a range comparable to movement thresholds obtained by other methods, the thresholds of the chimps and the children ranged from 27' to $1^{\circ}42'$ per second. Carpenter and Carpenter concluded from the available data that maturational level may be an important variable in the determination of the threshold for movement perception. Further developmental studies are necessary to verify this assumption.

Preliminary studies by Silfen and Ames (1964) and Ames and Silfen (1965), have shown clear age differences in infants' attention to moving checkerboard patterns. Using the visual fixation preference method, they presented pairs of stimuli in which one pattern moved at varying speeds, and the other pattern remained stationary. They measured the percent total looking time which was spent looking at the moving stimulus for five different age groups: 7 weeks, 11 weeks, 16 weeks, 20 weeks, and 24 weeks.

Their data indicate that the discrimination of movement is present and increases with age. It was found that a significant number of 24-week-olds showed preference for the moving stimulus over the non-moving stimulus at all speeds. A significant number of 20-week-olds and 16-week-olds showed a preference for the moving stimulus at the three fastest speeds, and a significant number of 11-week-olds preferred the moving stimulus at the two fastest speeds. While the 7-week-olds showed no significant preference for the moving stimulus even at the fastest speed, there was an indication that they were making some form of discrimination of movement. An increasing number of 7-week-olds looked longer at the moving stimulus than at the non-moving stimulus when the speed was at its fastest setting of $3^{\circ}3'$ visual angle per second. This preference did not appear with angular speeds slower than $2^{\circ}24'$ per second. These results seem to indicate that infants show preference for a wider range of speed as they get older.

It is obvious from the preceding studies, that research on the development of movement perception is somewhat scattered, unorganized, and still in a very elementary stage. Some of the variables that need to be studied in tracing this development are the speed ranges to which children are sensitive at different ages, relative sensitivity to direction of movement, relative sensitivity to different types of movement, and the effect of texture and detail in the sensitivity to movement.

Studies on Complexity

Some Definitions of Complexity

One of the major difficulties in studying any variable in psychology is to find a definition which will be operationally manageable. Several definitions of complexity have recently appeared in the literature, most of which have been reviewed in some detail by Moffett (1963) and Brennan (1965). This section will concern itself mainly with a summary of the various stimulus characteristics that were found to affect stimulus complexity.

Complexity has been defined by some as the amount of variety or diversity in a stimulus pattern (Berlyne, 1960). Complexity increases as the elements of the pattern become increasingly dissimilar, and also as the number of distinguishable elements increases. In this definition, the emphasis is on the number of "psychological" parts in the stimulus, rather than the number of physical parts.

Dember and Earl (1957) suggest that complexity can be defined in terms of change in stimulation. This change can be brought about through movement in the field or by increase in spatial heterogeneity or incongruity.

Walker (1964) states that complexity is a function of patterning of stimulus elements. Since pattern is regarded in terms of relations between elements, he suggests that information theory be used as a basis for constructing stimuli of varying complexity levels.

While several attempts have been made to define complexity at an operational level, most of them are unsatisfactory for various reasons. Many definitions are basically intuitive and do not lend themselves well to measurement. Others, such as information theory, have not proven to be satisfactory in spite of the attempt to be precise. Let us now turn to a review of the various studies in which complexity has been experimentally defined.

Complexity as Experimentally Defined in Adult Studies

Moffett (1963) has reviewed the various studies concerning the influence of complexity on adult learning and memory. She points out that experimenters such as Deese (1956), Fehrer (1935), French (1954), and Attneave (1955) agree that complexity varies with the number of parts that make up a figure. In general, learning and memory studies have yielded consistent positive findings only when complexity was defined in terms of the number of elements making up the stimulus. Some of these investigations indicate that symmetry could also be used as an index of complexity. The stimulus characteristic of number of parts is easily measurable, since it can be quantified, but the symmetry characteristic would not be as amenable to measurement.

Berlyne (1958a) investigated the effects of complexity on visual attention in adults. He presented pairs of stimulus figures simultaneously to adult subjects, and recorded the length of time spent fixating each member of a pair, as well as which stimulus was fixated first. He grouped stimuli in six categories, each of which was meant to represent a different aspect of complexity. For each pair within a category, one stimulus was "more complex" than the other. Berlyne's six categories were amount of material, irregularity of shape (symmetry vs. non-symmetry), irregularity of arrangement, heterogeneity of elements, incongruity (e.g., an elephant's massive head on a very fragile body), and incongruous juxtaposition (e.g., rabbit's head forming the front part of an automobile).

The major contribution of this study was Berlyne's attempt at making operational definitions of complexity. Several of the indices he used have been mentioned previously though his last two categories, incongruity and incongruous juxtaposition, seem to be his own creation.

Several researchers, in an attempt to be more precise, claim that complexity can be conceived of as a function of the information contained in a figure. Attneave (1957), however, found that there was no direct relationship between the amount of information contained in a stimulus and adults' judgments of the complexity of the stimulus.

The experimental results so far seem to indicate that the only definitions of complexity that have yielded consistent positive findings are those that consider the number of elements making up the stimulus. Attempts like Attneave's to find sophisticated definitions of complexity have, to the present, not been successful.

Complexity as Defined Intuitively in Studies on Infants

A survey of the literature reveals a growing body of information on the developmental approach to complexity. An excellent review of the developmental studies on complexity may be found in Brennan (1965). In this section, the author will merely summarize the studies which were reviewed in some detail by Brennan.

Cantor (1963), in reviewing studies on the visual attention of children to complex stimuli, found the same problem that exists in adult studies on complexity, namely that " ... there appears to be a serious need for intensive study of a few relatively simple and rigorously delimited stimulus properties which hopefully will supplant the vague notions of 'complexity' which are currently prevalent." (p. 21). Brennan (1965) pointed out that in studies on children, most designations of stimulus complexity levels have been either _post hoc_ or _a priori_, based on intuition.

In studying the effect of medication during labor on attention in newborn infants, Stechler (1964) presented each of three stimuli, a picture of a face, a die with three dots, and a blank card, three times for one minute in a single stimulus procedure. In terms of the average total fixation time for each stimulus, the order of decreasing preference for the three stimuli was face, die, and blank. In searching for an explanation of the results obtained, Stechler examined his stimuli and decided that they differed in complexity, the face being more complex than the die, and the die being more complex than the blank. He then gave a _post hoc_ explanation of the results of his experiment in terms of the complexity of the stimuli used. However, nowhere in the study did he offer a _definition_ of complexity.

As a pioneer in the field of visual attention in infants, Fantz was mainly concerned with showing that consistent visual preferences for certain stimuli were present in newborns and older human infants. In three separate studies (1958, 1961, and 1963) he recorded fixation times for pairs of stimuli presented to infants of different ages. He used such stimuli as checkerboards, horizontal stripes, bull's-eyes, faces, newsprint, etc. Fantz apparently ranked these stimuli as to the amount of form or pattern they possessed, but was not explicit about any independent grounds for classifying these stimuli. Fantz proposed that visual patterning is intrinsically stimulating, and that it elicits much more visual attention from birth than do color and brightness alone. Selectivity of attention, in general, favors more complex patterns, though this is dependent on pattern differences and the age of the subjects.

Several studies have made intuitive a priori designations of the order of complexity. Lewis, Meyers, and Kagan (1963) presented moving and blinking lights to 24-week-old infants. These stimuli could be interpreted as possessing form, number of elements, and movement, all of which could be conceived of as contributing to complexity. However, the experimenters did not give their reasons for assuming that the stimuli differed in complexity, and their ordering must be classified as intuitive.

Berlyne (1958b) performed an experiment to test the effects of albedo and complexity in visual fixation in the human infant. His figures, differing in degree of complexity, were made up of equal areas of black and white but were very different in form from each other. Berlyne explained the results he obtained by saying that the patterns that attracted first fixations significantly more often had more contour, and that this accounted for their high attention value. However, contour was not the only attribute on which the stimuli differed. They also varied as to the number of parts they possessed, the number of black and white alternations, and the number of independent angles contained in them. The results could be explained in terms of any one or all of these attributes.

Another method of ordering stimuli in terms of complexity is to use adult ratings. Thomas (1965) designated the rank order of complexity by means of ratings given his stimuli by college students. The indices which the adults used as bases for their judgments were not specified in this study. Moffett (1963) demonstrated that there is sometimes very little agreement between adults' judgments of complexity and infants' visual fixation on the same stimuli, suggesting that adult ratings on this dimension should be used with care in attempting to evaluate the results in infant studies.

Studies on Infants Using Explicit Definitions of Complexity

A few experimenters have attempted to give *a priori* ordering to their stimuli in terms of explicit definitions of complexity. Hershenson, Munsinger, and Kessen (1965) ordered stimuli in terms of the number of angles they contained. They noted that, if one defines complexity as the number of light-dark transitions in a stimulus, the complexity level increases as the number of angles increases. Moffett (1963) used stimuli composed of cross-hatched black lines on a white background, and systematically varied complexity by independently changing the number of parts and the number of lines. She found that the number of parts into which the area was divided was more important as an index of complexity than was the number of lines.

Spears (1964) used five series of four stimuli, each presented in a paired comparison procedure. He quantified precisely each of the stimuli along three complexity dimensions: amount of contour along transition boundaries of colored and white areas, the number of independent angles, and the degree of symmetry. He found that contour seemed to be the most important variable in determining the infant's visual preference, with symmetry apparently playing no role. Hershenson (1964) and Brennan, Ames, and Moore (1966) used checkerboard squares as stimuli, quantifying the complexity of each design in terms of the number of parts comprising it. In these cases, the complexity of the stimulus increased as the number of light-dark transitions increased.

Karmel (1966) recently attempted to delineate some of the physical properties of the stimulus which can determine pattern preference behavior. Using black and white squares, he independently varied amount of contour, element size, and element arrangement. He found, in general, that preferences were related to amount of contour (which is based on the number of elements) rather than degree of redundancy (which is based on configuration or arrangement). Infants' preferences for greater amounts of contour reversed to preferences for lesser amounts of contour when the threshold of acuity was approached. Karmel concluded that if complexity can be defined solely by the amount of contour in a pattern, then "complexity" becomes a superfluous concept. While this may be true, the two terms are still interchangeable when speaking of redundant patterns such as checkerboards, for the amount of contour is directly related to the number of parts in the stimulus array.

One major advantage of these studies over those employing intuitively chosen stimuli, is that the use of explicit definitions of complexity enables experimenters to compare results obtained from several different studies in which the same stimulus dimensions are manipulated. However, with the existing diversity of definitions, it becomes almost impossible to generalize the results from one experiment to another.

General Results of Complexity Experiments on Infants

Lewis, *et al.* (1963), Berlyne (1958b), Spears (1964), and Moffett (1963) all found that a definite preference was shown in infants for the most complex stimuli of the respective series presented. If one considered only the results of these studies, it would be reasonable to conclude that all infants, in the age range from two to nine months, prefer more complex stimuli. However, there is recent evidence to indicate that this is not the case.

Hershenson, et al. (1965) presented newborns with three stimuli, which contained 5, 10, and 20 angles respectively. The greatest attention was paid to the stimulus of intermediate complexity (ten turns), with the most complex stimulus (twenty turns) being preferred second. Further evidence that the most complex stimulus is not always preferred is offered in another study by Hershenson (1964), in which he presented three stimuli composed of black and white checkerboard squares to newborns. The three checkerboards contained 2 x 2, 4 x 4, and 12 x 12 squares respectively. Hershenson found that the least complex stimulus was the most preferred, and that the order of preference exhibited for the stimuli was in decreasing order of their complexity.

Thomas (1965) performed the first experiment in which there was a deliberate attempt to test age differences in the level of stimulus complexity preferred by infants. His stimuli were, in order of increasing complexity, stripes, a checkerboard, a face and a figure. His data indicated that as the infant grows older, there is a tendency for him to prefer more complex visual stimuli. However, certain criticisms may be offered regarding this experiment. Namely, that the stimuli he used varied along several dimensions simultaneously, making it difficult to ascertain which of the dimensions was contributing to the results. In addition, he used adult judgments to order the complexity of the stimuli which, as mentioned previously, is not always a wise procedure.

Brennan, Ames, and Moore (1966), in an attempt to clarify the findings regarding the effect of age on infant preferences for complexity, presented three black and white checkerboard patterns, consisting respectively of 2 x 2, 8 x 8, and 24 x 24 squares, to infants 3 weeks, 8 weeks, and 14 weeks of age. Their findings indicated that 3-week-old infants preferred the patterns in decreasing order of complexity, the 8-week-old group preferred the pattern of intermediate complexity (8 x 8) most, and the 14-week-old group preferred the patterns in increasing order of complexity.

The results of these preceding studies can be explained by Dember and Earl's "pacer" theory. Dember and Earl (1957) have proposed that attention may be aroused by both temporal and spatial changes in stimulation. They define stimulus change in terms of "complexity", which refers to the amount of variety or diversity in a stimulus pattern. They point out that any stimulus may have a different measure of complexity on each of its attributes, implying that one could increase the complexity of a stimulus along one attribute, while keeping other attributes constant.

In addition, Dember and Earl propose that attention is a function not only of stimulus complexity, but also the psychological complexity of the individual, which changes with experience. An individual supposedly has an ideal complexity value on each stimulus attribute which corresponds to his ability to interpret information on that attribute. These complexity values may change independently of one another. For example, an individual's ideal complexity value on one attribute may increase while his complexity value for another attribute remains the same. The ideal psychological complexity level is characteristic of an individual at a given time with respect to a specific stimulus attribute.

The ideal complexity levels take on increasing values with increased experience. Stimuli which are slightly more complex than the individual's momentary ideal will serve to increase the complexity of the individual. Dember and Earl call these "pacer" stimuli, and state that an individual will attend to a set of stimuli if the set contains a stimulus that is a "pacer" for him. "We postulate that under that condition, the individual will apportion his attention among the stimuli in the set in proportion to their similarity to the pacer, with the modal amount of attention applied to the pacer." (p. 95).

As the individual has continuous experience with this set of stimuli, his ideal level of complexity will increase until the set no longer contains a "pacer", <u>i.e.</u>, the set will no longer have the ability to change his level of psychological complexity. At this time, the set will lose its attention-eliciting property.

Presumably, as long as there are suitable "pacers" available in the environment, and as long as the individual can respond freely to all of the available stimuli, his ideal complexity level will continue to increase to the limits of his hereditary endowment.

Walker (1964) expands the basic concepts of Dember and Earl to situations where no event near the optimum complexity is available. If the situation involves complexity below the optimum, the subject becomes bored and restless. The most common behaviors that would result from such a situation would be a search of the environment for more complex events, locomotion to another environment that is more complex, attempts to differentiate previously unexplored potential complexity in the environment by shifting the attention, or the advent of self-produced stimulation through daydreaming or fantasy. Any of these devices would serve to increase the complexity level of the sequence of events that is occurring.

The opposite of the above would be a situation in which the level of complexity is above optimum. These situations are usually ones in which the sensory inputs are providing more information than the individual can process, and may result either when the external environment is too complex, or when the emotional system is in a highly aroused state. Reactions which are likely to occur in this instance would be attempts to narrow the attention to a limited portion of the stimulus input, locomotion to a less complex circumstance, or repeated attention to the same stimulus in an attempt to reduce the psychological complexity of the situation by organizing the very complex stimulation into a smaller number of "chunks". Through these various means, the individual seeks to maintain an optimal level of complexity that he can process. With progressive experience, the individual seeks more and more complex levels of stimulation to keep pace with his own development.

We can see that the results found by Thomas (1965) and Brennan, _et al_. (1966) give evidence to support Dember and Earl's theory. Namely, that as the infant grows older he shows an increasing preference for more complex visual stimuli. In these studies, the stimuli that were preferred were presumably those which were most similar in their sets to the "pacer" stimulus for infants of a given age. Thus, they attracted more attention than any of the other stimuli used. The relative preferences given to individual stimulus patterns will obviously be a function of the particular range of the stimuli used. For example, in the study by Brennan, _et al_. (1966), older infants showed greatest preference for the most complex stimulus patterns used. If stimuli of even greater complexity had been added to the sets, it might have been found that infants would not have paid greatest attention to the most complex of the set, but instead would have directed more attention to that stimulus which most resembled the "pacer" for them. It would seem that Dember and Earl offer a theory which lends itself to experimental verification, and it is surprising that so few experiments have been designed to test its implications.

The scarcity of experiments, at the infant level, may be attributed to the previous lack of reliable and valid research methods to test the perceptual capabilities of the very young child. As B. L. White (1963) points out, there is a great lack of knowledge about perceptual development in the human infant due to the problem of assessing changes in processes about which no normative data exist. We must develop procedural designs which will enable us to assess these changes. We will now turn to a review of a method which has been applied to the study of visual perception in infants.

The Visual Fixation Preference Method in Studies of Visual Perception in Infants

Gibson and Olum (1960), who give an excellent review of current experimental methods for studying perception in children, attribute the paucity of normative data in perception not to weakness in methodology, but to the general lack of a truly developmental approach to perceptual problems. A review of the literature would seem to bear this out. However, methodological problems do arise when one wishes to study perceptual development in the pre-verbal infant. The psychophysical methods which can be used with the verbal child cannot be applied satisfactorily to the infant. Instead, "indicator" responses must be used which are sufficiently well-coordinated at birth to be reliable. One of the most widely used of the indicator responses is ocular orientation. Most of the studies using this measure have emphasized eye movements and visual attention, measured by fixation.

McGinnis (1930) and Ling (1942) both used motion picture records to study eye movements during sustained visual fixation and pursuit, and eye movements were also used by Chase (1937) to study color vision in infants. Recent experiments have employed a method patterned after that used by Staples (1932) in a study of color discrimination. Staples assumed that if an infant were presented simultaneously with two stimulus patterns, and he looked at one stimulus significantly longer than at the other, it could be concluded that the infant was discriminating between the stimuli. In this method, the stimulus is said to be fixated when its corneal reflection is overlapping the pupils of the eyes. The experimenter, observing the child through a small aperture, records the length of time that each object is fixated. Berlyne (1958a) used a modification of Staples's apparatus to study the effects of albedo and complexity on visual fixation in the infant, and Fantz (1958, 1963) and Fantz, Ordy, and Udelf (1962) used a similar method to study pattern vision.

Modifications of the same method have been used to study form perception (Fantz, 1961); complexity and novelty (Fantz, 1963, 1964; Moffett, 1963; Saayman, Ames, and Moffett, 1964;

Meyer and Cantor, 1966); brightness and complexity (Hershenson, 1964); and visual acuity (Fantz and Ordy, 1959), to mention a few. The visual preference method is now being widely used in research on infant perception, and is the method employed in the present research.

Developmental Differences in Patterns of Looking Behavior

The findings of several earlier studies have indicated that there are distinct differences in patterns of looking behavior at different stages of development (Silfen and Ames, 1964; Ames and Silfen, 1965; Stechler, 1965). These differences in looking behavior are in themselves valuable for demonstrating the developmental changes that occur in the perceptual process. The previously mentioned studies have shown that babies less than two months of age tend to hold their fixation on one stimulus for a long time. Older babies (five months old) tend to engage in a much more active scanning of the visual field, which is reflected in the tendency to direct a larger number of shorter fixations to the stimulus patterns. These age differences are partially attributable to the inability of the young baby to shift his gaze easily, as a result of side preferences produced by the tonic-neck reflex. Once his attention is "captured" by a stimulus, his gaze remains fixated on it. He is, in essence, a passive viewer. As the child matures and gains sufficient muscular control over head and eye movements, he engages in a more active search process in which he "captures" the stimuli, rather than being "captured by" them. In addition, the older baby is more easily distracted by extraneous stimulation, and he spends more time engaged in a variety of diversive activities which take his gaze away from the stimulus patterns.

These different patterns of looking behavior deserve attention in future experimentation in order to determine their reliability, and to see if different aspects of looking behavior might give fuller information regarding the development of visual perception in the human infant.

Purpose of the Present Research

The collection of normative data on the perception of movement and complexity is potentially important because there is evidence that the perception of moving detail may form a basis for other types of discrimination, specifically the perception of depth and the development of social responsiveness. A review of this evidence follows.

The Role of Movement and Complexity in the Perception of Depth

In investigating the development of depth perception in different animals, Walk and Gibson (1961) employed a simple experimental set-up called the visual cliff. The cliff was a simulated one consisting of a board laid across a large sheet of heavy glass which was supported a foot or more above the floor. On one side of the board a sheet of patterned material was placed flush against the underside of the glass, giving the glass the appearance of solidity. On the other side a sheet of the same material was laid on the floor; this side becoming the visual cliff. Young organisms of several different species, including human infants, were placed on the cliff. Most of them responded by moving to the "shallow" side of the cliff, indicating at least a partial dependence on visual cues for the perception of depth.

Two visual cues which could have played a decisive role in the perception of depth were the size and spacing of the pattern, which decreased with distance, and the cue of motion parallax, which caused the pattern elements on the shallow side to move more rapidly across the field of vision when the organism moved its position. In subsequent experiments, Gibson and Walk isolated the effects of each of these cues from one another, and found that motion parallax plays an important part in the depth perception of humans and other animals by the time they acquire locomotion. They point out that anatomical evidence suggests that all animals with eyes are sensitive to motion perspective. Since only some animals register the perspective of binocular disparity, there must be at least a partial utilization of the monocular cue of motion parallax. Further evidence for this conclusion was provided by Walk and Dodge (1962) who found that depth perception on the visual cliff was present in a ten-month-old monocular infant.

These studies emphasize that the early ability of the infant to detect movement in a textured field could play an important role in depth perception. Therefore, it would seem worthwhile to collect normative data to determine how the perception of movement undergoes progressive development with age. The collection of normative data showing the ability to perceive movement at an early age would not prove that infants do use their movement perception ability as a basis for depth perception, but it would prove that they could use it.

The Role of Movement and Complexity in the Development of Social Responsiveness

Walters and Parke (1965) have recently proposed that the orientation reaction may be the primary foundation for the infant's social development. The modifications of attention that constitute this reaction bring the infant into frequent contact with the social agents who provide him with most of his visual and auditory stimulation. Under normal feeding and other caretaking conditions, the mother's face is frequently exposed to the child at optimal distances for pattern vision. Consequently, the infant has many opportunities to observe the mother's face, which has a large variety of stimulating properties. The face has contour and complexity, and moves almost constantly, providing stimulus change with every movement.

The face is therefore complex and mobile enough to hold the infant's attention and to provide him with ample opportunity to develop social responsiveness on a purely perceptual basis.

This viewpoint was first stated strongly by Rheingold (1961), who listed the following advantages of such a theory: it appears to fit the observed facts; it requires fewer assumptions than learned drive theories; it provides an alternative to theories which hold that there is some instinctual recognition of people as humans; and it can be investigated experimentally through an analysis of infant responses to movement, complexity, brightness, contour, etc.

In support of this viewpoint, we find evidence by Spitz (1946) that movement of all or parts of the face is sufficient to evoke a smile from the infant. Smiling has frequently been employed as an index of social responsiveness. Wolff (1963) indicated that the human head was effective for eliciting smiles in the fourth and fifth weeks of age only if it was in movement or where there was eye-to-eye contact between infant and observer. Ahrens (1954 a,b) and Ambrose (1961) have also emphasized the importance of movement and eye-to-eye contact. It would seem from this evidence that movement is a potent determinant in the development of social attachment. It is therefore surprising to find that no systematic study has ever been undertaken to determine sensitivity to or preference for movement in the human infant.

Movement and Complexity as Related to the Dember and Earl Theory

In addition to the possibility that the perception of movement might contribute cues to the previously mentioned types of discrimination, it might also be used to test Dember and Earl's pacer theory. Dember and Earl (1957) and Rheingold (1961) consider movement to be a dimension of complexity, as it involves both temporal and spatial changes in stimulation. Therefore, if increasing movement occurs in a visual field, the complexity of the field should be increased. In the same manner, an increasing number of parts in the visual field, in terms of textural detail, will also increase its complexity. If we increase both of these dimensions simultaneously, then presumably we produce a stimulus field which is of greater complexity than one produced by manipulating either dimension alone. If we add this to the premise that the ideal complexity of the child increases with age, then we can predict that there will be some combination of texture and movement that will represent a ceiling of complexity beyond which the child will no longer be attracted. This ceiling, or pacer, should be reached at lower levels of complexity by younger children.

A stimulus pattern which lends itself well to the simultaneous manipulation of both of these dimensions is the checkerboard. As discussed in Ames and Silfen (1965), "Not only have checkerboards been used widely in infant fixation studies, but they allow the easy control of keeping black and white areas equal while breaking up the total area into more and more parts . . . definitions of complexity in terms of number of turns, number of parts or amount of contour do not contradict each other. Finally, adult judgments of complexity are clear, and agree with these physical definitions in calling most complex that checkerboard with the largest number of squares in it." (p. 5.)

Preliminary work on movement perception (Ames and Silfen, 1965) has demonstrated that a moving checkerboard pattern is effective in eliciting attention in the infant. Its textured field is very similar to those used in early experiments on movement perception (Brown, 1931 a,b), and permits one to vary speed of movement, the size of the squares, or both.

Hypotheses of the Present Research

In the research to be presented in this thesis, 8-week-old, 16-week-old, and 24-week-old infants are presented with moving checkerboard stimuli, and their visual fixations of these stimuli recorded. Independent variables are age, speed of movement, and complexity of the checkerboard. The research was designed to test the following hypotheses:

1. The faster the stimulus moves, the more fixation it elicits from infants.

2. The older the infant, the more responsive he is to differences in speed of stimulus movement.

Although infants' response to stimulus movement has been hypothesized by others to be present and to form a basis for discrimination for depth (Walk and Gibson, 1961; Walk and Dodge, 1962) or for the development of social responsiveness (Rheingold, 1961; Walters and Parke, 1965), there are at present few data available on the effect of speed of movement on infants' responses. Studies compare movement with no movement (e.g., Morgan, 1965), but no age normative data on responses to different speeds of movement are available for children younger than six years old (Carpenter and Carpenter, 1958).

3. Within the ranges of age and of stimulus complexity used in the present research, the more complex the stimulus, the more fixation it elicits.

The research of Brennan, Ames, and Moore (1966) has shown that the older the infant, the more complex the checkerboard he fixates most. Depending on the age range and on the range of complexity used, it is possible to obtain any of several functions relating stimulus complexity to age. Using Dember and Earl's terminology (1957), if all the stimuli presented are above the infant's pacer level, then the more complex the stimulus, the less it will be looked at. If some of the stimuli are above and some below the pacer level, then looking will increase with complexity up to the pacer and then decrease with further increases in complexity. Finally, if all stimuli are below the infant's pacer level, then increases in complexity produce increased looking.

It is the latter case which is hypothesized to hold in the present research. The hypothesis is based on the results found by Brennan, Ames, and Moore (1966), using stationary checkerboards. They found that 8-week-old infants looked most at a checkerboard composed of 3/4 inch squares and significantly less at either more complex (1/4 inch squares) or less complex (3 inch squares) checkerboards. In the present research, the most complex level of checkerboard used is composed of 3/4 inch squares, and the youngest group of infants used is eight weeks old. Thus it appears that all the stimuli are at or below the presumed pacer level of even the youngest group of infants. Since with increasing complexity within the range used the stimulus will more closely approximate the pacer level, it is hypothesized that the more complex the stimulus, the more it will be fixated.

4. _The more complex the moving stimulus, the more responsive infants are to its speed_.

The predicted interaction between speed and complexity is based on the work done with adults by J. F. Brown (1931a), in which he found that movement in a field of small objects was perceived as phenomenally faster than it was in a field of equal size in which the objects were larger.

One possible interference with the applicability of this hypothesis must be noted. If a) as suggested by Dember and Earl (1957), movement and textural complexity are both regarded as components of some overall "stimulus complexity", and b) an addition or multiplicative interaction is assumed between them, and c) infants' responses are determined by the resultant overall complexity level, then it is possible that the total complexity presented might exceed the pacer level of the infants, especially of the younger infants. If this were so, one would hypothesize that when stimuli were simultaneously at high speeds and high levels of textural complexity, younger infants' looking would be less that what it was at lower levels of speed-complexity combination.

However, although Dember and Earl (1957) talk of both movement and textural complexity as being particular forms of "complexity", they have not specified the results to be expected when two separate components are combined, and it does not appear that experiments have been done to test this point. Therefore, for the time being, a simpler hypothesis is accepted for investigation.

5. The older the infant, the larger the number of separate looks, but the shorter the average duration of each look.

This hypothesis is based on previous work by Silfen and Ames (1964) and Ames and Silfen (1965). The present research, besides serving as an attempted replication of their findings, explores the implications of the different looking patterns for legitimate comparison of different age groups presented with the same stimuli. If infants look in different ways at different ages, what measure of looking behavior can be used to compare groups with one another?

CHAPTER 3

Method

Subjects

Infant subjects were obtained for the experiment from two sources. Notices were sent out to all parents in the Hamilton, Ont. area who announced the birth of their baby in the local evening newspaper. Further notices were placed in Vancouver, B.C. hospitals. In response to notices, parents phoned to volunteer their babies for the experiment. Each subject who came to the laboratory was given $2.00 whether or not he completed the experimental procedure. The only basis of subject selection was age, and infants were discarded during the experimental session only if they did not complete the stimulus series because of crying or falling asleep.

A total of 96 subjects were run in the experiment. Thirty-two subjects were run in each of three age groups: 8 weeks, 16 weeks, and 24 weeks of age. Subjects within an age group ranged in age between one week younger and one week older than the age used for labeling the group. Within each age group eight subjects were assigned randomly to each of four groups presented with different levels of stimulus complexity.

An additional 79 subjects were run but discarded from the data analysis because of failure to complete the experimental series. Most of the discarded subjects were from the oldest age group, and the cause of their failure to complete the series was crying and protest at having to lie supine. Data from 48% (N=30) of the 8-week-olds run, 20% (N=8) of the 16-week-olds run, and 57% (N-42) of the 24-week-olds run were discarded.

Apparatus

The apparatus consisted of a wooden chamber 28 inches x 27½ inches x 23 inches which enclosed a mobil crib 29½ inches long and 16 inches wide. Both the crib and chamber were mounted on a steel framework on wheels. One side of the chamber was open so that the crib could be rolled underneath it on a straight track along the midline of the box. The base of the crib was uniformly concave along its length and prevented gross body movements. A soft pillow served as a mattress and for the younger infants sponge pillows were placed at the sides of the head to prevent excessive head movements. The child's field of vision was restricted to the inside of the chamber, which was covered by navy blue felt, or to the blank cream-colored wall exposed by the open end of the box. Illumination was provided from below the infant's field of view by two 60W bulbs, just behind and to the left and right of his head.

A ¼-inch peephole was centered in the chamber ceiling

18 inches above the infant's head. Centered 18 inches to the right and left of the peephole were two belts which could be individually moved at different speeds. Each belt presented a flat viewing area of 12 inches x 9 inches to the infant. The belts ran on rubber rollers attached to the chamber ceiling and were driven by two Lafayette Color Mixer Motors, No. 204A, with variable range capacity from 0-4000 R.P.M. Speed was controlled by manually adjusted dial regulators. Two wooden hinged covers kept the upper view of the belts hidden from the experimenter. A window blind, covered with navy blue felt, was attached 4½ inches below the ceiling of the chamber and could be drawn horizontally across the chamber from bottom to top of the infant's field of vision. Responses were recorded on a Rustrak Model 92 four-channel event recorder moving at a speed of 1.2 mm per second. Two channels of the recorder were activated independently by two buttons attached to the top of the chamber.

Stimuli

The stimuli were four pairs of endless belts made of white sailcloth, painted with black and white checkerboard designs. For Complexity Level 1, the checkerboard design consisted of 4½ inch squares, half of them black and half of them white. Level 2 was a design composed of 3 inch black and white squares. Level 3 consisted of a checkerboard composed of 1½ inch squares, and Level 4 consisted of a checkerboard composed of 3/4 inch squares. Each level of complexity was presented to one group of subjects from each of the three age levels.

Procedure

All infants were brought to the laboratory by one or both of their parents. When the child was awake and in good humor he was placed in the cradle by his mother (or father) who remained in the room but out of the infant's field of vision. The crib was then pushed into the chamber to a position in which the infant's head was directly below the point at which the stimuli were to appear. The blind was already drawn and the stimulus patterns were not visible to the infant.

The experimenter stood behind the apparatus at the head of the infant. He released the blind halfway so that the infant could be seen through a 4 inch observation hole cut in the blind. When the infant was looking up at the center of the ceiling the blind was released the rest of the way, activating the recorder and a timer. The stimulus patterns were reflected on the corneas of the infant's eyes. When the eyes were directed towards a stimulus pattern the image of the pattern overlapped the pupil, as viewed through the observation hole. This overlap of reflected image and pupil was the criterion of fixation. While observing the subject through the observation hole, the experimenter recorded the length of time of each fixation on each stimulus by pressing one of the buttons on the top of the chamber. The left button corresponded to the left stimulus, and the right button to the right stimulus.

At the end of 30 seconds a buzzer in the timer sounded and the experimenter drew the blind, which stopped the timer and recorder. The stimulus velocity was then changed in preparation for the next trial and the infant was quieted or roused if this was necessary. The intertrial interval was approximately ten seconds, although this varied depending on the disposition of the infant.

A modified method of limits was used in the stimulus presentation. During each 30 second trial one stimulus remained stationary while the other moved from top to bottom of the visual field. The trial series started with the left stimulus moving at the fastest speed, continued with it moving slower on each successive trial until both stimuli were stationary, after which the right stimulus moved faster on each successive trial. Then the entire series was run in reverse order, for a total of 18 trials. The same speed settings were used for each of the four levels of complexity. Table 1 shows the order of stimulus presentation, with angular speed for each setting.

Table 1

Stimulus Presentation Order Showing Trial Number and Speed of Movement, Both in Inches Per Second and Degrees of Visual Angle Per Second

Trial	Left stimulus	Right stimulus
1	2.5 In./sec. (6°59')	Stationary
2	1.9 In./sec. (5°22')	Stationary
3	1.1 In./sec. (3°3')	Stationary
4	.4 In./sec. (1°12')	Stationary
5	Stationary	Stationary
6	Stationary	.4 In./sec.
7	Stationary	1.1 In./sec.
8	Stationary	1.9 In./sec.
9	Stationary	2.5 In./sec.
10	Stationary	2.5 In./sec.
11	Stationary	1.9 In./sec.
12	Stationary	1.1 In./sec.
13	Stationary	.4 In./sec.
14	Stationary	Stationary
15	.4 In./sec.	Stationary
16	1.1 In./sec.	Stationary
17	1.9 In./sec.	Stationary
18	2.5 In./sec.	Stationary

Interobserver Reliability

In the testing of two of the 8-week-olds, seven of the 16-week-olds, and two of the 24-week-olds, two observers were used. One observed the infant's eyes through the usual observation hole directly above the infant's head, and the other observed through a hole situated 7½ inches in front of the first hole. Thus, the second observation hole was above the center of the child's body and the second observer had to observe the child's eyes from an angle. As each observer operated two recording buttons on his respective side of the apparatus top, two independent recordings of the infant's fixations were obtained.

An inter-observer agreement score was calculated for each subject by counting the number of seconds per 30 second trial during which the observers agreed, that is, all time except that during which one observer recorded a fixation on one stimulus while the other observer either recorded a fixation on the other stimulus, or recorded no fixation at all. The scores were totalled over the number of trials for each subject and converted to percentage of total stimulus presentation time.

The median inter-observer agreement over the eleven subjects was 91%. For one subject agreement was only 77%, but agreement for the other ten ranged between 84% and 95%. As observations made by the second observer were not made from a central position over the infant's head, it was sometimes difficult for him to determine when the stimulus reflection was overlapping the pupil of the eye. Had he not been making observations under these disadvantageous conditions, one would have expected the inter-observer agreement to be even higher that it was.

Control for Sound and Vibration

Motors were mounted on metal stands resting directly on the floor, so that they were connected to the viewing chamber only by the plastic drive belts attaching them to the rubber rollers which moved the stimulus belts. However, the logical possibility of the infants responding to cues of vibration or of sound remained, especially at the higher speeds when the motors produced a whir audible to the experimenters. Therefore, control trials for sound and vibration were run, using the same speeds that were utilized for the major experiment.

The experimental procedure was the same as outlined in the general procedure above. In the control trials, both stimulus belts were shielded from the subject's view by stationary checkerboard designs painted on white cardboard, placed just below the belts in the chamber ceiling. The checkerboards were identical to the patterns presented by non-moving belts on Complexity Level 3 (composed of 1½ inch squares).

Otherwise, the apparatus and procedure were identical to that reported in the main experiment. The motors moved the belts at different speeds, but the belts were hidden from view by the stationary patterns. An additional eleven 16-week-old infants were used as control subjects.

CHAPTER 4

Results for Total Looking Time and Percent Looking Time

Results for Control Trials

Sound Control

Eleven 16-week-old infants were used to test for the possible effect of motor noise and vibration on looking behavior, while viewing stationary stimulus patterns with motor noise present. The results of these data are summarized in Table 2. Figure 1 represents the data graphically, showing the total time spent looking at the stimulus pattern on the side where the motor sound was located. An analysis of variance, represented in Table 3, reveals no significant effects of noise or vibration upon the infants' looking time.

Stationary Trials

In order to assess the relative attention-arousing properties of the four levels of complexity without the addition of movement to the field, an analysis was made of the two trials in the regular experimental series during which both checkerboard patterns remained stationary. These data are summarized in Table 4, and presented graphically in Figure 2. A two-way analysis of variance (Table 5) indicates significant main effects of age and complexity. A Tukey test

Table 2

Summary of Sound Control Trials, Showing Total Time Spent Looking at the Stimulus Pattern Located on the Same Side as the Motor Noise. Looking Time is Averaged Over Subjects

	Motor Speed (inches/second)			
	.4	1.1	1.9	2.5
Total Looking Time	22.23	22.45	24.79	24.39

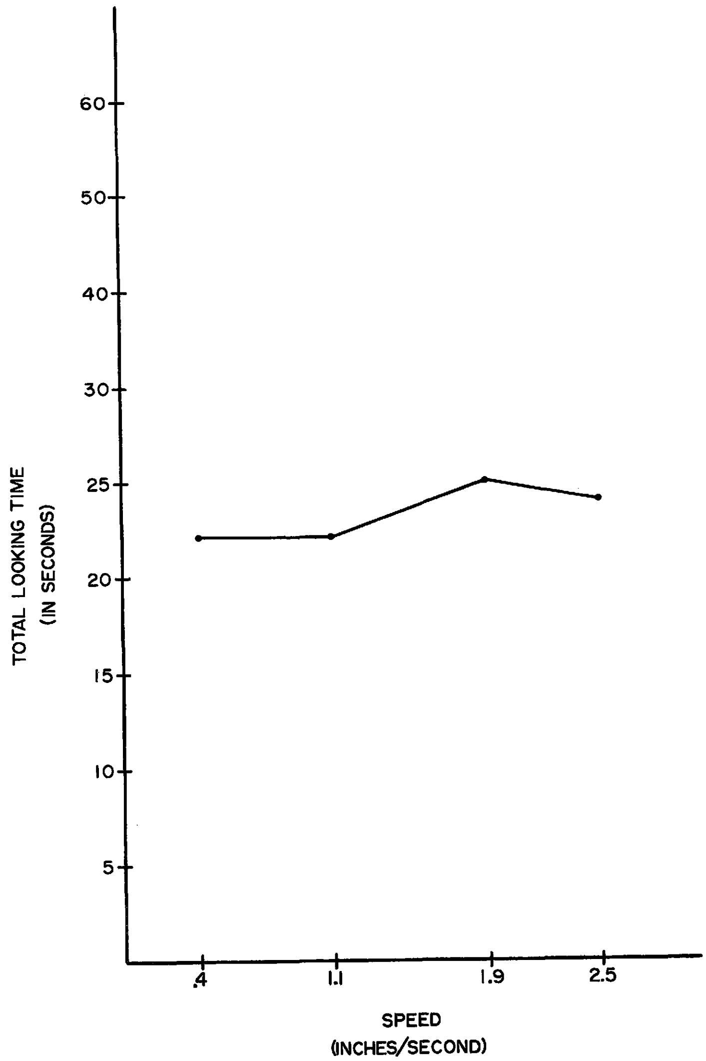

Fig. 1. Sound control data, showing total time spent looking at the stimulus pattern located on the same side as the motor noise. Looking time averaged over subjects.

Table 3

Summary Table of Analysis of Variance for Sound Control Trials

Source	SS	df	MS	F	P
Between subjects	2395.19	10			
Within subjects	968.99	33			
Speeds	56.96	3	18.99	-	
Residual	912.03	30	30.40		
Total	3364.18	43			

Table 4

Total Time Spent Looking at Stimulus Patterns during Trials when Both Patterns were Stationary. Looking Time Recorded over Four Levels of Complexity for 8 Week-old, 16 Week-old, and 24 Week-old Infants, and Averaged over Subjects

	Complexity Level				
Age	1	2	3	4	Mean LT each Age Group
8 weeks	29.63	44.61	43.51	47.87	41.40
16 weeks	19.64	34.18	38.71	29.35	30.47
24 weeks	15.78	17.32	22.29	20.61	19.00
Mean LT for Each Complexity	21.68	32.04	34.84	32.61	

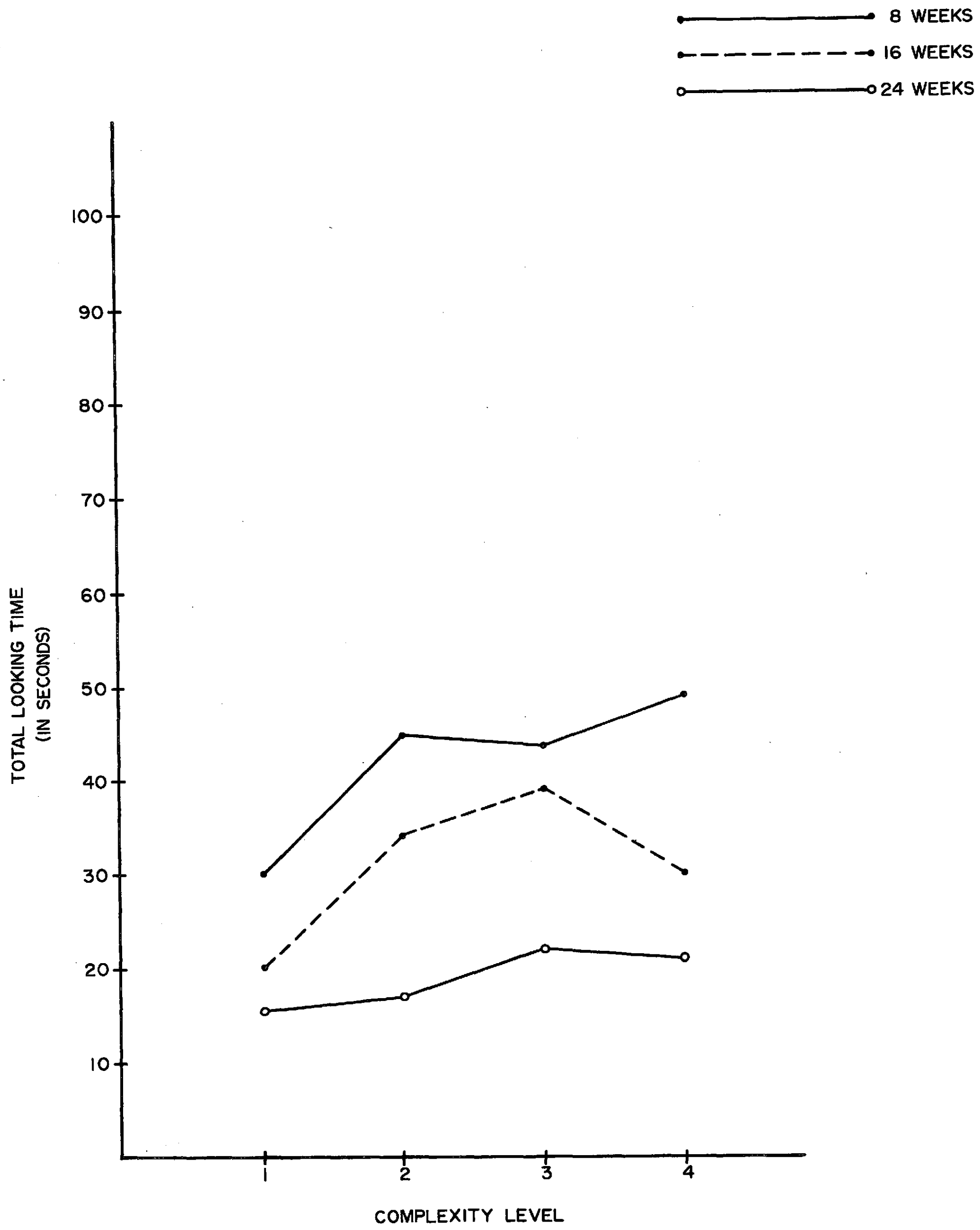

Fig. 2. Total time spent looking at stimulus patterns during trials in regular experimental series when both checkerboard patterns remained stationary. Looking time recorded for 8-week-old, 16-week-old, and 24-week-old infants, averaged over subjects.

Table 5

Summary Table of Two-way Analysis of Variance on Total Time Spent Looking at Both Checkerboard Patterns During Trials When Movement was not Present over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants

Source	SS	df	MS	F	P
Total	20805.82	95			
Age	8034.16	2	4017.08	35.90	less than .001
Complexity	2476.79	3	825.60	7.38	less than .001
Age x Complexity	898.95	6	149.83	1.34	
Within cell	9395.92	84	111.86		

(Ryan, 1959) shows significant differences in looking time for comparisons made between all age groups, indicating that the 8-week-old group looks significantly more than the 16-week-old and 24-week-old groups, and that the 16-week-old group looks significantly more than the 24-week-old group (all p's less than .01). The significance of the complexity factor indicates that, taken over all ages, there were changes in total looking time for different levels of complexity. A Tukey test indicates that Level 1 was looked at less than all higher levels of complexity (p's less than .01), but Levels 2, 3, and 4 were not significantly different from each other. The interaction between age and complexity was not significant.

Results for Total Looking Time and Percent Looking Time

The results of the present study were derived from two response measures, total looking time at the moving stimulus, and percent looking time at the moving stimulus. Total looking time is defined as the total amount of time spent fixating the moving stimulus averaged over subjects. Percent looking time is defined as the proportion of total looking time at both moving and non-moving stimuli that was devoted to fixation of the moving stimulus. In other words, percent looking time gives a comparison of the relative amount of looking time devoted to the moving stimulus, as compared to the non-moving stimulus.

Total Looking Time

Table 6 shows the total time spent looking at the moving stimulus over four different speeds at each of the four levels of complexity, by the 8-week-old, 16-week-old, and 24-week-old infants. The same data are presented graphically in Figure 3. Table 7 presents a summary of a three-way analysis of variance of total looking time at the moving stimulus for each age group at each speed and level of complexity. The three main effects were significant, as was the interaction between age and speed. In order to explore the nature of the significant differences, an analysis of linear trend was performed on the data (Table 8). Even though true scale values for complexity were unknown, equal intervals were assigned to this dimension so that a linear analysis could be performed.[1] The same variables and interactions that were significant in the over-all analysis of variance were also significant in the linear trend analysis.

The age effect (Figure 4) is due to a decrease in total looking time with increased age. The analysis of linear trend indicates that the slope of the age effect is significantly different from zero. Tukey comparisons indicate that the 8-week-olds and the 16-week-olds look at the moving stimulus

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1. Abelson and Tukey (1963) state that, when equal intervals are assigned to a monotonic dimension whose true scale values are unknown, the assigned values will correlate at least .60 with the true scale values.

Table 6

Total Time Spent Looking at Stimulus Moving at Four Different Speeds over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants, Averaged over Subjects

	Complexity Level 1				Complexity Level 2				Mean Total Looking Time for Each Age Group
Speed	SS	S	F	FF	SS	S	F	FF	
Age									
8 weeks	38.39	45.64	53.66	74.37	44.18	50.31	60.76	71.96	
16 weeks	30.33	44.68	46.41	60.24	36.16	51.31	70.31	78.34	
24 weeks	29.80	36.09	49.87	53.06	28.11	46.23	51.13	57.42	
Mean Total Looking Time for Each Stimulus	32.84	42.14	49.98	62.56	36.15	49.28	60.73	69.24	
	Complexity Level 3				Complexity Level 4				
8 weeks	50.46	57.03	63.44	67.81	47.04	56.42	79.86	81.31	58.91
16 weeks	43.68	57.74	83.14	89.76	31.85	49.41	61.63	75.94	56.93
24 weeks	25.99	36.88	42.04	50.48	29.70	36.75	62.45	64.36	43.77
Mean Total Looking Time for Each Stimulus	40.04	50.55	62.88	69.35	36.20	47.77	67.98	73.87	

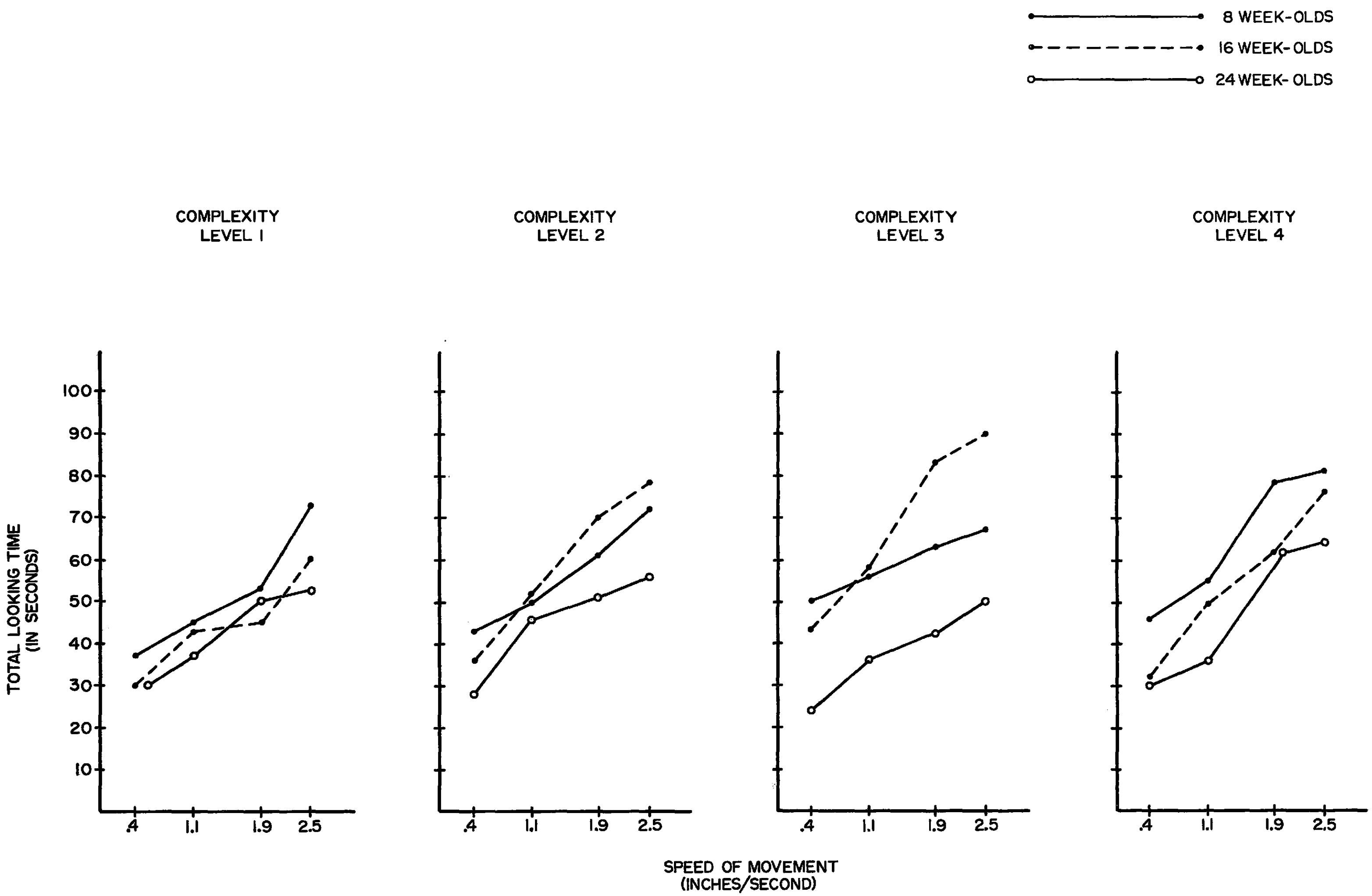

Fig. 3. Total time spent looking at the moving stimulus at each of the four levels of complexity, by 8-week-old, 16-week-old, and 24-week-old infants. Looking time averaged over subjects.

Table 7

Summary Table of Analysis of Variance of Total Looking Time Spent Looking at Moving Stimulus for Four Speeds of Movement over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants

Source	SS	df	MS	F	P
Between Subjects	86246.25	95			
Age	17337.27	2	8668.64	13.14	less than .001
Complexity	5457.98	3	1819.33	2.76	less than .05
Age x Complexity	8017.88	6	1336.31	2.02	
Subjects within Groups	55433.12	84	659.92		
Within Subjects	98401.01	288			
Speed	58847.95	3	19615.98	154.35	less than .001
Age x Speed	1929.29	6	321.55	2.53	less than .025
Complexity x Speed	1852.24	9	205.80	1.62	
Age x Complexity x Speed	3751.74	18	208.43	1.64	
Speed x Subjects within Groups	32026.79	252	127.09		

Table 8

Analysis of Linear Trend Components in the Three-way Analysis of Variance for Total Looking Time at the Moving Stimulus

Source	SS	df	MS	F	P
Age (linear)	14672.78	1	14672.78	22.23	less than .001
Complexity (linear)	4435.51	1	4435.51	6.72	less than .05
Age x Complexity (linear)	880.04	2	440.02	-	
Subjects within Groups		84	659.92		
Within Subjects (linear)	78088.88	96			
Speed (linear)	58462.88	1	58462.88	324.70	less than .001
Age x Speed (linear)	1617.34	2	808.67	4.49	less than .05
Complexity x Speed (linear)	978.22	3	326.07	1.81	
Age x Complexity x Speed (linear)	1905.90	6	317.65	1.76	
Speed x Subjects within Groups (linear)	15124.54	84	180.05		

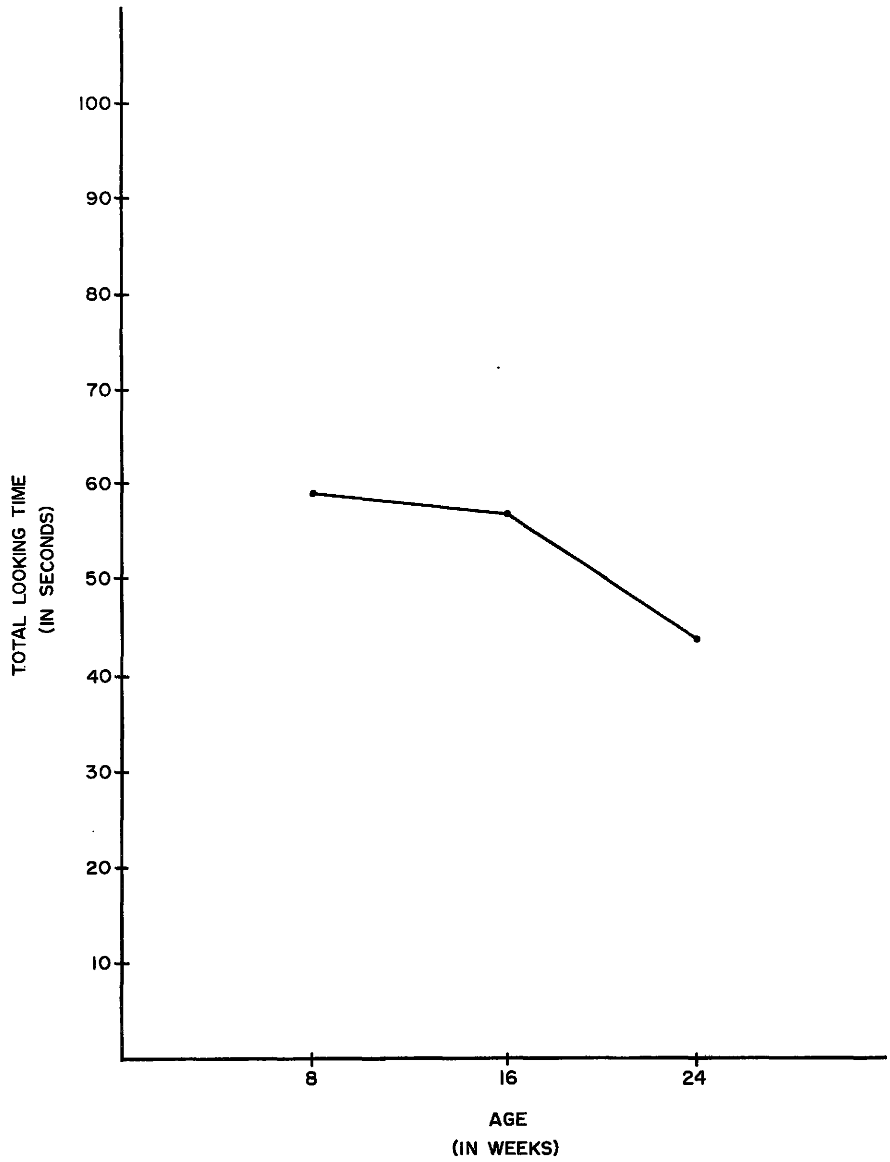

Fig. 4. The effect of age on total looking time at the moving stimulus, averaged over all levels of complexity, all speeds of movement, and subjects.

significantly longer than do the 24-week-olds (p's less than .01), but that there is no significant difference between the looking time of the 8-week-olds and the 16-week-olds.[2]

The complexity effect (Figure 5) indicates that, as complexity is increased, total looking time also increases. The linear analysis indicates that the slope of this effect is significantly different from zero. Tukey comparisons failed to reveal any significant differences between individual pairs of complexity levels. However, the differences between Level 1 and Level 4 did approach significance at the .05 level.

The speed effect (Figure 6) shows a general increase in looking time as speed of movement is increased. The linear analysis indicates that the slope of this effect is significantly different from zero. Tukey tests indicate that there are significant differences in looking time between all comparisons of speed levels (all p's less than .01).

The interaction between age and speed is represented in Figure 7. The linear trend analysis shows that the significant interaction between age and speed can be attributable to differences in the slope of the best-fitting straight lines over levels of speed. An analysis comparing linear trends of

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2. Ryan (1959) warns that, when using many levels of the experimental variable, one increases the probability of finding some erroneously significant results, so that Tukey comparisons made in a three-way analysis of variance should probably be interpreted as yielding a higher error rate than is reported in the significance level.

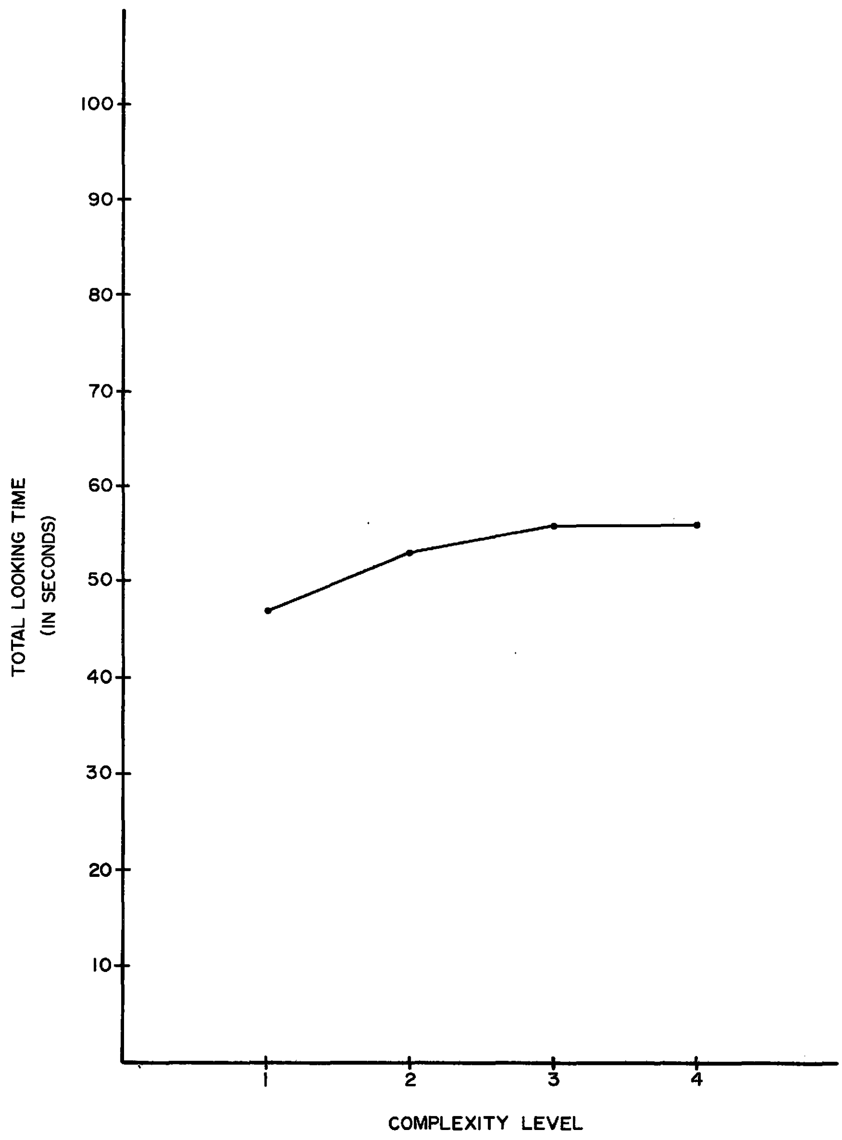

Fig. 5. The effect of complexity on total looking time at the moving stimulus, averaged over all ages, speeds of movement, and subjects.

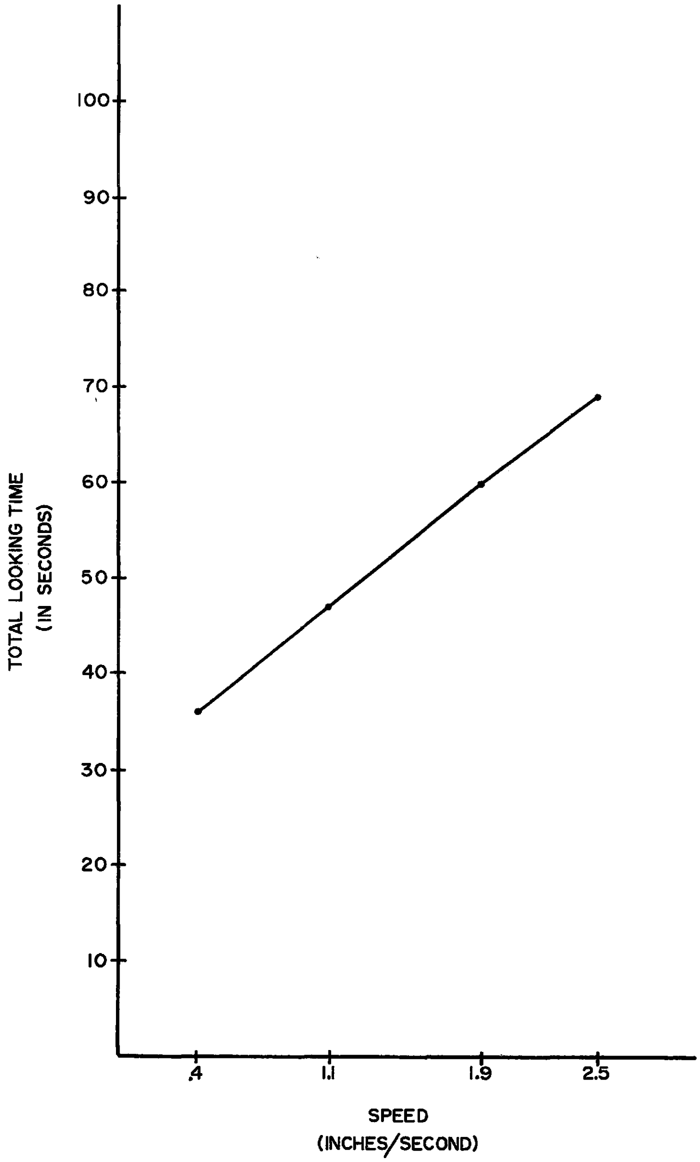

Fig. 6. The effect of speed on total looking time at the moving stimulus, averaged over all ages, levels of complexity, and subjects.

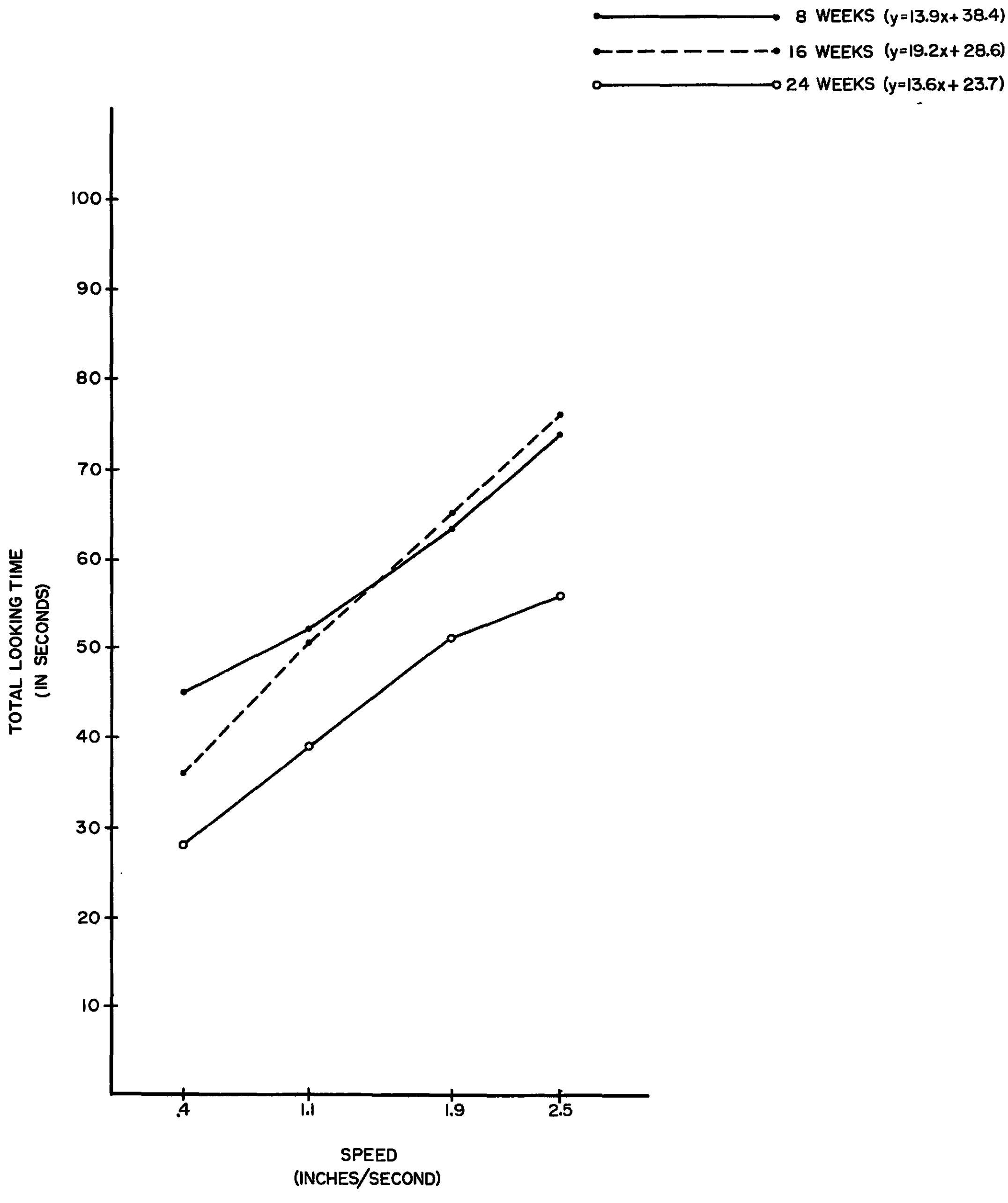

Fig. 7. The interaction effect of age and speed on total looking time at the moving stimulus. Looking time is averaged over subjects.

the individual lines shows that the slope of the 16-week-old group is significantly greater than the slope of the 8-week-old group (p less than .025) and that of the 24-week-old group (p less than .025). The slopes of the 8-week-old and 24-week-old groups are not significantly different from each other.

Percent Looking Time[3]

Table 9 shows the percent looking time directed toward the moving stimulus, at each speed and level of complexity, by 8-week-old, 16-week-old, and 24-week-old subjects. These data are represented graphically in Figure 8. Table 10 presents a

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3. Winer (1962) and Meyer (1966) discuss the application of data transformations in cases where the distribution of scores departs from the assumptions of normality and homogeneity of variance. In the case of proportion measures, the scores have a binomial distribution and do not fulfill the assumption of normality. This condition can also be accompanied by extreme heterogeneity of variance over treatment populations. An arc-sine transformation is often applied to proportion measures in order to stabilize the within-groups variance and to reduce the probability of falsely obtaining a significant F ratio. However, the arc-sine transformation stabilizes variances only when the denominators of proportions are the same. In the present study, the denominators of the proportions were not the same since total looking time fluctuated from trial to trial. Therefore, it was highly probable that the distributions of these scores were not subject to the usual distortions found in proportion data. To test this assumption, chi square tests were used to evaluate the significance of departures of the obtained distributions from the assumed normal distributions. The test was applied to each age sample under each experimental condition, as suggested in Meyer (1966, p. 62). In no case did the scores show a significant departure from a normal distribution. It was assumed, therefore, that there was no need to employ the arc-sine transformation in the present data analysis.

Table 9

Percent Time Spent Looking at the Stimulus Moving at Four Different Speeds over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants Averaged over Subjects

	Complexity Level 1				Complexity Level 2				Mean % LT for Each Age Group
Speed	SS	S	F	FF	SS	S	F	FF	
Age									
8 weeks	52	56	69	82	56	58	64	74	
16 weeks	58	77	78	76	54	75	91	89	
24 weeks	59	64	80	82	66	82	81	84	
Mean % Looking Time for Each Stimulus	56	66	75	80	58	72	79	82	
	Complexity Level 3				Complexity Level 4				
8 weeks	55	60	60	70	55	61	76	82	64
16 weeks	55	70	87	92	52	66	78	89	74
24 weeks	55	75	81	84	58	71	83	86	74
Mean % Looking Time for Each Stimulus	55	68	76	82	55	66	79	86	

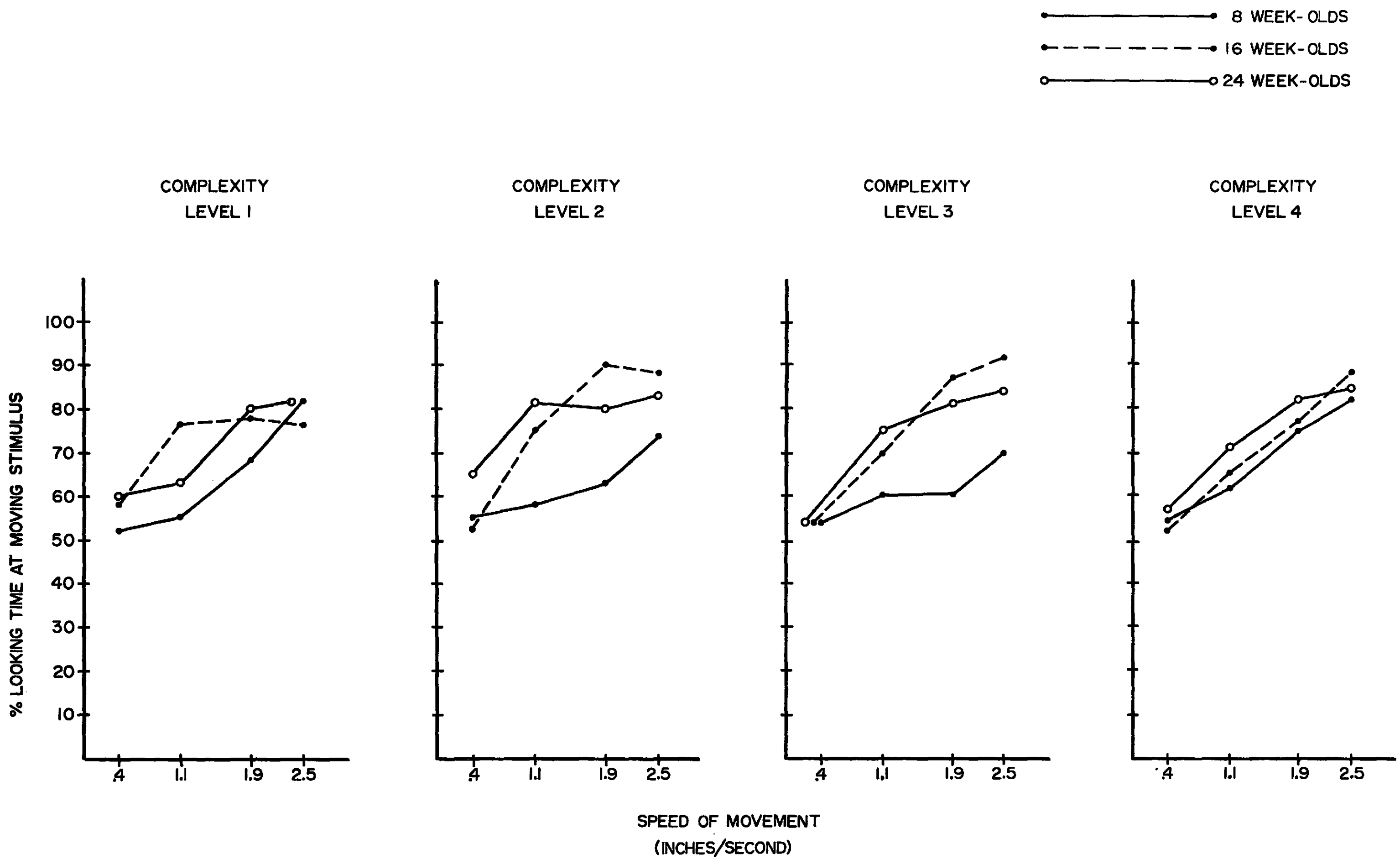

Fig. 8. Percent looking time at the moving stimulus at each of the four levels of complexity, by 8-week-old, 16-week-old, and 24-week-old infants. Looking time is averaged over subjects.

Table 10

Summary Table of Analysis of Variance of Percent Looking Time at the Moving Stimulus for Four Speeds of Movement over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants

Source	SS	df	MS	F	P
Between Subjects	4.5331	95			
Age	.8455	2	.4228	10.31	less than .001
Complexity	.0629	3	.0210	-	
Age x Complexity	.1842	6	.0307	-	
Subjects within Groups	3.4405	84	.0410		
Within Subjects	7.1391	288			
Speed	3.8839	3	1.2946	129.46	less than .001
Age x Speed	.2594	6	.0432	4.32	less than .001
Complexity x Speed	.0802	9	.0089	-	
Age x Complexity x Speed	.3844	18	.0214	2.14	less than .01
Speed x Subjects within Groups	2.5312	252	.0100		

summary of a three-way analysis of variance of percent looking time at the moving stimulus for each age group at each level of complexity and each speed. The main effects of age and speed were significant, as was the interaction of age x speed and the interaction of age x complexity x speed. In order to explore the nature of these differences more fully, an analysis of linear trend was performed on the data (Table 11). The same variables and interactions that were significant in the over-all analysis of variance were found to be significant in the linear trend analysis. The age effect (Figure 9) has a slope which is significantly different from zero. A Tukey test shows that 24-week-olds and 16-week-olds direct a significantly greater proportion of their looking time toward the moving stimulus than do the 8-week-olds (p's less than .01), but that the 24-week-olds and the 16-week-olds are not significantly different from each other.

The complexity effect and the interaction of age and complexity were not significant in either the over-all analysis of variance or the analysis of linear trend.

The speed effect (Figure 10) shows that increased speed of movement elicits increased looking from all age groups. The linear analysis indicates that the slope of this function is significantly different from zero. Tukey comparisons reveal significant differences between all pairs of speed levels (all p's less than .01).

Table 11

Analysis of Linear Trend Components in the Three-way Analysis of Variance for Total Looking Time at the Moving Stimulus

Source	SS	df	MS	F	P
Age (linear)	.66	1	.657	16.24	less than .001
Complexity (linear)	.01	1	.006	-	
Age x Complexity (linear)	.02	2	.008	-	
Subjects within groups		84	.041		
Within Subjects (linear)	5.27	96			
Speed (linear)	3.78	1	3.78	290.77	less than .001
Age x Speed (linear)	.09	2	.045	3.46	less than .05
Complexity x Speed (linear)	.05	3	.017	1.31	
Age x Complexity x Speed (linear)	.24	6	.040	3.08	less than .05
Speed x Subjects within groups (linear)	1.11	84	.013		

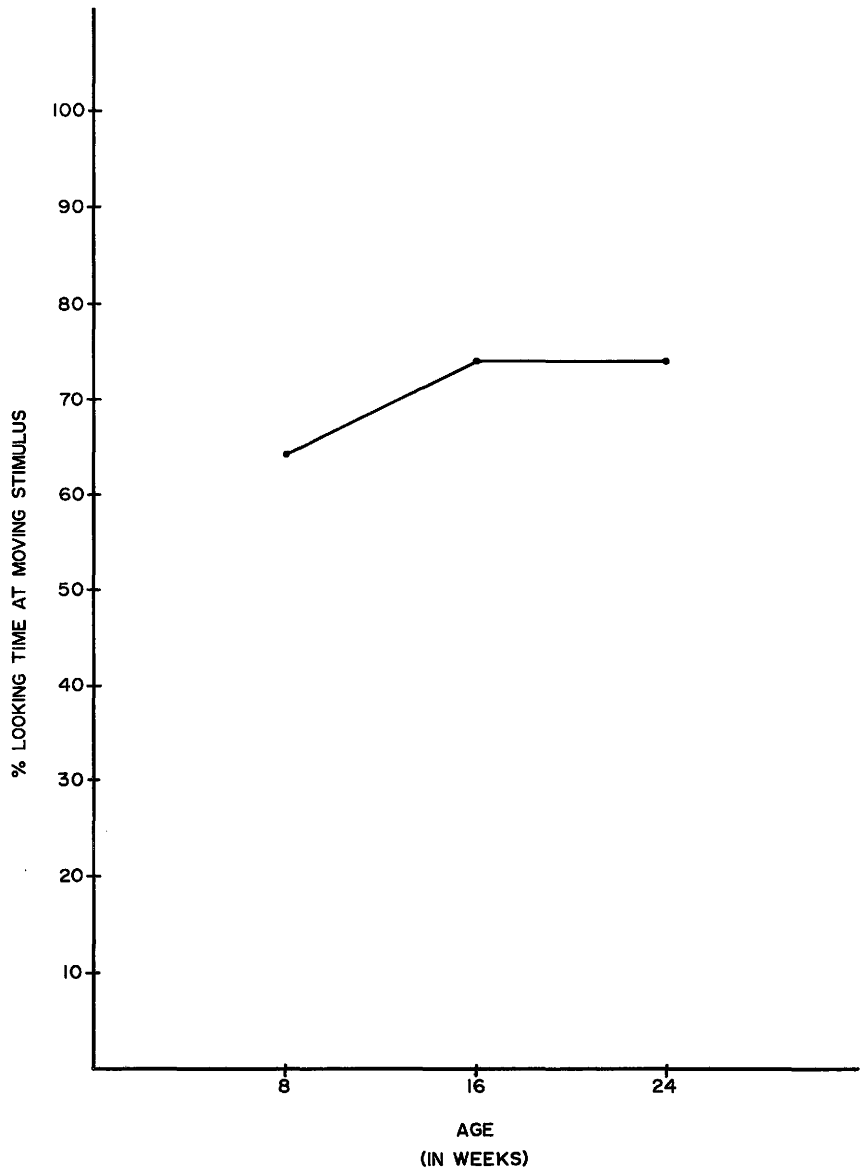

Fig. 9. The effect of age on percent looking time at the moving stimulus, averaged over all levels of complexity, all speeds of movement, and subjects.

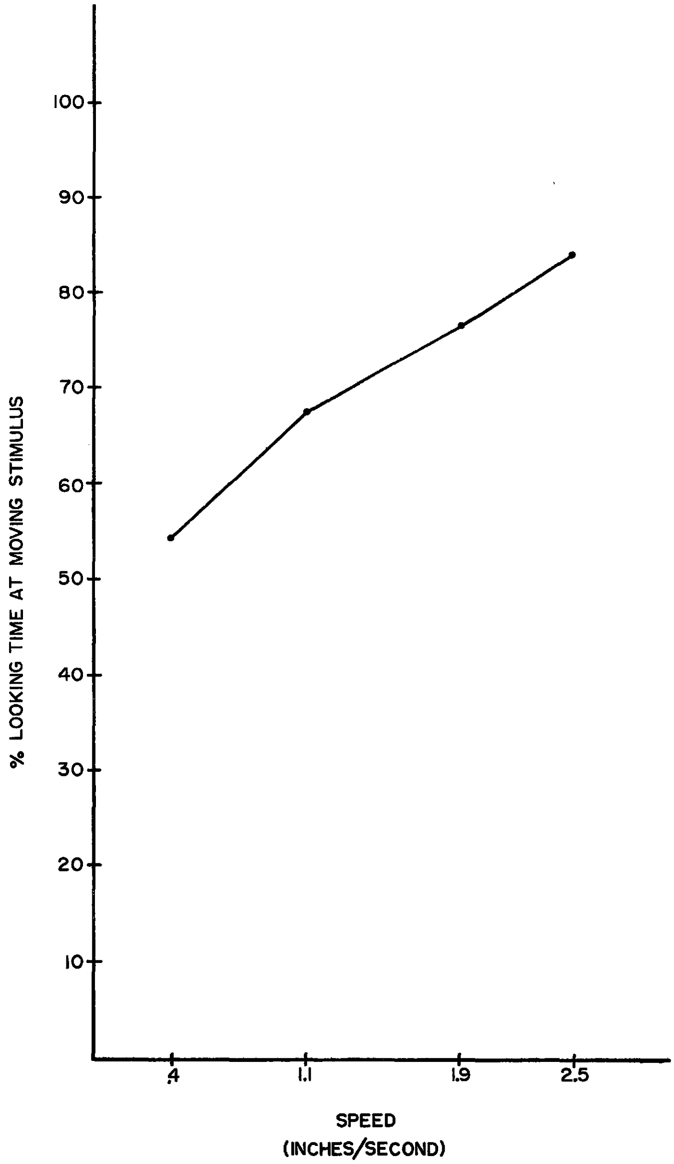

Fig. 10. The effect of speed on percent looking time at the moving stimulus, averaged over all ages, levels of complexity, and subjects.

Figure 11 illustrates the interaction between age and speed. The analysis of linear trend indicates that the significant interaction might be attributable to differences in the slopes of the best-fitting straight lines over levels of speed. Comparisons between individual lines show that the slope of the 16-week-olds is significantly greater than that of the 8-week-olds (p less than .025) and that of the 24-week-olds (p less than .05). The slopes for the 8-week-olds and the 24-week-olds were not significantly different from each other.

The significance of the triple interaction of age x complexity x speed (see Figure 8) is somewhat surprising in view of the fact that complexity and its interactions with age and with speed are not significant. In order to find the source of this interaction, separate analyses of variance were performed on the age x speed interactions within each of the four levels of complexity (Table 12). These analyses show that the patterns of preference for movement are the same for all three age groups on Level 1 and Level 4, but differ from one another on Level 2 (p less than .001) and Level 3 (p less than .005). Analyses of linear trend performed on Level 2 and Level 3 appear in Table 13. On Level 2, comparisons between best-fitting straight lines over speeds show that the slope of the 16-week-olds is significantly steeper than that of the 8-week-olds (p less than .025), and is also significantly steeper than that of the 24-week-olds (p less than .01). The slopes of

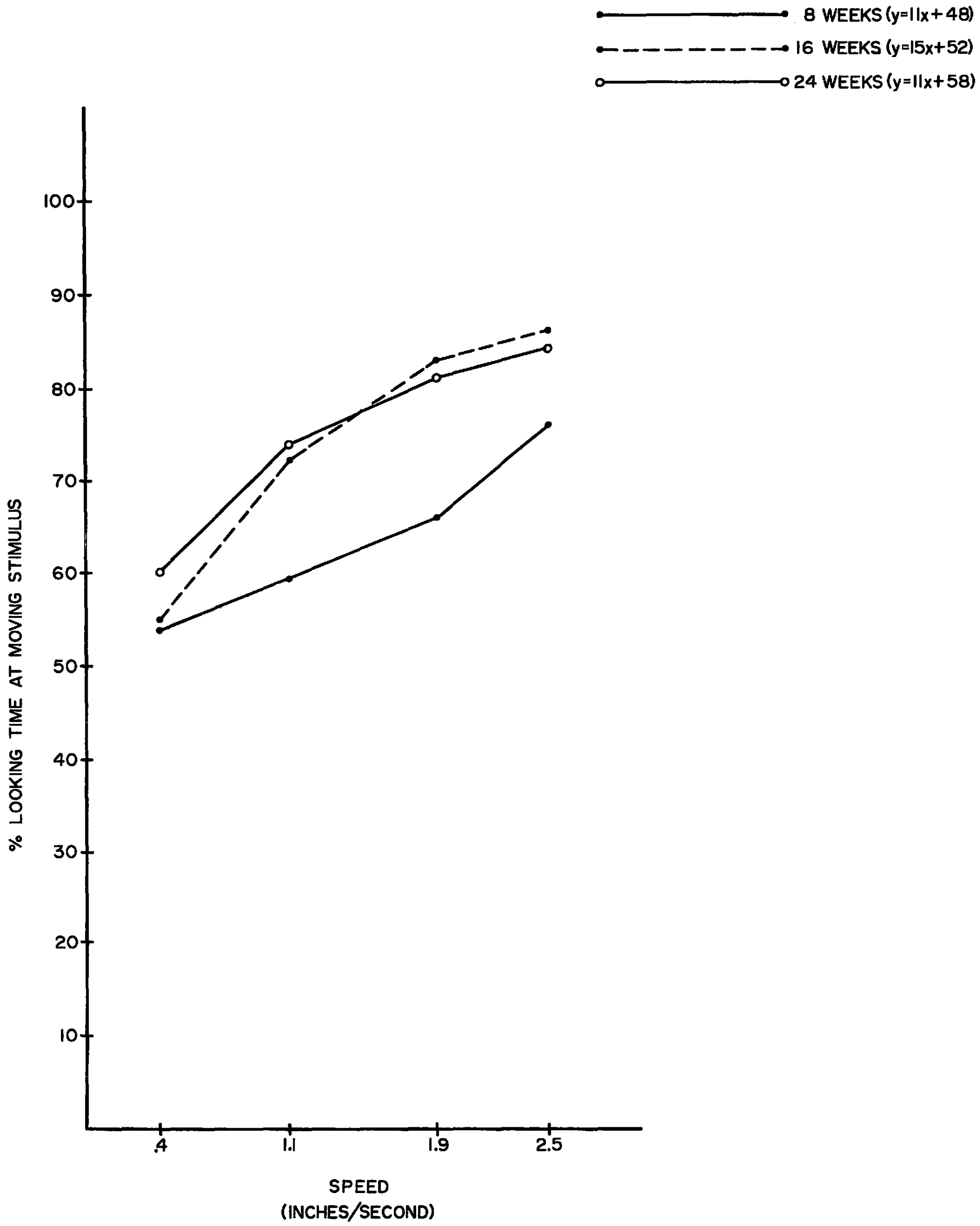

Fig. 11. The interaction effect of age and speed on percent looking time at the moving stimulus. Looking time is averaged over subjects.

Table 12

Summary Table of Two-way Analysis of Variance for Percent Looking Time within Each of Four Levels of Complexity

Source	SS	df	MS	F	P
		Complexity Level 1			
Between Subjects	1.4185	23			
Age	.1096	2	.0548	-	
Subjects within groups	1.3089	21	.0623		
Within Subjects	1.9251	72			
Speed	.8227	3	.2742	18.40	less than .001
Age x Speed	.1618	6	.0270	1.81	
Speed x Subjects within Groups	.9406	63	.0149		

Table 12 (cont.)

Source	SS	df	MS	F	P
Complexity Level 2					
Between Subjects	1.0810	23			
Age	.4696	2	.2348	8.07	less than .005
Subjects within groups	.6114	21	.0291		
Within Subjects	1.4352	72			
Speed	.7965	3	.2655	41.48	less than .001
Age x Speed	.2332	6	.0389	6.08	less than .001
Speed x Subjects within Groups	.4055	63	.0064		

Table 12 (cont.)

Source	SS	df	MS	F	P
		Complexity Level 3			
Between Subjects	1.1171	23			
Age	.3827	2	.1964	5.69	less than .025
Subjects within groups	.7244	21	.0345		
Within Subjects	1.7103	72			
Speed	.9805	3	.3268	39.37	less than .001
Age x Speed	.2095	6	.0349	4.20	less than .005
Speed x Subjects within Groups	.5203	63	.0083		

Table 12 (cont.)

Source	SS	df	MS	F	P
		Complexity Level 4			
Between Subjects	.8534	23			
Age	.0577	2	.0289		
Subjects within groups	.7957	21	.0379		
Within Subjects	2.0686	72			
Speed	1.3643	3	.4548	42.91	less than .001
Age x Speed	.0395	6	.0066		
Speed x Subjects within Groups	.6648	63	.0106		

Table 13

Analysis of Linear Trend Components Involving the Speed Effect Within Complexity Level 2 and Level 3 for Percent Looking Time at the Moving Stimulus

Complexity Level 2

Source	SS	df	MS	F	P
Within Subjects (linear)	1.0473	24			
Speed (linear)	.7340	1	.7340	74.14	less than .001
Age x Speed (linear)	.1054	2	.0527	5.32	less than .025
Speed x Subjects Within Groups (linear)	.2079	21	.0099		

Table 13 (cont.)

Complexity Level 3

Source	SS	df	MS	F	P
Within Subjects (linear)	1.3318	24			
Speed (linear)	.9523	1	.9523	85.79	less than .001
Age x Speed (linear)	.1468	2	.0734	6.61	less than .01
Speed x Subjects Within Groups (linear)	.2327	21	.0111		

the 8-week-olds and 24-week-olds are not significantly different from each other. The slope for the 16-week-olds is $Y = .18x + .51$; the slope for the 8-week-olds is $Y = .08x + .51$; and the slope for the 24-week-olds is $Y = .07x + .68$. On Level 3, comparisons between individual lines show that the slope of the 16-week-olds is significantly steeper than that of the 8-week-olds (p less than .005). The slope of the 24-week-olds is not significantly different from those of the other two groups. The slope for the 16-week-olds is $Y = .18x + .20$; the slope for the 8-week-olds is $Y = .06x + .52$; and the slope for the 24-week-olds is $Y = .13x + .55$.

Discussion

Both the total looking time and the percent looking time measures give valuable information regarding age differences in the looking behavior of infants; therefore a comparison of the results obtained from these different response measures seems warranted. The information obtained from these measures is complementary in some cases, and seemingly dissonant in others. These measures will be discussed concurrently in terms of the significant effects found in each.

Both measures yielded a significant effect produced by age. There is a general decrease in total looking time with increased age. This finding is in keeping with the results of earlier studies (Silfen and Ames, 1964; Ames and Silfen, 1965; Stechler, 1965; and Karmel, 1966). However, the results obtained from percent looking time reveal that, while total looking time is decreasing overall, the older infant is actually spending a larger proportion of the total time looking at the moving stimulus than is the younger infant. Therefore, the reduction in total looking time does not reflect a lack of interest in the moving stimulus. Older babies are much more prone to distractions by extraneous stimulation than are younger babies, and therefore often spend more time engaged in a variety of diversive activities which take away from the time spent looking at the stimulus patterns. The percent looking time measure shows us that when the older baby does look at the patterns, he is much more likely than the younger baby to look at the moving one.

Both measures give similar results in the case of the speed effect. Increasing speed of movement produces a steady increase in both total looking time and percent looking time, over all ages and complexity levels. Not only do the infants spend more total time looking at the stimulus patterns as they move faster, but also a greater proportion of the looking time is directed to the moving stimulus as compared to the non-moving stimulus. Movement may therefore be considered as a potent attention-getter, no matter which of the two response measures is used.

In the case of the complexity effect, we find a difference between the two measures. The total looking time measure is sensitive to changes in textural complexity of the stimulus pattern. Both during the stationary trials and during trials when movement occurred, an increase in complexity produced an increase in total looking time. In the case of the stationary trials, a significant increase occurred between Level 1 and the higher levels of complexity. During trials where movement occurred, no significant differences were found between individual comparisons even though the overall complexity effect was significant. However, the difference between Level 1 and Level 4 approached significance. If one examines the curves for total looking time during stationary trials and during trials where movement occurred, one notices that the same general pattern is evident. In both cases, the greatest increase in looking time occurs between Level 1 and Level 2, with the curves leveling off at higher levels of complexity.

There is no significant main effect of complexity on the percent looking time at the moving stimulus. This would seem to indicate that even though changes in textural complexity are influencing the total looking time, they are _not_ affecting the infant's relative attention toward the moving stimulus. Adding more elements to the stimulus field does not seem to aid the infant in "picking up" the movement more easily, or in influencing his preference for it. However, this conclusion is somewhat modified by the fact that complexity is involved in a significant interaction that is difficult to interpret.

The age x speed interaction effect is similar in both response measures. When one uses differences in the slopes of the best-fitting straight lines as an index of age differences in preference for increasing speed, the results from both response measures seem to indicate that infants at 16 weeks are more responsive to differences in rate of movement than are either younger or older infants. These results are somewhat surprising since it was assumed that 24-week-old infants would be most responsive to increasing rates of movement in view of the higher level of maturation of their visual mechanisms. In fact, the use of slope gives a somewhat incomplete picture of the actual age differences that do exist in response to speed changes. In the case of total looking time, the apparent superiority of the 16-week-olds will be analyzed further in the following chapter. In the case of percent looking time, further analysis is called for.

In addition to differences in slope, one can further explore the meaning of the age x speed interaction in percent looking time by employing a separate two-way analysis of variance at each of the four speed settings. These analyses reveal significant age differences at each of the three fastest speeds (all p's at least .005), but not at the slowest speed setting. At the speed of 1.1 inches/second, the second slowest speed, Tukey tests show that the 16-week-olds and the 24-week-olds are not significantly different from each other, but that they both look significantly more at the moving stimulus than do the 8-week-olds (all p's less than .01). Similar comparisons are found for the next higher speed of 1.9 inches/second (all p's less than .01). The same result is obtained at the fastest speed setting of 2.5 inches/second, where comparisons again show that the two older age groups are not significantly different from one another, but that the 8-week-olds look significantly less than both the 16-week-olds (p less than .01) and the 24-week-olds (p less than .05).

These results seem to indicate that both the 16-week-olds and the 24-week-olds are responding alike at each of the four speeds, and that they show greater response to movement than do the 8-week-olds at the three fastest speeds. We may conclude, therefore, that the age x speed interaction is largely due to two basic age differences in response to increased speed of movement; namely, the response of the two older age groups as compared to that of the youngest group. The individual analyses at each speed have shown that, even though there are differences in slopes between the two oldest groups, there are no significant differences between them in terms of their responses at each individual speed setting. Both of the older groups give evidence of greater ability to discriminate movement than the youngest group. A similar finding was reported in an earlier study by Ames and Silfen (1965) who, using only one level of textural complexity and five groups of infants between 7 and 24 weeks of age, found that an increasing number of infants show preference for movement over non-movement at slower speeds, as age increases. They concluded that older infants show finer discrimination of movement by showing preference for it over a wider range of speeds than do younger infants.

The significance of the triple interaction between age x complexity x speed in percent looking time can be attributed to differences in the slopes of age x speed trends within the four levels of complexity. At Levels 2 and 3 the 16-week-old group exhibits the steepest slope, as was found in the overall age x speed interaction. To further explore the meaning of the age x speed interactions, separate single-factor analyses of variance were performed within these two levels of complexity, at each of the four speed settings. These analyses revealed that there are no significant age differences at the slowest speed setting in either Level 2 or Level 3, but that significant age differences do occur at the three fastest speed settings in both levels of complexity (all p's at least .05). Tukey comparisons again reveal the same patterns found in the overall age x speed interaction, namely that the 16-week-olds and 24-week-olds are not significantly different from each other but that, at the three fastest speeds, they look significantly more than do the 8-week-olds (all p's at least .05). The author can offer no explanation for the failure of the age x speed interaction to appear at Level 1 and Level 4.

Summary

Both total looking time and percent looking time yielded a significant effect of age. With increased age, total looking time decreased, but a greater proportion of the looking time was directed toward the moving stimulus.

Both measures gave similar results for the effect of speed, with increased speed of movement eliciting greater total and percent looking time from infants.

Total looking time and percent looking time yielded similar results in the case of the significant age x speed interaction, with 16-week-old infants showing the steepest slope of preference for increasing speed of movement, and the 8-week-olds and 24-week-old infants yielding slopes of speed preference similar to each other. Further analyses indicated that slopes of preference gave an incomplete picture of age differences in the response to increased movement. Discussion of the meaning of the age x speed interaction in total looking time was deferred to a future chapter. The significance of this interaction in percent looking time was attributed to age differences in response patterns to increased movement, with the two older age groups showing greater preference over slower speeds than the youngest group. The significant age x complexity x speed interaction in percent looking time was due to the appearance of similar age x speed interactions at complexity Levels 2 and 3.

The effect of stimulus complexity on the two response measures is not as clear as are the effects of age and speed. The total looking time measure revealed a significant main effect of complexity, with infants spending more time looking at stimulus patterns as complexity increased. However, this same effect was found on the two trials during which the stimuli did not move. Furthermore, there was no significant main effect of complexity on the percent looking time measure, indicating that overall, complexity did not seem to affect the proportion of time infants looked at moving rather than stationary stimuli. In addition, neither measure showed significant two-way interaction of complexity with age or with speed. Instead, by the percent measure, a significant age x complexity x speed interaction was found.

It appears, then, that there is evidence that age, speed and the interaction of age and speed affect infants' looking behavior. There is evidence that 16-week-olds and 24-week-olds are more responsive to differences in movement than are 8-week-olds. The effects of complexity are less clear. Infants do show some tendency to look more at more complex stimuli, but this is just as true for non-moving as for moving stimuli. Beyond a rather confusing three-way interaction of complexity with the other two variables, there is little evidence that the complexity of the stimulus is related to the infant's ability to respond to the movement of that stimulus.

CHAPTER 5

Results for Average Span of Looking Time and Total Number of Looks

Total number of looks is defined as the number of separate looks at the moving stimulus, averaged over subjects. Average span is a measure derived by dividing the total looking time for each 30-second trial by the total number of looks that occurred during the same interval. It therefore gives a measure of the average length of each look. Average span multiplied by total number of looks yields the total looking time measure used in Chapter 4. Although average span and total number of looks tend to be somewhat negatively correlated with each other because both are limited by the finite duration of a trial, there is still much room for independent variation. It is an extremely rare occurrence for an infant to fixate the stimulus for the entire 30 seconds in a trial.

It has been demonstrated (Ames and Silfen, 1965) that within the age range of 7 to 24 weeks, infants use different combinations of average span multiplied by total number of looks to yield the same overall total looking time. In the present chapter, total looking time is broken down into average span and total number of looks to see whether this additional analysis adds information to that gained by analysis of total and percent looking time. In the presentation of the results that follows, results for the two new measures are presented concurrently.

Table 14 shows the average span of time spent looking at the stimulus moving at four different speeds, over four levels of complexity, by the 8-week-old, 16-week-old, and 24-week-old infants. Table 15 gives analogous information for the total number of looks at the moving stimulus. The same data are shown graphically in Figures 12 and 13 respectively.

Table 16 presents a summary of a three-way analysis of variance of the average span of looking time at the moving stimulus for each age group at each level of complexity and each speed. Table 17 summarizes an analogous three-way analysis of variance of the total number of looks at the moving stimulus.

In order to explore the nature of the significant differences, analyses of linear trend were also performed on the data. The linear trend analyses for average span of looking time and for total number of looks appear in Table 18 and Table 19 respectively. In the presentation of the results, each variable and interaction will be discussed separately, along with all relevant information obtained from analyses and trend analyses on both response measures.

Age

The age effect is significant in both measures (Figure

Table 14

Average Span of Time Spent Looking at Stimulus Moving at Four Different Speeds Over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants, Averaged Over Subjects

	Complexity Level 1				Complexity Level 2				Mean Average Span for Each Age Group
Speed	SS	S	F	FF	SS	S	F	FF	
Age									
8 weeks	3.84	3.21	3.72	5.74	3.84	4.95	5.27	7.24	
16 weeks	2.65	3.28	3.71	5.88	2.43	3.41	4.05	5.08	
24 weeks	2.42	2.40	3.12	3.60	1.68	2.41	2.70	3.66	
Mean Average Span for Each Stimulus	2.97	2.97	3.52	5.07	2.65	3.59	4.01	5.33	

Table 14 (cont.)

Speed	Complexity Level 3: SS	S	F	FF	Complexity Level 4: SS	S	F	FF	Mean Average Span for Each Age Group
Age									
8 weeks	6.25	8.58	9.85	12.48	3.71	4.56	11.46	10.98	6.60
16 weeks	2.27	2.89	5.46	6.16	1.39	2.70	2.98	3.51	3.62
24 weeks	1.53	2.19	2.23	2.35	1.73	1.98	3.57	2.91	2.53
Mean Average Span for Each Stimulus	3.35	4.55	5.85	6.99	2.28	3.08	6.00	5.80	

Table 15

Total Number of Looks Directed Toward Stimulus Moving at Four Different Speeds Over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants Averaged Over Subjects

	Complexity Level 1				Complexity Level 2				Mean Number of Looks for Each Age Group
Speed	SS	S	F	FF	SS	S	F	FF	
Age									
8 weeks	14	16	16	16	13	11	13	11	
16 weeks	12	15	13	12	15	16	19	17	
24 weeks	13	14	15	18	17	20	19	18	
Mean Number of Looks for Each Stimulus	13	15	15	15	15	16	17	15	

Table 15 (cont.)

	Complexity Level 3				Complexity Level 4				Mean Number of Looks for Each Age Group
Speed	SS	S	F	FF	SS	S	F	FF	
Age									
8 weeks	14	13	12	11	17	15	9	9	13
16 weeks	22	22	19	17	24	22	22	25	18
24 weeks	16	18	20	22	18	20	21	25	19
Mean Number of Looks for Each Stimulus	17	18	17	16	20	19	17	19	

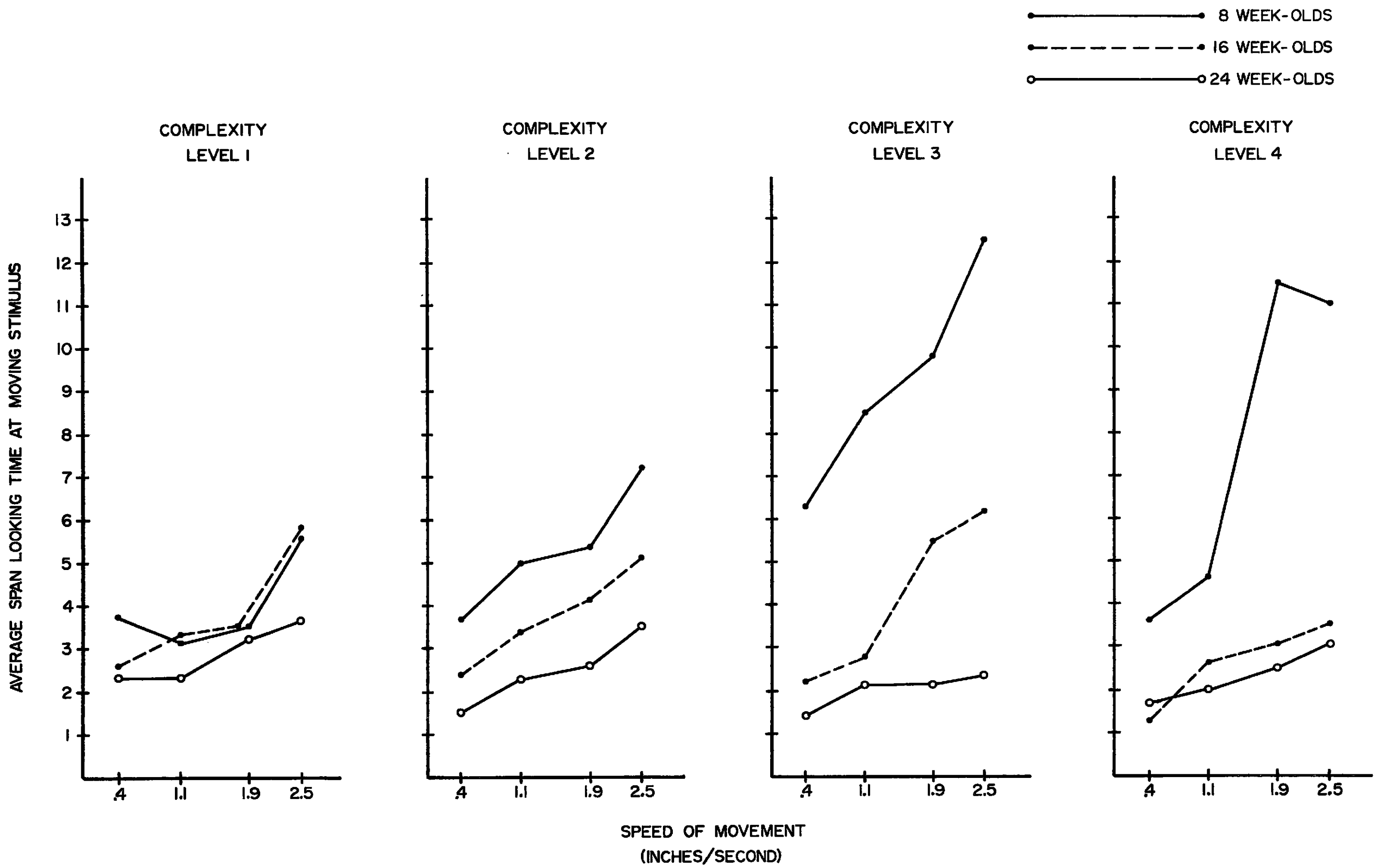

Fig. 12. Average span of looking time at the moving stimulus at each of four levels of complexity, by 8-week-old, 16-week-old, and 24-week-old infants. Looking time is averaged over subjects.

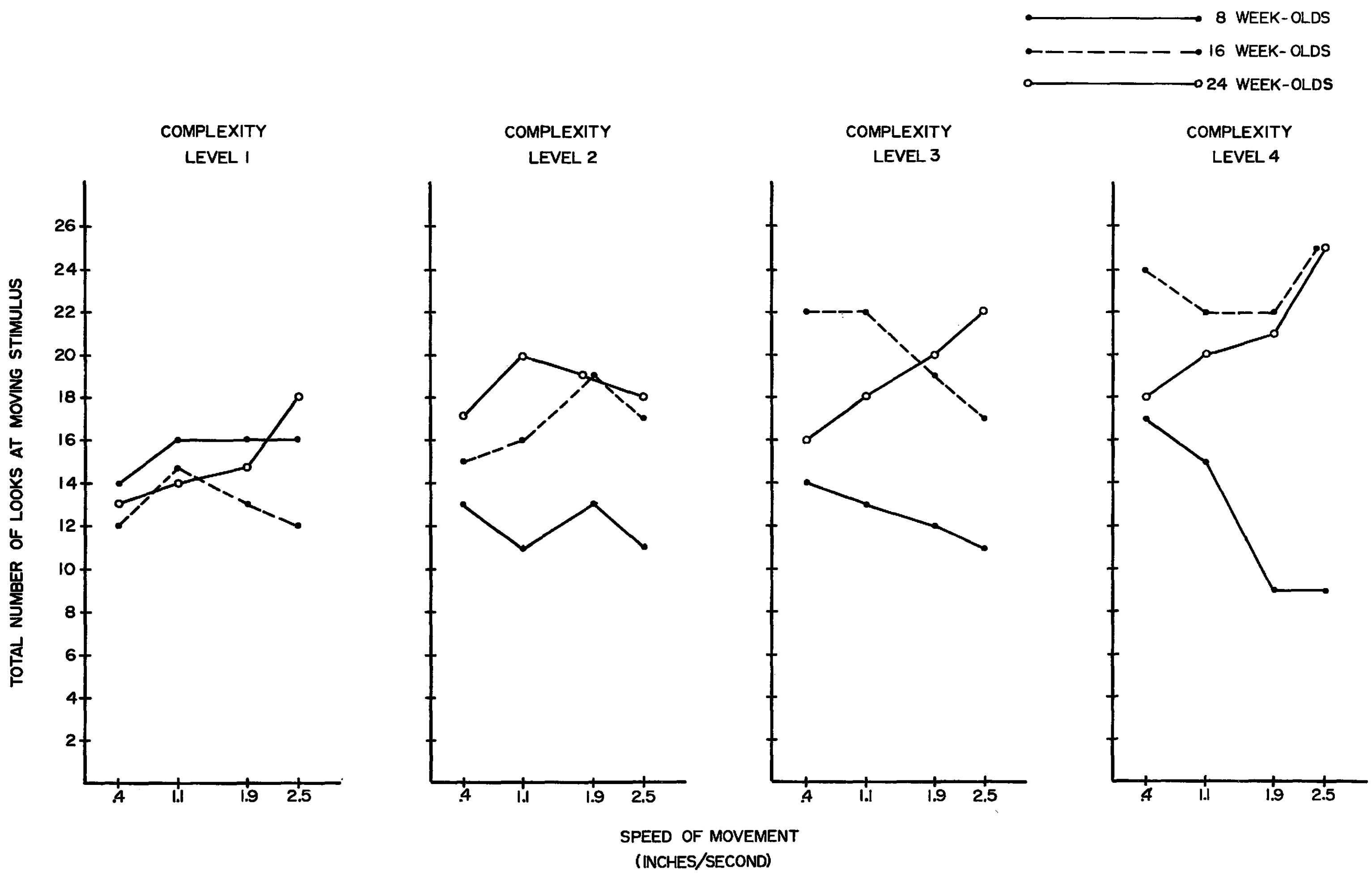

Fig. 13. Total number of looks at the moving stimulus at each of four levels of complexity, by 8-week-old, 16-week-old, and 24-week-old infants. Number of looks is averaged over subjects.

Table 16

Summary Table of Analysis of Variance of Average Span of Looking Time at the Moving Stimulus for Four Speeds of Movement Over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants

Source	SS	df	MS	F	P
Between Subjects	4602.86	95			
Age	1139.61	2	569.81	16.55	less than .001
Complexity	133.45	3	44.48	1.29	
Age x Complexity	437.15	6	72.86	2.12	less than .10
Subjects within Groups	2892.65	84	34.44		
Within Subjects	1972.23	288			
Speed	509.41	3	169.80	38.94	less than .001
Age x Speed	118.19	6	19.70	4.52	less than .001
Complexity x Speed	87.33	9	9.70	2.22	less than .025
Age x Complexity x Speed	157.34	18	8.74	2.00	less than .005
Speed x Subjects within Groups	1099.96	252	4.36		

Table 17

Summary Table of Analysis of Variance of Total Number of Looks at the Moving Stimulus for Four Speeds of Movement Over Four Levels of Complexity by 8 Week-old, 16 Week-old, and 24 Week-old Infants

Source	SS	df	MS	F	P
Between Subjects	14829.43	95			
Age	2259.02	2	1129.51	9.56	less than .001
Complexity	957.59	3	319.20	2.70	
Age x Complexity	1688.41	6	281.40	2.38	less than .05
Subjects within Groups	9924.41	84	118.15		
Within Subjects	5244.25	288			
Speed	14.77	3	4.92	-	
Age x Speed	542.42	6	90.40	5.94	less than .001
Complexity x Speed	263.03	9	29.23	1.92	.05
Age x Complexity x Speed	591.57	18	32.87	2.16	less than .005
Speed x Subjects within Groups	3832.46	252	15.21		

Table 18

Analysis of Linear Trend Components in the Three-way Analysis of Variance for Average Span of Looking Time

Source	SS	df	MS	F	P
Age (linear)	1062.39	1	1062.39	30.85	less than .001
Complexity (linear)	51.30	1	51.30	1.49	
Age x Complexity (linear)	310.77	2	155.39	4.51	less than .05
Subjects within Groups		84	34.44		
Within Subjects (linear)	1218.88	96			
Speed (linear)	504.35	1	504.35	90.87	less than .001
Age x Speed (linear)	112.07	2	56.04	10.10	less than .001
Complexity x Speed (linear)	35.03	3	11.68	2.10	
Age x Complexity x Speed (linear)	101.46	6	16.91	3.05	less than .05
Speed x Subjects within Groups (linear)	465.97	84	5.55		

Table 19

Analysis of Linear Trend Components in the Three-way Analysis of Variance for Total Number of Looks

Source	SS	df	MS	F	P
Age (linear)	1774.52	1	1774.52	15.02	less than .001
Complexity (linear)	947.81	1	947.81	8.02	less than .01
Age x Complexity (linear)	1534.16	2	767.08	6.49	less than .005
Subjects within Groups		84	118.15		
Within Subjects (linear)	2858.55	96			
Speed (linear)	1.81	1	1.81		
Age x Speed (linear)	531.01	2	265.51	12.51	less than .001
Complexity x Speed (linear)	84.12	3	28.04	1.32	
Age x Complexity x Speed (linear)	458.93	6	76.49	3.60	less than .05
Speed x Subjects within Groups (linear)	1782.68	84	21.22		

14). The average span of looking time (Figure 14a) decreases with age. The analysis of linear trend indicates that the slope of this age effect is significantly different from zero. Tukey comparisons indicate that the average span of looking time of the 8-week-olds is significantly greater than that of the 16-week-olds and that of the 24-week-olds (p's less than .01), but that there is no significant difference between the average span of the 16-week-olds and that of the 24-week-olds.

The total number of looks (Figure 14b) increases with age. The analysis of linear trend indicates that the slope of this effect is significantly different from zero. Tukey comparisons indicate that both the 16-week-olds and the 24-week-olds give a significantly greater number of looks than do the 8-week-olds (p's less than .01), but that the 16-week-olds and the 24-week-olds do not differ from one another in total number of looks.

Speed

The significance of the speed effect in average span of looking time indicates that infants increase the average length of each look as speed increases (Figure 15). The linear trend analysis indicates that the slope of the speed effect is significantly different from zero. Tukey tests indicate that there are significant differences in average span of looking time between all comparisons of speed levels (p for difference between the two slowest speeds less than

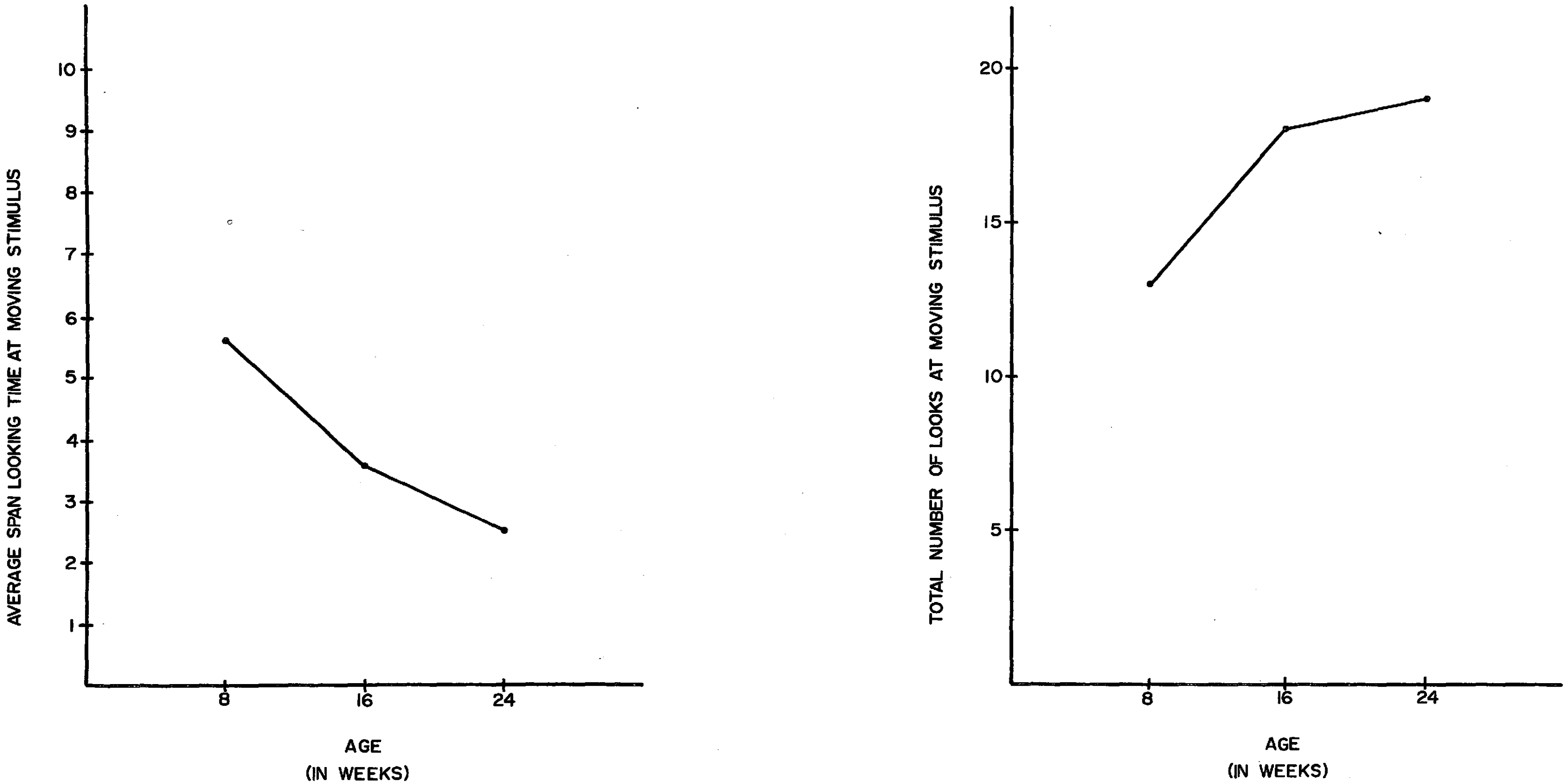

Fig. 14. The effect of age on average span and on total number of looks at the moving stimulus, averaged over all levels of complexity, all speeds of movement, and subjects.

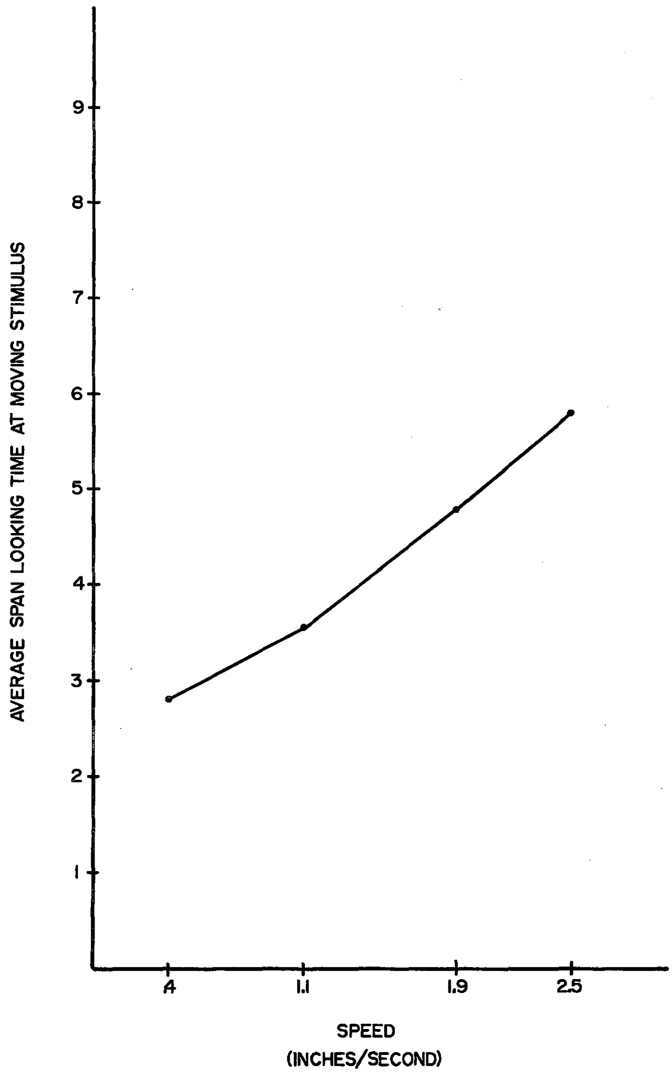

Fig. 15. The effect of speed on average span of looking time at the moving stimulus, averaged over all ages, levels of complexity, and subjects.

.05; all other p's less than .01).

The effect of speed is not significant in total number of looks.

Complexity

The complexity effect failed to reach a significance level of p=.05 in either measure.

Age x Complexity

The interaction of age and complexity was significant only for the measure involving total number of looks (Figure 16). The linear trend analysis shows that the significant interaction between age and complexity can be attributed to differences in the slopes of the best-fitting straight lines over levels of complexity. An analysis comparing linear trends of the individual lines shows that the slope of the 8-week-olds is significantly different from that of the 16-week-olds (p less than .001), and that of the 24-week-olds (p less than .05), but that the slopes of the 16-week-olds and the 24-week-olds are not significantly different from each other. The slope of the best-fitting straight line for the 8-week-olds is negative while those of the 16-week-olds and 24-week-olds are positive.

Age x Speed

The interaction of age and speed is significant for

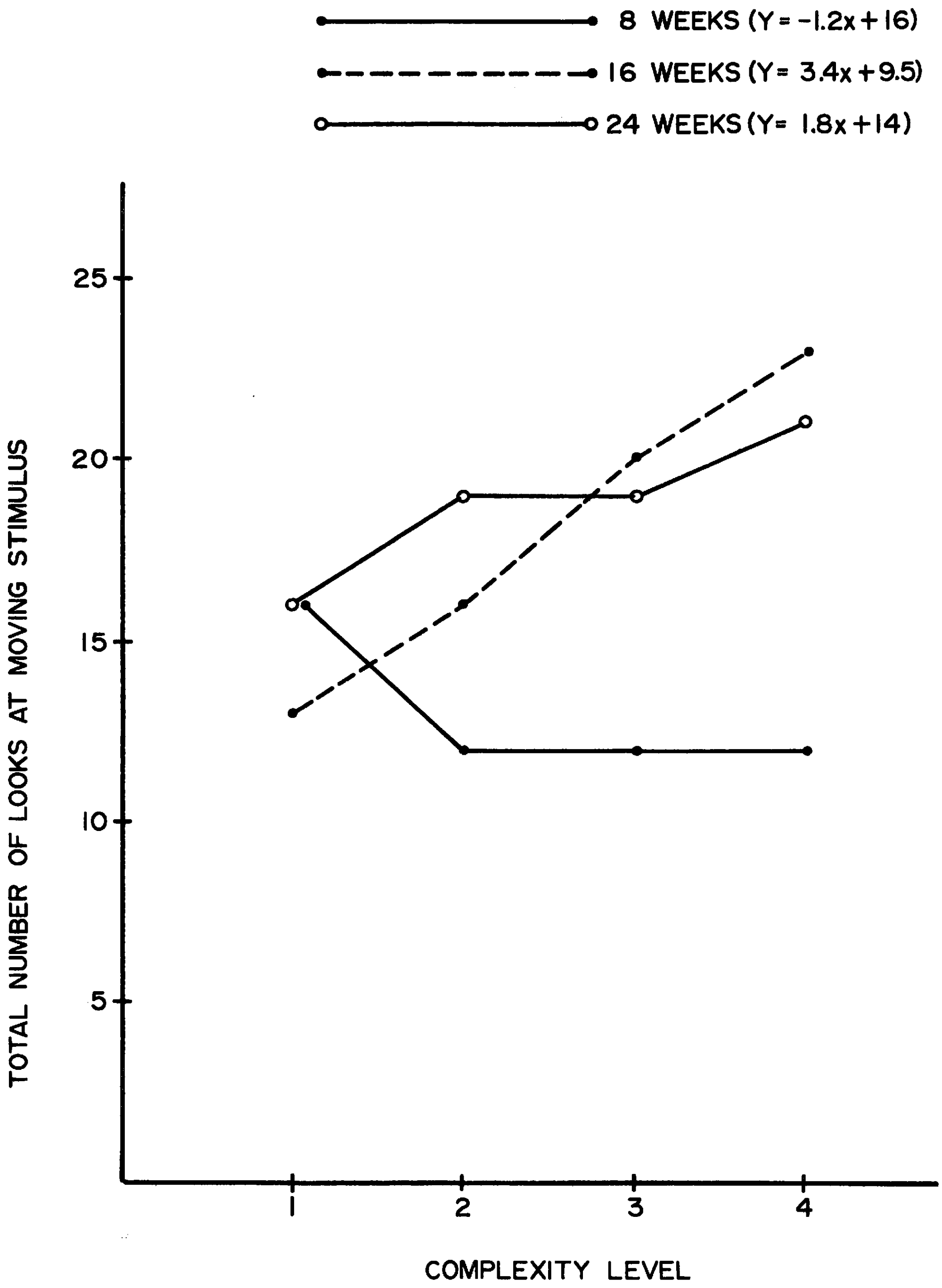

Fig. 16. The interaction effect of age and complexity on the total number of looks at the moving stimulus. Number of looks is averaged over subjects.

both measures (Figure 17). The linear trend analysis for average span indicates that the significant interaction can be attributed to differences in the slopes of the best-fitting straight lines over levels of speed (Figure 17a). Comparisons between individual lines show that the slope for the 8-week-old group is significantly steeper than that of the 16-week-old group (p less than .025) and that of the 24-week-old group (p less than .001), and that the slope of the 16-week-old group is significantly steeper than that of the 24-week-old group (p less than .05).

The linear trend analysis for total number of looks indicates that the significant interaction can be attributed to differences in the slopes of the best-fitting straight lines over levels of speed (Figure 17b). Comparisons between individual lines show that the slope for the 24-week-olds is significantly different from that of the 16-week-olds and that of the 8-week-olds (p's less than .001), but that the slopes of the 16-week-olds and that of the 8-week-olds are not significantly different from each other.

Complexity x Speed

The interaction of complexity and speed is shown in Figure 18. Although the interaction is significant for both response measures, its linear component is not significant in either measure. Analysis of quadratic trend also fails to

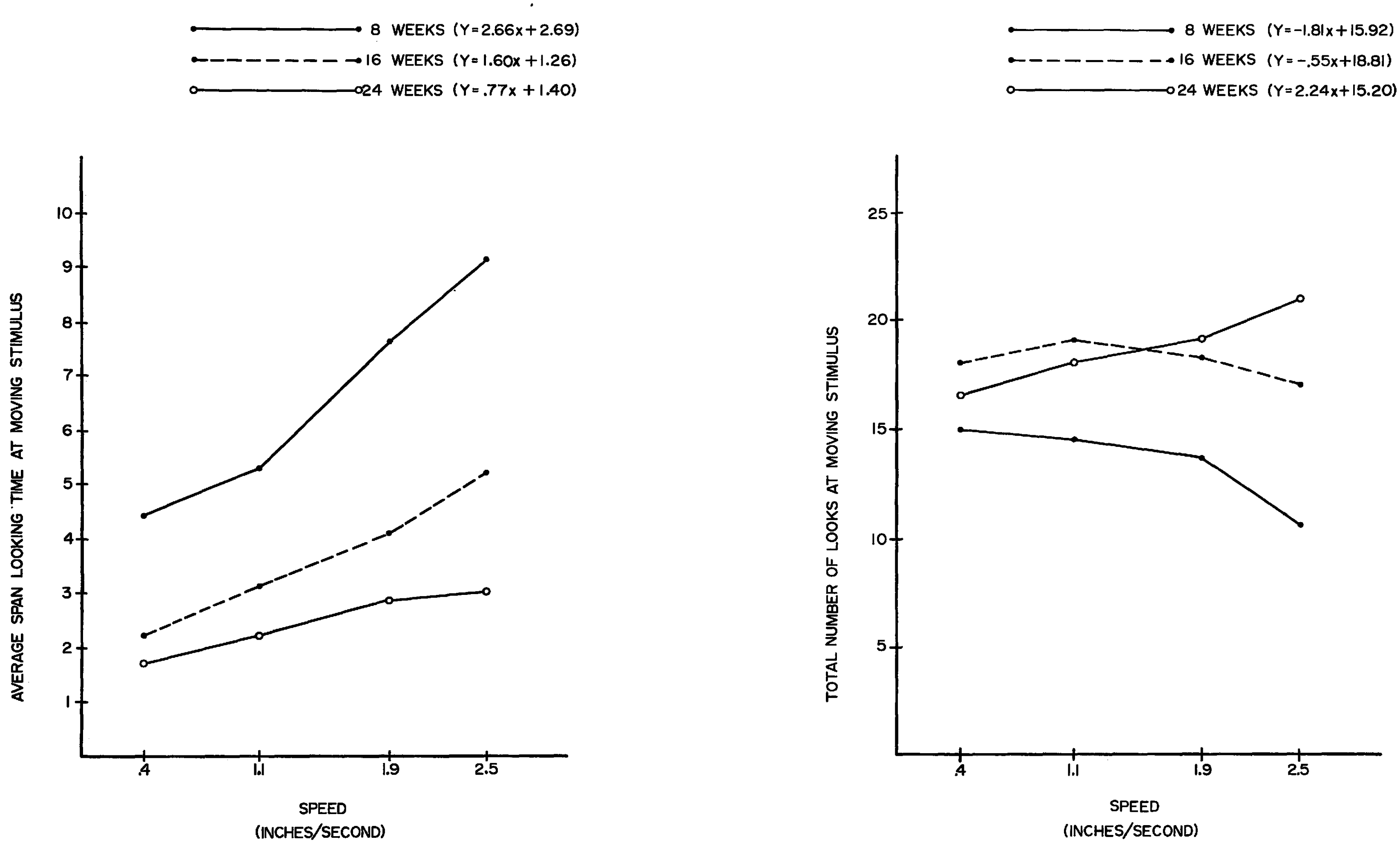

Fig. 17. The interaction effect of age and speed on average span and on total number of looks at the moving stimulus, averaged over subjects.

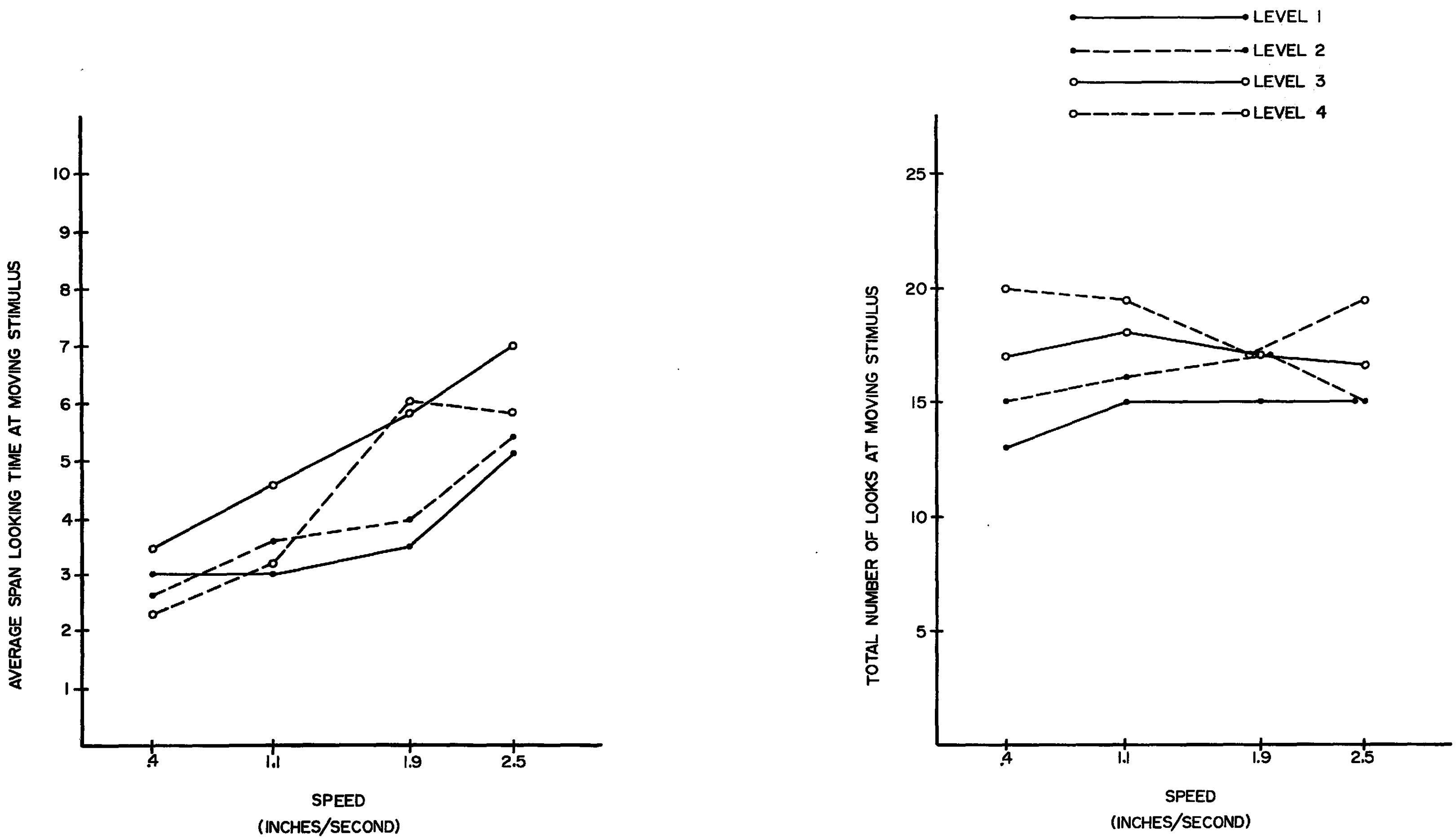

Fig. 18. The interaction effect of complexity and speed on average span and on total number of looks at the moving stimulus, averaged over subjects.

reveal easily interpretable differences. In both measures this interaction is involved in a significant three-way interaction, and the form of its specification is best left for consideration as part of this higher-order interaction.

Age x Complexity x Speed

The interaction of age x complexity x speed is significant in both measures. The interactions are presented graphically in Figures 12 and 13. In order to find the source of interaction for each measure, separate analyses of variance were performed on the age x speed interactions within each of the four levels of complexity (Table 20 and Table 21). For average span of looking time, the analyses show that the patterns of response to movement are the same for all three age groups on Levels 1, 2, and 3, but differ from each other on Level 4 (p less than .001). An analysis of linear trend performed on Level 4 (Table 22) shows that the interaction is attributable to differences between the slopes of the best-fitting straight lines over speeds. Comparisons between individual lines show that the slope of the 8-week-old group is significantly steeper (p less than .001) than that of the 16-week-old group, and is significantly steeper (p less than .001) than that of the 24-week-old group. The slopes of the 16-week-olds and the 24-week-olds are not significantly different from each other. The slopes are: for the 8-week-olds,

Table 20

Summary Table of Two-way Analysis of Variance for Average Span of Looking Time within Each of Four Levels of Complexity

Source	SS	df	MS	F	P
		Complexity Level 1			
Between Subjects	191.01	23			
Age	27.65	2	13.83	1.78	
Subjects within Groups	163.36	21	7.78		
Within Subjects	227.06	72			
Speed	71.20	3	23.73	10.50	less than .001
Age x Speed	13.53	6	2.26	1.00	
Speed x Subjects within Groups	142.33	63	2.26		

Table 20 (cont.)

Source	SS	df	MS	F	P
		Complexity Level 2			
Between Subjects	208.32	23			
Age	118.93	2	59.47	13.96	less than .001
Subjects within Groups	89.39	21	4.26		
Within Subjects	235.44	72			
Speed	88.71	3	29.57	13.14	less than .001
Age x Speed	5.06	6	.84		
Speed x Subjects within Groups	141.67	63	2.25		

Table 20 (cont.)

Source	SS	df	MS	F	p
			Complexity Level 3		
Between Subjects	3181.87	23			
Age	880.12	2	440.06	4.10	less than .05
Subjects within Groups	2301.75	21	109.61		
Within Subjects	634.86	72			
Speed	179.23	3	59.74	9.83	less than .001
Age x Speed	72.39	6	12.07	1.99	
Subjects within Groups	383.24	63	6.08		

Table 20 (cont.)

Source	SS	df	MS	F	P
Complexity Level 4					
Between Subjects	888.19	23			
Age	550.05	2	275.03	17.08	less than .001
Subjects within Groups	338.14	21	16.10		
Within Subjects	874.88	72			
Speed	257.60	3	85.87	12.50	less than .001
Age x Speed	184.55	6	30.76	4.48	less than .001
Speed x Subjects within Groups	432.73	63	6.87		

Table 21

Summary Table of Two-way Analysis of Variance for Total Number of Looks within Each of Four Levels of Complexity

Source	SS	df	MS	F	P
			Complexity Level 1		
Between Subjects	2865.24	23			
Age	117.15	2	58.58		
Subjects within Groups	2748.09	21	130.86		
Within Subjects	962.25	72			
Speed	97.87	3	32.62	2.75	less than .05
Age x Speed	117.60	6	19.60	1.65	
Speed x Subjects within Groups	746.78	63	11.85		

Table 21 (cont.)

Source	SS	df	MS	F	P
		Complexity Level 2			
Between Subjects	1659.62	23			
Age	677.25	2	338.63	7.24	less than .005
Subjects within Groups	982.37	21	46.78		
Within Subjects	1067.00	72			
Speed	69.70	3	23.23	1.61	
Age x Speed	90.42	6	15.07	1.05	
Speed x Subjects within Groups	906.88	63	14.39		

Table 21 (cont.)

Source	SS	df	MS	F	P
		Complexity Level 3			
Between Subjects	**4043.49**	**23**			
Age	1048.27	2	524.14	3.67	less than .05
Subjects within Groups	2995.22	21	142.63		
Within Subjects	**1307.25**	**72**			
Speed	21.03	3	7.01		
Age x Speed	329.32	6	54.89	3.61	less than .025
Speed x Subjects within Groups	956.90	63	15.19		

Table 21 (cont.)

Source	SS	df	MS	F	P
		Complexity Level 4			
Between Subjects	5303.49	23			
Age	2104.77	2	1052.39	6.91	less than .005
Subjects within Groups	3198.72	21	152.32		
Within Subjects	1907.75	72			
Speed	89.20	3	29.73	1.53	
Age x Speed	596.65	6	99.44	5.13	less than .005
Speed x Subjects within Groups	1221.90	63	19.40		

Table 22

Analysis of Linear Trend Components Involving the Speed Effect Within Complexity Level 4 for Average Span of Looking Time at the Moving Stimulus

Source	SS	df	MS	F	P
Within Subjects (linear)	464.70	24			
Speed (linear)	218.43	1	218.43	42.91	less than .001
Age x Speed (linear)	139.30	2	69.65	13.68	less than .001
Speed x Subjects within Groups (linear)	106.98	21	5.09		

Y = 4.1X + 1.6; for the 16-week-olds, Y = .94X + 1.26; for the 24-week-olds, Y = .75X + 1.44.

For the total number of looks, the individual analyses show that patterns of response to movement are the same for all three age groups on Levels 1 and 2, but are significantly different on Level 3 (p less than .025) and Level 4 (p less than .005). Analyses of linear trend made at these two levels of complexity appear in Table 23. At both levels, the interaction was attributable to differences between the slopes of the best-fitting straight lines over speeds. At Level 3, comparisons between individual lines show that the slope of the 24-week-old group is significantly different from that of the 16-week-old group (p less than .01) and that of the 8-week-old group (p less than .025). The slopes of the 16-week-olds and the 8-week-olds are not significantly different from each other. The 24-week-olds have a positive slope (Y = 2.81X + 14.86), while the other two groups have negative slopes. The slope for the 16-week-olds is Y = -2.53 X + 23.73; the slope for the 8-week-olds is Y = -1.4 X + 14.57.

At Level 4, comparisons between individual lines show that the slope of the 8-week-old group is significantly different from that of the 16-week-old group (p less than .005) and that of the 24-week-old group (p less than .001). The slopes of the 16-week-olds and the 24-week-olds are not significantly different from each other. The slope for the

Table 23

Analysis of Linear Trend Components Involving Speed Effect within Complexity Level 3 and Level 4 for Total Number of Looks at the Moving Stimulus

Complexity Level 3

Source	SS	df	MS	F	P
Within Subjects (linear)	902.15	24			
Speed (linear)	16.50	1	16.50	-	
Age x Speed (linear)	307.88	2	153.94	5.60	less than .025
Speed x Subjects Within Groups (linear)	577.77	21	27.51		

Table 23 (cont.)

Complexity Level 4

Source	SS	df	MS	F	P
Within Subjects (linear)	1092.85	24			
Speed (linear)	9.35	1	9.35	-	
Age x Speed (linear)	560.11	2	280.06	11.24	less than .001
Speed x Subjects Within Groups (linear)	523.39	21	24.92		

8-week-olds is negative ($Y = -4.3\ X + 18.83$), while the slope for the other two groups is positive. The 16-week-olds' slope is $Y = .36\ X + 22.72$; the 24-week-olds' slope is $Y = 3.1\ X + 16.50$.

Discussion

In an earlier study by Ames and Silfen (1965) it was found that different patterns of looking behavior characterized infants of different ages, with younger infants (7 - 8 weeks of age) taking a smaller number of looks, but of longer span and older infants (24 weeks of age) taking a larger number of looks, but of shorter span. In the present chapter the response measures of total number of looks and average span of looking were analyzed to determine whether the previous findings were replicable, and also whether these measures might give information about infants' looking responses to speed and complexity that would be a valuable addition to the results obtained from the total looking time and percent looking time measures analyzed in the previous chapter. As the measures of average span and total number of looks are components of the total looking time measure, the discussion to follow will include discussion of the relation of the results presented in this chapter to those presented in the previous chapter.

<u>Age</u>

Both average span and total number of looks yielded a significant effect of age. With increasing age, the average span of looking time decreases and the total number of looks increases. This indicates that younger infants tend to look at the moving stimulus fewer times than do older infants, but that the individual looks last for a longer span of time than do the looks of an older infant. This result supports the earlier findings of Ames and Silfen (1965).

It will be remembered that there were significant age differences in total looking time, with older babies looking less than younger babies. From analysis of average span and number of looks, it can be seen that the decrease in total looking time with age is mainly a result of the older infant's tendency to take shorter individual looks.

<u>Speed</u>

The average span of looking time increases with increased speed of movement, while the total number of looks does not change with speed. This seems to indicate that the increase in total looking time as speed is increased is mainly a result of increasing the span of individual looks.

not of any increase in the number of looks at the moving stimulus.[1]

Complexity

Neither the average span nor the number of looks shows a significant main effect of complexity. In spite of the lack of significance, inspection of the complexity data for these two measures shows that there is some tendency for each of the measures to increase with increased complexity, and the multiplication of these two measures into total looking time, as previously analyzed, did reveal a significant main effect of complexity.

Age x Speed

The age x speed interaction is significant in all three measures -- average span, total number of looks, and total looking time. The average span of looking increases for all three age groups as speed of movement is increased, but the 8-week-olds show the greatest increase in average span, with the 16-week-olds showing less of an increase, and

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[1] It should be noted that this finding is unrelated to work on adults' fixation of a moving stimulus, reviewed in Chapter 2. In the studies reported by Gibson, et. al. (1957) and Mashhour (1964), emphasis was on a comparison of fixation and pursuit as modes of looking at a moving stimulus. In the present work on infants, emphasis is on measurement of the time span that starts when an infant shifts his gaze to the moving stimulus and ends when he shifts from the moving stimulus to either the non-moving stimulus or to some other part of the visual field. Within this time span the infant may either be fixating some particular point or pursuing the moving stimulus.

the 24-week-olds showing the smallest increase. For total number of looks a different result is obtained, with 24-week-olds giving a significantly greater increase in number of looks as speed increases than do the two younger groups.

It will be recalled that analysis of total looking time revealed a significant age x speed interaction in which the 16-week-olds exhibited a steeper slope over speeds than did either the 8-week-olds or the 24-week-olds. The reason for this unhypothesized and rather surprising finding of 16 weeks being an age of particularly great responsiveness to differences in movement can now be discussed. Figure 19 shows separate plots of response to movements of different speeds for each age group on each of the three response measures. It may be concluded that, as speed increases, infants of all three age groups "look more" at the moving stimulus. However, at different ages different patterns of looking are used to reveal this response to speed. Over increasing speeds, the looking pattern of the 24-week-olds is characterized by an increasing number of looks, with the average span of looking becoming slightly longer. The 16-week-old group shows a fairly steady number of looks, with the average span of looking becoming longer. The looking pattern of the 8-week-olds is characterized by a decreasing number of looks, but with greatly increasing span.

The multiplication of these two measures results in

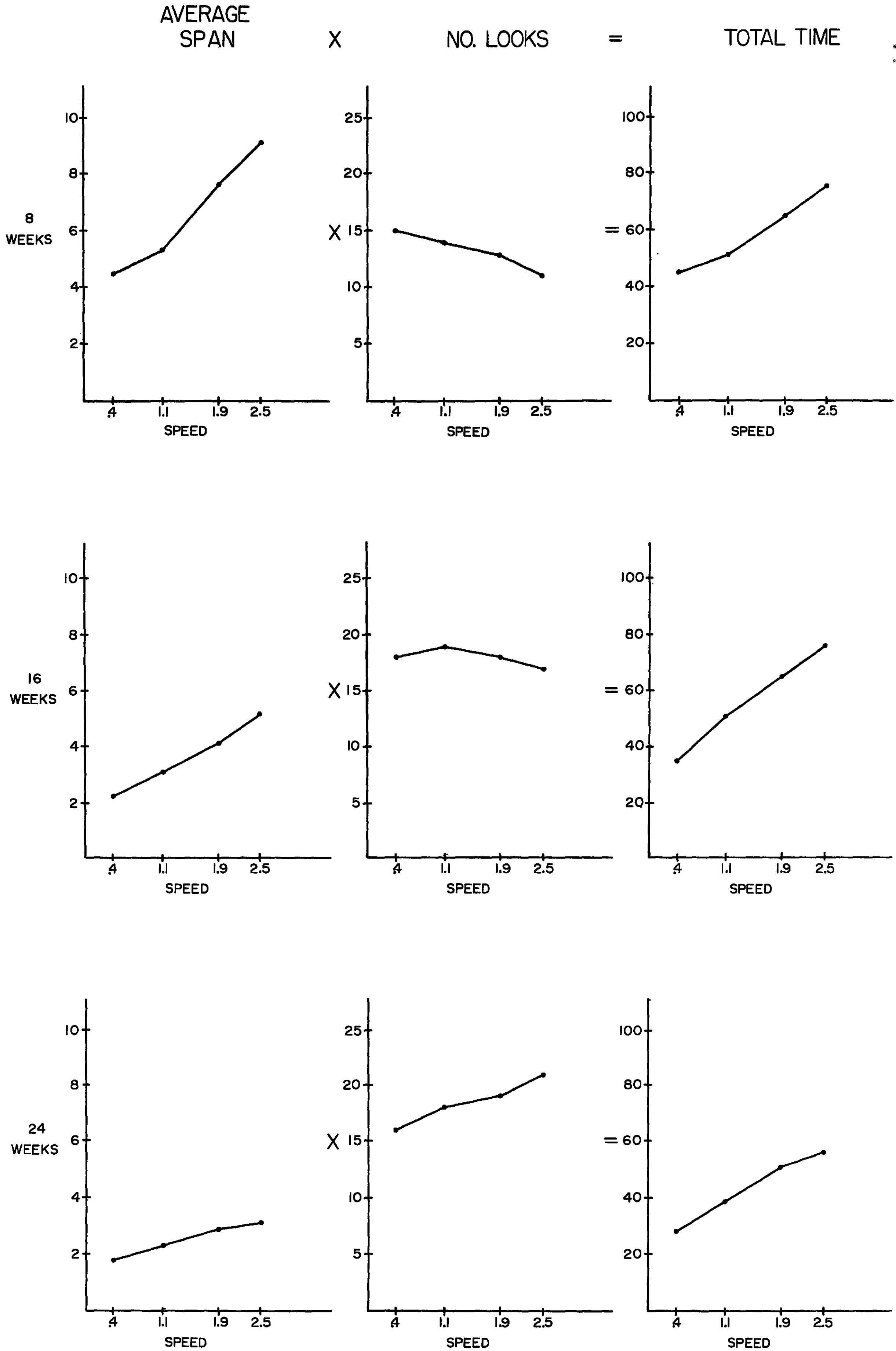

Fig. 19. Response to movement of different speeds for

the 16-week-olds coming out best in total looking time. Whereas all three age groups show increased total looking as speed increases, the slope of the 16-week-olds is steepest. However, it would be incorrect to conclude, as one would from the analysis of total looking time alone, that 16-week-olds are particularly responsive to increases in speed. The 8-week-olds are most responsive to increases in speed if average span is used as a measure; the 24-week-olds are most responsive to increases in speed if the number of looks is used as a measure. The decision as to which age group shows the steepest slope of response to increased speed depends entirely on which response measure is used. It is therefore impossible to designate any one of the three age groups as most responsive to speed changes overall.

Age x Complexity

The age x complexity interaction was significant only for the total number of looks. Both the 24-week-olds and the 16-week-olds exhibited a steeper slope across complexity levels than did the 8-week-olds. The two older groups increased the number of looks at the moving stimulus as complexity increased, while the slope of the best-fitting straight line for 8-week-olds' number of looks across levels of increasing complexity was negative.

The interaction of age x complexity for average span did not reach significance at the .05 level. Inspection of the data, however, shows that the average span for the 8-week-olds tended to increase with increasing complexity, while the span for the 16-week-olds and 24-week-olds declined slightly. Figure 20 shows separate plots of responses to different levels of complexity for each age group on the response measures of average span, total number of looks, and total looking time. It can be seen from this figure that the results for average span tend to cancel out the results for total number of looks, a finding that accounts for the lack of significance of the age x complexity interaction in total looking time. With increasing complexity, the 8-week-olds show a large increase in span, which is partially offset by a small decrease in the number of looks. The two older age groups show the opposite pattern -- i.e., with increasing complexity the number of looks increases, but this increase is partially offset by a small decline in the average span of looking. In all age groups, the total looking time obtained by multiplying average span by number of looks reveals that as complexity increases, total looking time increases. There is no significant difference between the slopes of total looking time over complexity levels for the different age groups. However, the analysis of average span and number of looks leads to the conclusion that the 8-week-olds are very different from the two older groups in the pattern of looking

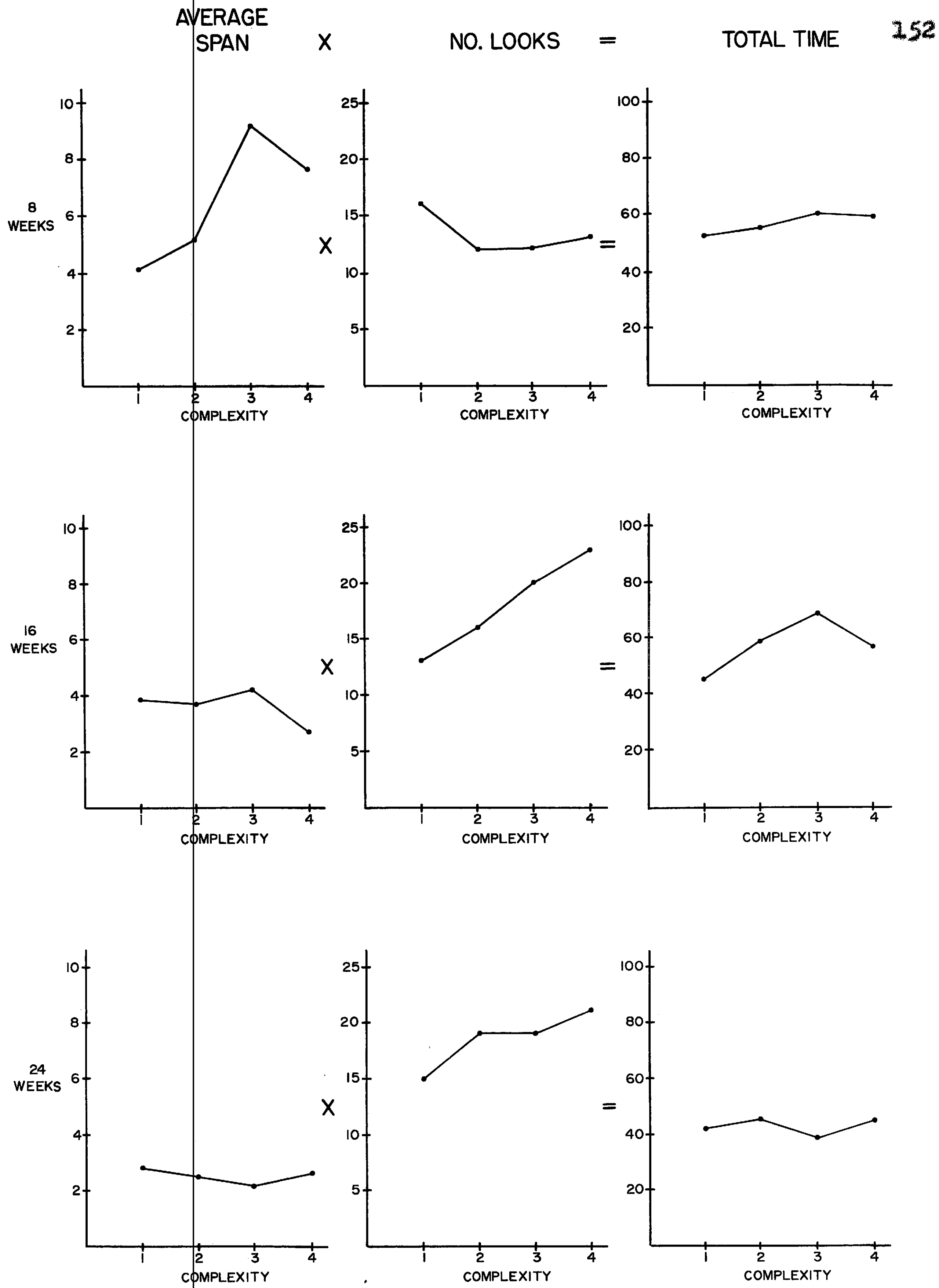

Fig. 20. Response to different complexity levels for each age group on each of three different response measures.

by which they accomplish the increase in looking time across complexity levels.

Complexity x Speed

Although there was a significant interaction of complexity and speed for both average span and total number of looks, the interaction was not significant in a linear trend analysis for either response measure. In addition, the previous analysis of total looking time did not reveal any significant complexity x speed interaction.

Overall, then, the complexity x speed interaction is not as easily interpretable as are the other two-way interactions of age x speed and age x complexity. As all three variables are involved in a significant three-way interaction, perhaps the most parsimonious way to interpret the complexity x speed interaction is in terms of the age x complexity x speed interaction.

Age x Complexity x Speed

The three-way interaction was significant for both average span and total number of looks. In each case, the interaction can be attributed to the fact that differences between slopes over speed for different age groups are found only at high levels of complexity. For average span, the significant age x speed interaction is found only in complexity Level 4, where the 8-week-olds show a steep increase over speed levels, an increase not shown by the other two age groups. In total number of looks, significant age x speed interactions are found at Levels 3 and 4. At Level 3, only the 24-week-olds increase the number of looks as speed increases; at Level 4, both the 16-week-olds and the 24-week-olds increase their number of looks as speed increases; the 8-week-olds do not.

No significant three-way interaction was found with the total looking time measure. Comparisons of plots for average span (Figure 12) and total number of looks (Figure 13) show again that this lack of results is due to the two measures cancelling each other out when they are combined into the total looking time measure. This cancellation, of the type described in the discussion of the age x speed interaction, occurs at Levels 3 and 4 of complexity, the only levels at which age x speed interactions are present.

In general, it can be concluded that the analyses of average span and number of looks do add appreciably to the information obtained from the analysis of total looking time. Indeed, the results of total looking time alone are somewhat misleading. Among other things, the total looking time data seem to show that a) 16-weeks is an age at which infants are more responsive to differences in speed of movement than they are at 8 weeks or 24 weeks of age; and that b) stimulus complexity plays either no role or a very small role in infants' responses to moving stimuli. Analyses of average span and number of looks show that these preliminary conclusions are not true. Because infants in the three different age groups use different patterns of looking -- i.e., different combinations of average span and number of looks -- it is impossible to conclude that any one of the three ages is "most responsive" to speed differences. By total looking time, the 16-week-olds give the steepest slope of response over speeds; by average span, the 8-week-olds' slope is the steepest; and by number of looks, the 24-week-olds' slope is steepest. The only meaningful conclusion that can be drawn is that infants at any of the three ages do increase their looking behavior as the speed of stimulus movement increases.

Analyses of average span and number of looks also reveal that, for all three age groups, the complexity of the stimulus effects the infants' response to the speed of movement of that stimulus. In each age group, a steeper slope of response as speed increases is obtained at high levels of complexity than is obtained at low levels of complexity. For the 8-week-olds this steeper slope occurs in the measure of average span, while for the two older groups it is shown in number of looks.

Summary

Analyses of variance and linear trend analyses of the response measures of average span of looking and total number of looks were performed. These analyses helped to expand and clarify the results obtained from the analysis of total looking time.

With increasing age, the average span of looking time decreases and the total number of looks increases. The average span of looking increases with increased speed of movement. Neither average span nor number of looks shows a significant main effect of complexity, although their multiplication into total looking time does produce a measure that increases with increases in complexity, as reported in the previous chapter.

As speed increases, the different age groups use different patterns of looking to indicate greater response. Eight-week-olds give a decreasing number of looks, but greatly increase the span of each look. Sixteen-week-olds maintain a fairly steady number of looks, but their average span of looking increases. Twenty-four-week-olds increase the number of looks, and the average span of looking becomes slightly longer.

Although there were no age differences in response to increases in complexity when total looking time was used as a measure, it appears that this is due to the fact that, in all three age groups, changes in average span tend to cancel out changes in total number of looks. Across levels of increasing complexity, 8-week-olds show a large increase in span, which is partially offset by a small decrease in number of looks. Sixteen-week-olds and 24-week-olds show an increase in number of looks, but this increase is partially offset by a small decline in the average span of looking. Thus, although in all age groups there are changes in looking behavior as complexity is increased, the nature of these changes depends on the age of the child.

Significant age x speed interactions of the type described occur only at high levels of complexity, thus accounting for the significant three-way interaction found in both average span and total number of looks. In contrast to the preliminary results of the previous chapter, stimulus complexity does play a role in infants' response to speed of movement of the stimulus.

CHAPTER 6

Results for Percent Average Span of Looking Time and Percent Total Number of Looks

Thus far the same data have been analysed by four different measures of visual fixation. Total looking time, the measure most commonly used by workers in the field, has been split into average span and total number of looks in order to reveal age differences in patterns of looking behavior. In addition, analysis of percent looking time has been performed in order to determine whether increases in total looking time at the moving stimulus are due to an increased proportion of looking time being directed to the moving rather than the non-moving stimulus or whether they are due merely to some more general effect -- e.g., increased arousal -- which produces increased looking time at both the moving and the non-moving stimuli.

The results for percent looking time showed that the results obtained by analysis of total looking time were not attributable merely to this sort of effect. The proportion of looking time spent looking at the moving stimulus increased with both the age of the subject and the speed of movement.

However, the possibility remains that results obtained from one of the components of total looking time -- i.e., either average span or total number of looks -- might be reflecting mainly arousal differences and not a discrimination between the moving and non-moving stimuli. It is to this possibility that the present chapter is addressed. Here, both of the components are converted to proportional measures -- percent total number of looks, and percent average span of looking time.

Percent total number of looks is defined as the proportion of the total number of looks at both moving and non-moving stimuli that was directed toward the moving stimulus. Percent average span is defined as the proportion of the overall span of looking time at both moving and non-moving stimuli that was devoted to the fixation of the moving stimulus. It is derived as follows:

$$\frac{\dfrac{\text{Tot. looking time at moving st.}}{\text{Tot. no. looks at moving st.}}}{\dfrac{\text{Tot. looking time moving}}{\text{Tot. number looks moving}} \text{ plus } \dfrac{\text{Tot. looking time non-moving}}{\text{Tot. number looks non-moving}}}$$

As in the case of percent looking time, these measures give a comparison of the relative changes in response to the moving stimulus as compared to the non-moving stimulus. In the following presentation, results for both response measures are presented concurrently.[1]

1. Chi square tests were employed to see whether there were any significant departures from normality in the distributions of these proportion measures. As in Chapter 4, the test was applied to each age sample under each of the experimental conditions. Since there were no instances of significant departure from normal distribution, arc-sine transformations were not employed in the analyses for either of the two percent measures.

Table 24 shows the percent average span directed toward the moving stimulus, at each speed and level of complexity by the 8-week-old, 16-week-old, and 24-week-old infants. Table 25 gives analogous information for the percent total number of looks at the moving stimulus. The same data are presented graphically in Figure 21 and Figure 22 respectively.

Table 26 presents a summary of a three-way analysis of variance of the percent average span of looking time at the moving stimulus for each age group at each level of complexity and each speed. Table 27 summarizes an analogous three-way analysis of variance of the percent total number of looks at the moving stimulus.

In order to explore the nature of the significant differences, trend analyses were also performed on the data. The linear trend analysis for percent average span appears in Table 28. The linear trend analysis for percent total number of looks is presented in Table 29. In the presentation of the results, each variable and interaction will be discussed separately, along with all relevant information obtained from analyses and trend analyses on both response measures.

Age

The age effect is significant in both measures (Figure 23). The percent average span measure generally increases with age (Figure 23a). The analysis of linear trend indicates

Table 24

Percent Average Span Looking Time Directed at Stimulus Moving at Four Different Speeds Over Four Levels of Complexity, by 8-week, 16-week, and 24-week-old Infants, Averaged over Subjects

	Complexity Level 1				Complexity Level 2				Mean % Avg. Span LT for Each Age Group
Speed	SS	S	F	FF	SS	S	F	FF	
Age									
8 weeks	.56	.58	.66	.76	.55	.59	.60	.76	
16 weeks	.66	.67	.72	.83	.56	.71	.81	.83	
24 weeks	.61	.65	.76	.80	.61	.74	.73	.81	
Mean % Avg. Span for Each Stimulus	.61	.63	.71	.80	.57	.68	.71	.80	
	Complexity Level 3				Complexity Level 4				
8 weeks	.59	.58	.63	.73	.53	.58	.78	.76	.64
16 weeks	.55	.69	.80	.87	.56	.68	.73	.84	.72
24 weeks	.52	.73	.72	.73	.58	.64	.77	.76	.70
Mean % Avg. Span for Each Stimulus	.55	.66	.71	.77	.56	.63	.76	.79	

Table 25

Percent Total Number of Looks at Stimulus Moving at Four Different Speeds Over Four Levels of Complexity, by 8-week, 16-week, and 24-week-old Infants, Averaged Over Subjects

	Complexity Level 1				Complexity Level 2				
Speed	SS	S	F	FF	SS	S	F	FF	Mean % Number of Looks for Each Age Group
Age									
8 weeks	.49	.53	.55	.67	.50	.50	.58	.51	
16 weeks	.54	.61	.65	.57	.52	.60	.73	.67	
24 weeks	.54	.53	.67	.67	.57	.68	.63	.63	
Mean % Number of Looks for Each Stimulus	.52	.56	.62	.64	.53	.59	.65	.60	
	Complexity Level 3				Complexity Level 4				
8 weeks	.51	.53	.54	.53	.51	.53	.53	.61	.54
16 weeks	.50	.54	.63	.68	.49	.54	.60	.66	.60
24 weeks	.51	.59	.66	.69	.56	.62	.71	.68	.62
Mean % Number of Looks for Each Stimulus	.51	.55	.61	.63	.52	.56	.61	.65	

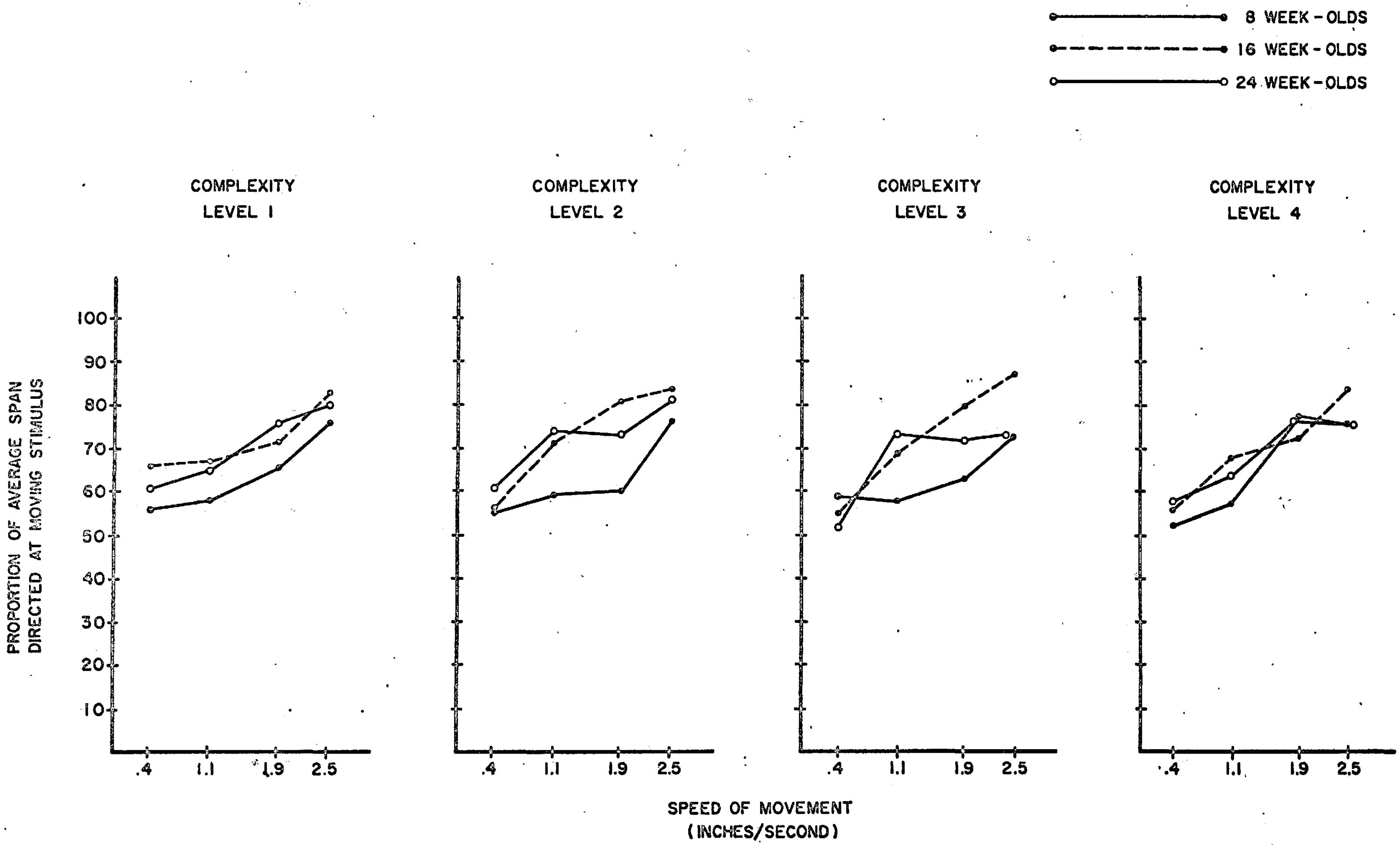

Fig. 21. Percent average span of looking time directed at the moving stimulus at each of four levels of complexity, by 8-week-old, 16-week-old, and 24-week-old infants. Percent average span is averaged over subjects.

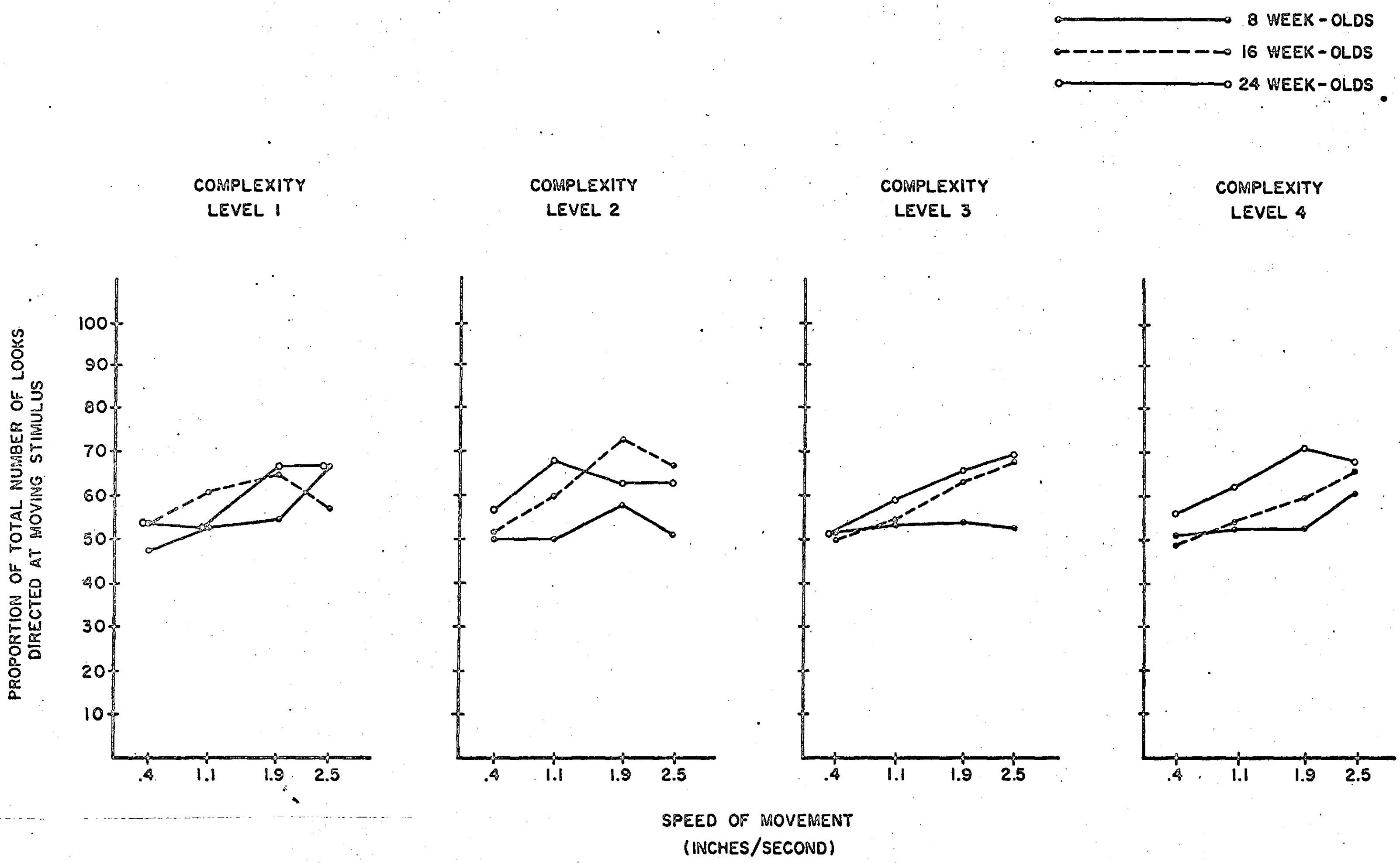

Fig. 22. Percent total number of looks directed at the moving stimulus at each of four levels of complexity, by 8-week-old, 16-week-old, and 24-week-old infants. Percent total number of looks is averaged over subjects.

Table 26

Summary Table of Analysis of Variance of Percent Average Span of Looking Time at the Moving Stimulus for Four Speeds of Movement over Four Levels of Complexity by 8-week-old, 16-week-old, and 24-week-old Subjects

Source	SS	df	MS	F	P
Between Subjects	2.5278	95			
Age	.4454	2	.2227	9.13	less than .001
Complexity	.0130	3	.0043	-	
Age x Complexity	.0693	6	.0116	-	
Subjects within Groups	2.0501	84	.0244		
Within Subjects	5.6030	288			
Speed	2.5014	3	.8338	80.95	less than .001
Age x Speed	.1405	6	.0234	2.27	less than .025
Complexity x Speed	.1278	9	.0142	1.38	
Age x Complexity x Speed	.2487	18	.0138	1.34	
Speed x Subjects within Groups	2.5846	252	.0103		

Table 27

Summary Table of Analysis of Variance of Percent Total Number of Looks at the Moving Stimulus for Four Speeds of Movement over Four Levels of Complexity by 8-week-old, 16-week-old, and 24-week-old Infants

Source	SS	df	MS	F	P
Between Subjects	2.8397	95			
Age	.4569	2	.2285	8.46	less than .001
Complexity	.0129	3	.0043	-	
Age x Complexity	.1048	6	.0175	-	
Subjects within Groups	2.2651	84	.0270		
Within Subjects	3.0087	288			
Speed	.8024	3	.2675	38.21	less than .001
Age x Speed	.0773	6	.0129	1.84	
Complexity x Speed	.0627	9	.0070	1.00	
Age x Complexity x Speed	.3100	18	.0172	2.46	less than .001
Speed x Subjects within Groups	1.7563	252	.0070		

Table 28

Analysis of Linear Trend Components in the Three-way Analysis of Variance for Percent Average Span of Looking Time

Source	SS	df	MS	F	P
Age (Linear)	.2186	1	.2186	8.96	less than .005
Complexity (Linear)	.0034	1	.0034	-	
Age x Complexity (Linear)	.0233	2	.0117	-	
Subjects within Groups		84	.0244		
Within Subjects (Linear)	3.6182	96			
Speed (Linear)	2.4970	1	2.4970	213.42	less than .001
Age x Speed (Linear)	.0462	2	.0231	1.97	
Complexity x Speed (Linear)	.0205	3	.0068	-	
Age x Complexity x Speed (Linear)	.0710	6	.0118	1.01	
Speed x Subjects within Groups (Linear)	.9835	84	.0117		

Table 29

Analysis of Linear Trend Components in the Three-way Analysis of Variance for Percent Total Number of Looks

Source	SS	df	MS	F	P
Age (Linear)	.4356	1	.4356	16.13	less than .001
Complexity (Linear)	.0080	1	.0080	-	
Age x Complexity	.0380	2	.0190	-	
Subjects within Groups		84	.0270		
Within Subjects (Linear)	1.9273	96			
Speed (Linear)	.7509	1	.7509	65.87	less than .001
Age x Speed (Linear)	.0404	2	.0202	1.77	
Complexity x Speed (Linear)	.0216	3	.0072	-	
Age x Complexity x Speed (Linear)	.1564	6	.0261	2.29	less than .05
Speed x Subjects within Groups (Linear)	.9580	84	.0114		

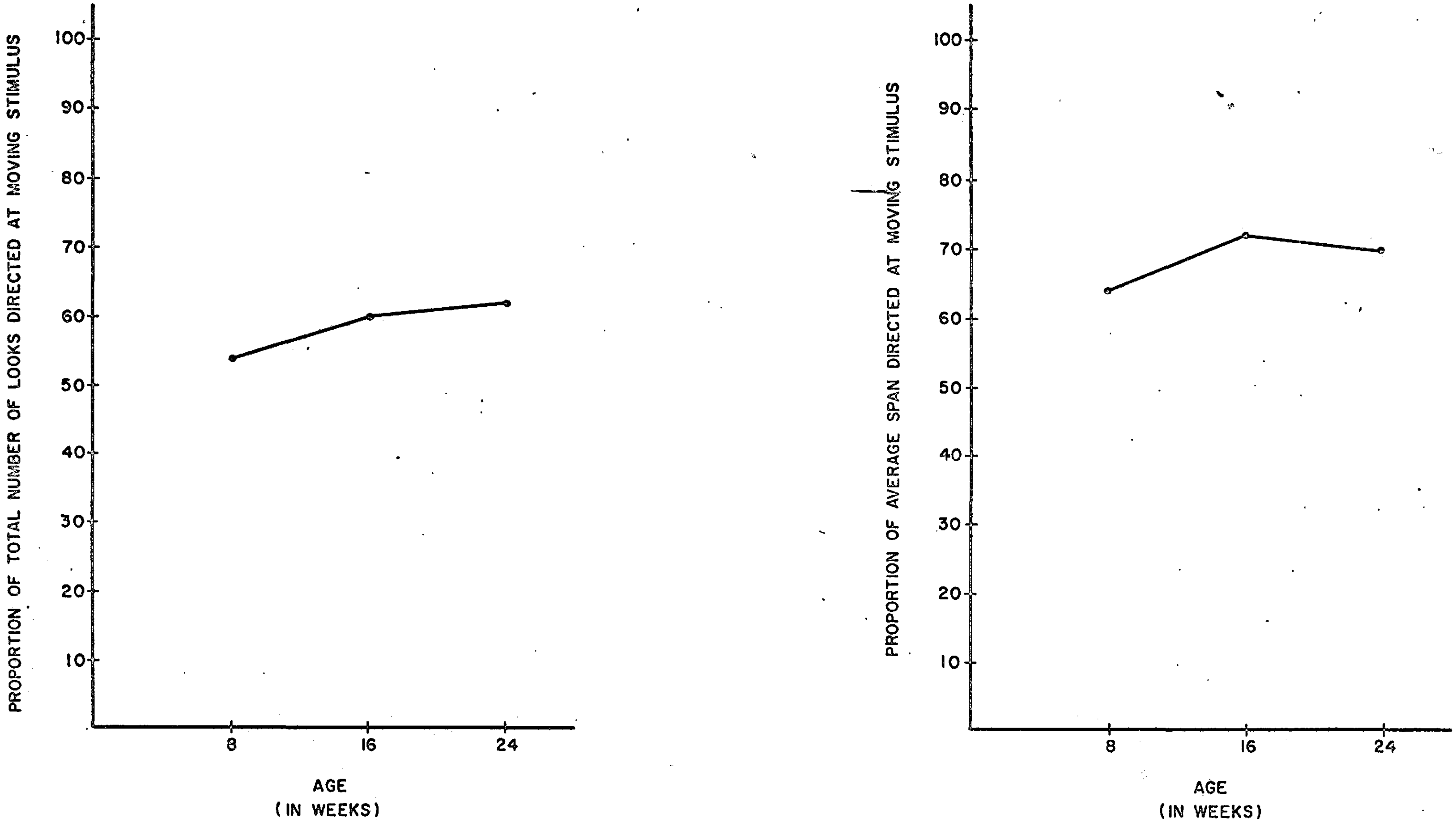

Fig. 23. The effect of age on percent total number of looks directed at the moving stimulus, and percent average span of looking time, averaged over all levels of complexity, all speeds of movement, and subjects.

that the slope of the age effect is significantly different from zero. Tukey comparisons indicate that the percent average span of the 16-week-olds and of the 24-week-olds is significantly greater than that of the 8-week-olds (p's less than .01), but that there is no significant difference between the percent average span of the 16-week-olds and that of the 24-week-olds.

The percent total number of looks (Figure 23b) also increases with age. The analysis of linear trend indicates that the slope of this effect is significantly different from zero. Tukey comparisons indicate that both the 16-week-olds and the 24-week-olds direct a significantly higher percentage of looks toward the moving stimulus, as compared to the non-moving stimulus, than do the 8-week-olds (p's less than .01). However, the 16-week-olds and the 24-week-olds do not differ from one another in percent total number of looks.

Speed

The effect of speed is significant in both measures indicating that, as speed of movement increases, infants look a greater number of times toward the moving stimulus than toward the non-moving stimulus, and that the average length of each fixation is longer for the moving stimulus than for the non-moving stimulus (Figure 24). In Figure 24a, we see that the percent average span increases with speed, and the linear trend analysis indicates that the slope of the speed effect is significantly different from zero. Tukey tests reveal significant differences in percent average span between comparisons of all speed levels (p's less than .01).

In Figure 24b, we see that percent total number of looks also increases with speed, and the linear trend analysis indicates that the slope of the speed effect is significantly different from zero. Tukey comparisons reveal significant differences between all speed levels (p's less than .01), except for the two fastest speeds, which were not significantly different from one another.

Complexity

The complexity effect failed to reach a significance level of $p = .05$ in either measure.

Age x Complexity

The interaction between age and complexity also failed to reach a significance level of $p = .05$ in either measure.

Age x Speed

The interaction between age and speed was significant only for the measure involving percent average span of looking time (Figure 25). Although this interaction is significant, its linear component is not significant, indicating that the shapes of the age functions over levels of speed are irregular. This would indicate that different age groups respond to changes in speed in different ways. In order to understand these age

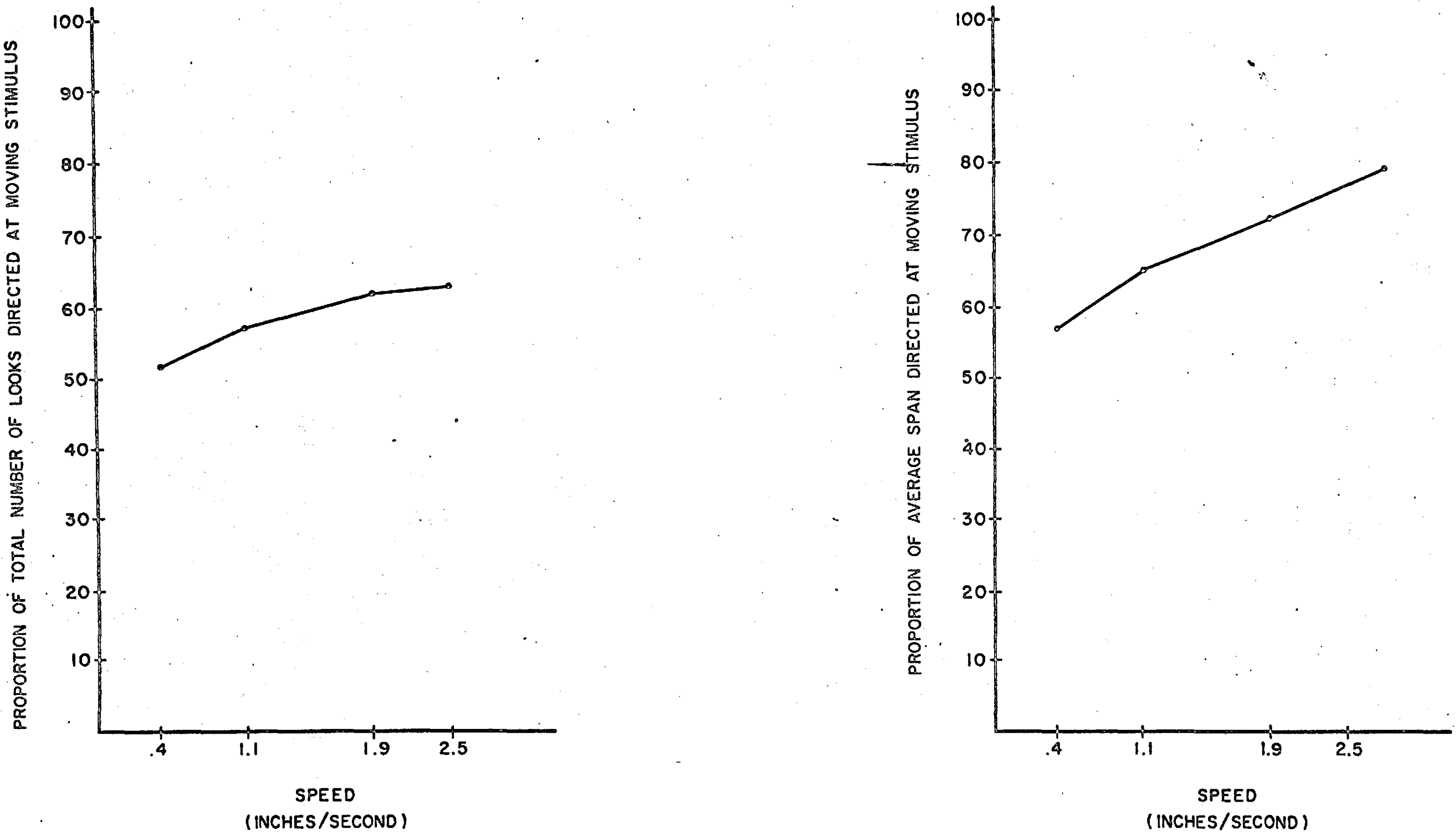

Fig. 24. The effect of speed on percent total number of looks and percent average span of looking time directed at the moving stimulus, averaged over all ages, levels of complexity, and subjects.

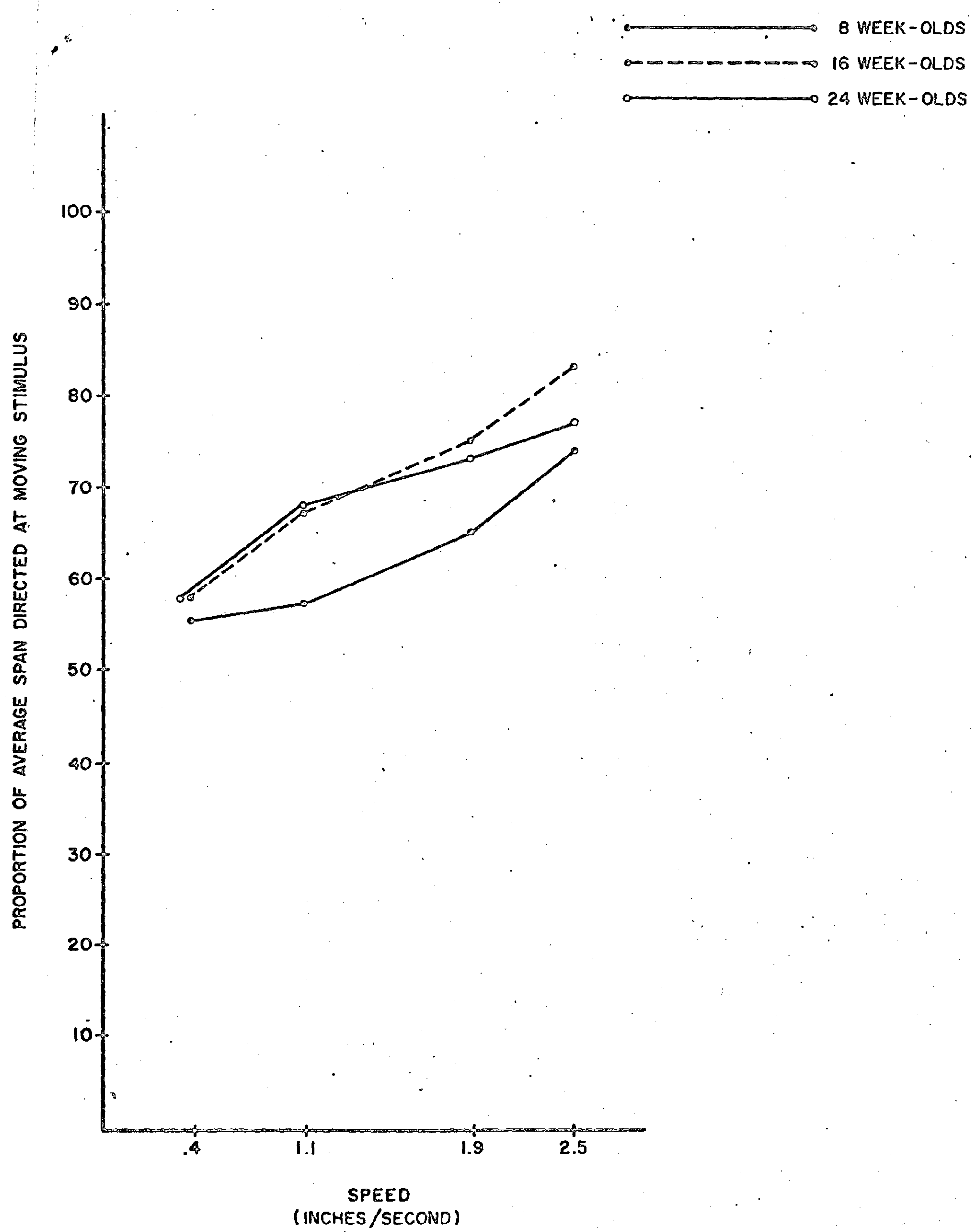

Fig. 25. The interaction effect of age and speed on the percent average span of looking time directed at the moving stimulus. Percent average span is averaged over subjects.

differences better, separate two-way analyses of variance were performed at each of the four speeds of movement (Table 30).

These analyses revealed significant age differences at each of the three fastest speeds, but not at the slowest speed. At the speed of 1.1 inches/second, the second slowest speed, Tukey comparisons revealed that the 16-week-olds and 24-week-olds are not significantly different from one another, but that they both direct a longer average span at the moving stimulus than the 8-week-olds (p's less than .01). At the next higher speed of 1.9 inches/second, similar comparisons were found, with 16-week-olds and 24-week-olds showing significantly longer spans than 8-week-olds (p's less than .01 and .05, respectively), but not being significantly different from each other. At the fastest speed of 2.5 inches/second, the 16-week-olds directed a significantly longer average span at the moving stimulus than the 8-week-olds (p's less than .01), but there were no significant differences between the average span of the 24-week-olds and either of the other two age groups.

Complexity x Speed

The interaction between complexity and speed failed to reach a significance level of $p = .05$ in either measure.

Age x Complexity x Speed

The interaction of age x complexity x speed is significant only in the measure involving percent total number of looks

Table 30

Summary Table of Two-way Analyses of Variance for Age and Complexity Effects in Percent Average Span within Each of Four Speeds of Movement

Source	SS	df	MS	F	P
		.4 INCHES/SECOND			
Age	.0091	2	.0046	-	
Complexity	.0484	3	.0161	1.83	
Age x Complexity	.0723	6	.0121	1.38	
Subjects within Groups	.7383	84	.0088		
Total	.8681	95			
		1.1 INCHES/SECOND			
Age	.2495	2	.1248	8.49	less than .001
Complexity	.0379	3	.0126	-	
Age x Complexity	.0343	6	.0057	-	
Subjects within Groups	1.2365	84	.0147		
Total	1.5582	95			

Table 38 (Cont'd)

Source	SS	df	MS	F	P
		1.9 INCHES/SECOND			
Age	.1792	2	.0896	6.01	less than .005
Complexity	.0443	3	.0148	-	
Age x Complexity	.1761	6	.0294	1.97	
Subjects within Groups	1.2501	84	.0149		
Total	1.6497	95			
		2.5 INCHES/SECOND			
Age	.1481	2	.0741	5.70	less than .005
Complexity	.0102	3	.0034	-	
Age x Complexity	.0353	6	.0059	-	
Subjects within Groups	1.0898	84	.0130		
Total	1.2834	95			

(see Figure 22). In order to find the source of this interaction, separate analyses of variance were performed on the age x speed interactions within each of the four levels of complexity (Table 31). These analyses show that the age groups' responses to speed differ from one another on Level 1 (p less than .05), on Level 2 (p less than .025), and on Level 3 (p less than .05), but are not significantly different on Level 4.

Analysis of linear trend (Table 32) reveals that the interaction at Level 3 can be attributed to differences between slopes of the best-fitting straight lines over speeds. Comparisons between the individual lines show that the slope of the 16-week-olds and the slope of the 24-week-olds are both significantly steeper than that of the 8-week-olds (both p's less than .025), but that they are not significantly different from one another. The slope for the 8-week-olds is Y = .01X + .51; the slope for the 16-week-olds is Y = .09X + .46; and the slope for the 24-week-olds is Y = .09X + .48.

Linear and quadratic trend analyses of Levels 1 and 2 failed to reveal any interpretable trends in the interactions of age x speed at these two levels.

Discussion

As was seen in the previous chapter, the analyses of responses to a moving stimulus indicate that looking behavior is characterized by different combinations of average span

Table 31

Summary Table of Two-way Analyses of Variance for Percent Total Number of Looks within Each of Four Levels of Complexity

Source	SS	df	MS	F	P
		COMPLEXITY LEVEL 1			
Between Subjects	1.0541	23			
Age	.0317	2	.0159	-	
Subjects within Groups	1.0224	21	.0487		
Within Subjects	1.0122	72			
Speed	.2143	3	.0714	6.87	less than .001
Age x Speed	.1405	6	.0234	2.25	less than .05
Speed x Subjects within Groups	.6574	63	.0104		

Table 31 (Cont'd)

Source	SS	df	MS	F	P
		COMPLEXITY LEVEL 2			
Between Subjects	.5851	23			
Age	.2463	2	.1232	7.65	less than .005
Subjects within Groups	.3388	21	.0161		
Within Subjects	.2097	72			
Speed	.1706	3	.0569	8.49	less than .001
Age x Speed	.1153	6	.0192	2.87	less than .025
Speed x Subjects within Groups	.4238	63	.0067		

Table 31 (Cont'd)

Source	SS	df	MS	F	P
		COMPLEXITY LEVEL 3			
Between Subjects	.6389	23			
Age	.1252	2	.0626	2.56	
Subjects within Groups	.5137	21	.0245		
Within Subjects	.6737	72			
Speed	.2387	3	.0796	14.21	less than .001
Age x Speed	.0843	6	.0141	2.52	less than .05
Speed x Subjects within Groups	.3507	63	.0056		

Table 31 (Cont'd)

Source	SS	df	MS	F	P
			COMPLEXITY LEVEL 4		
Between Subjects	.5486	23			
Age	.1584	2	.0792	4.26	less than .05
Subjects within Groups	.3902	21	.0186		
Within Subjects	.6131	72			
Speed	.2414	3	.0805	15.78	less than .001
Age x Speed	.0473	6	.0079	1.55	
Speed x Subjects within Groups	.3244	63	.0051		

Table 32

Analysis of Linear Trend Components Involving Speed Effect Within Complexity Level 3 for Percent Total Number of Looks at the Moving Stimulus

Source	SS	df	MS	F	P
Within Subjects (Linear)	.4816	24			
Speed (Linear)	.2328	1	.2328	28.39	Less than .001
Age x Speed (Linear)	.0774	2	.0387	4.72	Less than .025
Speed x Subjects within Groups (Linear)	.1714	21	.0082		

and number of looks at different stages of development. However, the analyses in Chapter 5 were concerned specifically with responses to the moving stimulus and, therefore, did not involve data from the non-moving stimulus. The possibility existed that the results obtained from average span and total number of looks might be reflecting some form of general arousal differences which would produce an increase in looking time at both the moving and the non-moving patterns. In the present chapter, both measures were converted to proportions in order to see whether the previous results were attributable to this sort of effect. In the discussion to follow, the results from percent average span and percent total number of looks will be compared with results from previous chapters, with particular emphasis on the analysis of percent looking time.

<u>Age</u>

Both percent average span and percent total number of looks yielded a significant effect of age. Both measures indicate that the older babies direct a larger proportion of the average span and number of looks toward the moving stimulus than do the younger babies.

It was noted in the previous chapter that the moving stimulus elicited a fewer number of longer looks from younger infants than from older infants. The results from the percent measures indicate that, even though the average span is decreasing overall with age, the older infant actually directs proportionately longer looks toward the moving stimulus than does the younger infant. In addition, as the overall number of looks increases with age, so does the proportionate number directed toward the moving stimulus.

These results support those in Chapter 4, where it was found that older babies spend less total time looking at the stimulus patterns than do younger babies, but when they do look at the stimulus patterns, they are much more likely than the younger babies to look at the moving one. In addition, we may now say that when the older babies look at the stimulus patterns, they are also more likely than the younger babies to take a greater number of longer looks toward the moving stimulus than toward the non-moving stimulus.

Speed

The percent average span and percent total number of looks both increase with faster speed of movement indicating that, as speed of movement increases, infants direct a larger number of longer looks at the moving stimulus than at the non-moving stimulus.

In the previous chapter, it was found that the average span of looking time increases with faster speed of movement. Since the percent average span also increases with faster speed, it may be concluded that the average span of looking time at the moving stimulus is not accompanied by an increase in average span of looking at the non-moving stimulus. In addition, results from the previous chapter indicated that the total number of looks toward the moving stimulus does not change with increased speed. Since the proportion of looks does increase with speed, it may be concluded that fewer looks are directed at the non-moving stimulus as the speed of the moving stimulus is increased.

The results from all three percent measures point to the fact that, within the speed range employed in this experiment, a moving stimulus will attract an increasing amount of visual attention away from a non-moving stimulus as the speed of movement is increased.

Complexity

Neither percent average span nor percent total number of looks showed a significant main effect of complexity. We must therefore conclude that the addition of more elements to the stimulus field does not produce any relative differences in the patterns of looking behavior between the moving and non-moving stimuli. This is consonant with the results on percent looking time in Chapter 4.

Age x Speed

The interaction between age and speed was significant only for percent average span of looking time. The presence of the interaction indicated that infants of different ages do not respond to increases in speed of movement in the same way.

In general, all three age groups show an increasing tendency to direct longer looks at the moving stimulus than at the non-moving stimulus. The interaction seems to result from basic differences in response patterns between the 8-week-olds and the two older age groups. While the two older age groups respond alike at each of the four speeds of movement, they show a greater increase in average span than do the 8-week-olds at the three fastest speeds. These results are identical to those found in Chapter 4 for percent looking time. Both of these response measures give indication that older babies are better able than younger babies to discriminate movement from non-movement at slower speeds. From these results, it is possible to conclude that both percent looking time and percent average span would be sensitive measures to use for the detection of gross age differences in infants' visual response to speed changes.

Age x Complexity

Neither of the percent measures shows significant age differences across levels of increasing complexity. This would indicate that there are no age differences in the relative number of looks or length of looks between the moving and non-moving stimuli with increases in complexity. This finding is consonant with that in Chapter 4 for percent looking time.

Complexity x Speed

The complexity x speed interaction was not significant in either percent average span or percent total number of looks. The previous analysis of percent looking time also failed to reveal significant interactions between complexity and speed.

Age x Complexity x Speed

The significance of the triple interaction in percent total number of looks is difficult to interpret. Since separate analyses of age x speed trends within each level of complexity also failed to reveal any consistent results, we must conclude that the source of this triple interaction in percentage measures is too abstruse to make any meaningful interpretation possible.

In general, it may be concluded that the analyses of percent average span and percent total number of looks have contributed additional information toward the understanding of age differences in patterns of looking. Percent average span appears to be sensitive to age differences in the response to increased speed, whereas percent number of looks does not. Both percent looking time and percent average span concur in showing that 16-week-old infants and 24-week-old infants respond more to increased movement than do the 8-week-old infants, and that the increased response occurs at slower speeds for older babies.

The analyses of these percent measures indicate that the increases in average span and total number of looks observed in the previous chapter are not merely due to a general increase in arousal, but can be attributed to the greater attention value of the moving stimulus.

Summary

Analyses of variance and trend analyses of the response measures of percent average span of looking time and percent total number of looks were performed. These analyses helped to expand on the results obtained from the two previous chapters.

With increasing age, both the percent average span and percent total number of looks increase, indicating that, as babies get older, they direct a larger number of longer looks toward the moving stimulus than toward the non-moving stimulus. The percent average span and percent total number of looks both increase with increased speed of movement indicating that, as speed increases, the moving stimulus attracts a greater number of longer looks than does the non-moving stimulus. Neither measure shows a significant effect of complexity.

As speed increases, there is a tendency for all three age groups to increase the comparative length and the comparative number of looks toward the moving stimulus. However, the percent average span appears to be the only measure sensitive to age differences in response to speed changes. As in Chapter 4, there is supportive evidence that older babies show greater

response to speed changes than do younger babies because they show a higher preference for the moving stimulus than for the non-moving stimulus, even at fairly slow speeds.

Since there was no main effect of complexity on either measure, it was concluded that complexity does not generally affect the comparative number or the comparative length of looks directed toward the moving rather than the non-moving stimulus. In addition, neither measure showed significant two-way interactions of complexity with age or with speed. A significant age x complexity x speed interaction was found in the percent total number of looks measure, but its exact meaning was impossible to interpret due to the absence of any significant two-way interactions or significant main effect of complexity.

It was concluded that the analysis of percent average span and percent number of looks have shown that results from the previous chapter can be attributed to the greater attention value of the moving stimulus, rather than some general increase in arousal.

CHAPTER 7

Summary and Conclusions

The research reported in this thesis was concerned with the systematic variation of the speed and complexity of stimulus fields in order to investigate developmental changes in visual fixation. It was hypothesized that speed of movement would influence the amount of visual fixation elicited from infants, with looking time increasing as the stimulus pattern moved faster, and that older infants would be more responsive to differences in speed of movement than younger infants.

It was also hypothesized that more complex stimuli would be looked at more than less complex stimuli, and that the complexity of the stimulus would influence the perception of movement, with movement being more easily detected in fields composed of a larger number of small elements than in fields composed of a small number of large elements.

It was further hypothesized that development is accompanied by changes in patterns of looking behavior, and that these changes could be detected by examining response measures other than that of total looking time.

Using a modified method of limits procedure, groups of infants at 8 weeks, 16 weeks, and 24 weeks of age were presented with a moving and a non-moving stimulus simultaneously. Each of four groups at each age level was presented with two moveable belts painted with checkerboard patterns of one of four levels of textural complexity. Within each group, belts were moved at four different speeds of movement. Fixation preferences were obtained by recording total fixation time at each of the stimulus patterns for each subject. Besides total looking time, the measures of percent looking time, average span of looking, total number of looks, percent average span, and percent total number of looks were also analyzed.

Age Differences in the Visual Fixation Response

Fixation preferences in the present experiment were determined through analysis of six different response measures of looking. Three were measures of the absolute amount of looking: total looking time, total number of looks, and average span of looking time. The other three were measures of the percentage of looking directed at the moving stimulus rather than the non-moving stimulus. The three percentage measures were: percent total looking time, percent number of looks, and percent average span.

Results Obtained from Absolute Measures

The results indicated that increased age produces a decrease in total looking time. This was attributed to greater susceptibility to distractions by extraneous stimulation in the older babies, causing them to engage in a variety of diversive activities which take away from the total time spent looking at the stimulus patterns. This finding is consonant with those of earlier studies (Silfen and Ames, 1964; Ames and Silfen, 1965; Stechler, 1965; and Karmel, 1966).

The hypothesized differences in patterns of fixation were also found. The results indicate that it is imperative to employ several different response measures when studying fixation in infants of different ages. Average span of looking time appears to be the most sensitive measure for the detection of response differences in 8-week-olds. For 24-week-olds, total number of looks is the most sensitive measure for picking up response differences. It would appear, therefore, that there is a developmental transition in the way in which infants pick up visual information from the environment, with long looks being the primary means for the young infants, and a large number of looks the primary means for older infants. The 16-week-old infants are apparently in a transition phase between the two, since their looking patterns are characterized by both a high average span and a large number of looks. These two characteristics of looking behavior combine together to give the 16-week-olds a higher total looking time than either of the other two age groups. If total looking time had been the only measure employed, it would have been concluded that 16-week-olds were more sensitive to stimulus differences than the other two age groups, which was not true. If one examines average span and total number of looks for this age group, it becomes apparent that both means are utilized in response to movement and complexity, with this group responding to speed primarily through increasing span and to complexity through an increase in the total number of looks.

The above findings suggest that age differences in response patterns should be kept in mind in future experimentation using the fixation method, and that care should be taken in finding response measures most appropriate to the age range being investigated. Even if this is done, however, the problems of making age comparisons are not solved. There is no one visual fixation measure involving absolute amount of looking that can be applied across the age range used in the present research, and this means that several comparisons one would like to make are impossible. With age differences in total amount of looking and in patterns by which this total is reached, one is not justified in saying that one age group is "more responsive" or "less responsive" to a particular stimulus than is another age group. The age differences found in the present research are confined to those in patterns of looking. Once these age differences are established, it becomes impossible to compare groups in the <u>amount</u> of their response to speed or complexity.

Results Obtained from Percentage Measures

The problems encountered in making age comparisons using absolute measures are somewhat remedied when one utilizes percentage measures instead. All three measures employed in the present research revealed a higher percentage of looking at the moving stimulus at 16 weeks and 24 weeks of age than at 8 weeks of age. In all three measures, the 16-week-olds and 24-week-olds were not significantly different from one another, but both directed a significantly higher proportion of their looking toward the moving stimulus than did the 8-week-olds. Therefore, the previously mentioned reduction in total looking time in older babies does not reflect a lack of interest in the moving stimulus. Even though the total time is decreasing overall, the older infant is actually spending a larger proportion of the total time looking at the moving stimulus than is the younger infant, and he does so through a proportionately larger number of longer looks. These results suggest that, while perhaps not being sensitive to small age differences in response, percentage measures are much more reliable than absolute measures in making comparisons across this age range. Percentage measures do allow us to make gross comparisons between age groups in terms of amount of response.

Infants' Visual Fixation Responses to Speed and Complexity

It was hypothesized that 1) the faster a stimulus moves, the more fixation it elicits from infants, and that 2) the older the infant, the more responsive he is to differences in speed. The first hypothesis is upheld by the data. The overall effect of speed in eliciting looking behavior is pronounced in total looking time, percent looking time, average span, percent average span, and percent total number of looks. Within the speed range employed, infants of all three age groups perceive and respond to movement, looking more at the moving stimulus than at the non-moving stimulus as the speed of movement is increased. This result supports the earlier findings of Ames and Silfen (1965).

For the reasons outlined above, there appears to be no way to test the second hypothesis meaningfully through the use of absolute response measures. However, through an examination of percent looking time and percent average span, there is evidence that 16-week-olds and 24-week-olds are more responsive to differences in speed than are 8-week-olds. In both response measures, all three age groups show an increase in response to faster movement. While the 16-week-olds and 24-week-olds respond alike at each of the four speeds of movement, they look significantly more than do the 8-week-olds at the three fastest speeds of movement in both response measures. This would seem to indicate that older babies are better able than younger babies to discriminate movement from non-movement at slower speeds.

It was further hypothesized that, within the age range and the range of complexity used, more complex stimuli would elicit the most looking. This hypothesis was upheld. For control trials with non-moving stimuli and experimental trials with moving stimuli, total looking time increased as the complexity of the stimulus increased. All three percent measures indicated that this increase was comparable for both moving and non-moving stimuli, when both were presented simultaneously. This was true over all age groups, even though the increase in total looking time was accomplished by the different characteristic patterns of looking for each age. The hypothesis that more complex stimuli elicit the most looking was predicated on the belief that the checkerboard stimuli used in the present research were below the "pacer levels" of the infants used. The results obtained presumably might not be found if younger infants or more complex stimuli were used. In these cases it would be hypothesized that when infants were presented with stimuli more complex than the infants' complexity level, looking time would decrease with higher levels of complexity.

The final hypothesis regarding speed and complexity was: the more complex the moving stimulus, the more responsive infants are to its speed. There is some support for this hypothesis in the data obtained from absolute measures, but it is also entangled in the age differences in patterns of looking. When looking at the data for the moving stimulus alone, in each age group a steeper slope of response as speed increases is obtained at high levels of complexity than at low levels of complexity. For the 8-week-olds, this steeper slope is found in average span; for the two older groups it is found in number of looks. However, these results must be qualified somewhat. Since there was no clear interaction of complexity with speed or age in any of the percentage measures, it does not appear that change in the complexity of the checkerboard strongly affects the ease with which its movement is discriminated. The percent results indicate that the changes observed in response to the moving stimulus at higher levels of complexity are also in effect for the non-moving stimulus, and that there is no difference in the response to the moving stimulus as compared to the non-moving stimulus.

In conclusion, it is asserted that evidence has been obtained to show that infants do respond to both movement and complexity. It appears, then, that the ability to respond to these two stimulus dimensions is available to be employed by the infant in the perception of depth, as maintained by Walk and Gibson (1961) and in the development of social responsiveness, as suggested by Rheingold (1961) and Walters and Parke (1965). While no results were obtained in the present research that would disagree with Dember and Earl's "pacer" theory (1957), further experimentation with a wider range of ages and complexities needs to be undertaken before the theory's implications for infant visual responses can be tested fully.

Methodological Considerations for Future Research

In view of the large number of infants that had to be discarded because of failure to complete the experimental series, it is suggested that the experimental procedure could be improved. The supine position of the infant was not very satisfactory. The 24-week-old infants tended to become restless and disturbed when forced to lie on their backs over a period of time. It is suggested that, when working with infants over a fairly wide age range, it would be more advantageous to have the infant sit up in a tilted chair, and to present the stimuli in the vertical plane. Several infant experiments reported in the literature since the present study was begun have used this modification with satisfactory results.

In the present study, stimulus patterns were presented according to a modified method of limits. In this method, even though the moving stimulus was presented twice on each side for each speed setting, it occurred on the same side for several successive trials. This leads to the possibility that an acquired positional response set might have influenced the preference for the moving stimulus, particularly when movement occurred on one side for eight consecutive trials. Watson (1965) mentions that infants may acquire such response sets when they are visually reinforced in the same position for more than 15 seconds. In the case of the present study, this possibility was assessed by comparing responses during trials occurring after position changes with comparable trials occurring after a sequence of presentations on the same side. Trial 6 was compared with trial 4, trial 15 with trial 13, and trial 1 with trial 9 (see Table 1). These comparisons were made on percent looking time at complexity Level 3, using samples of 8-week-olds (N = 12), 16-week-olds (N = 13) and 24-week-olds (N = 9). There were no significant differences found in any of these comparisons and it was concluded that positional response set was not influencing the results in the present case. However, it is suggested that complete randomization of stimulus presentation would be a better procedure to use in future studies on visual fixation.

Under the conditions of the present experiment, it was not possible to tell whether the infants were responding to movement with fixation or pursuit, or with central or peripheral vision, factors which have been shown in adults to cause a difference in the phenomenal velocity. Salapatek and Kessen (1966) have demonstrated, through the use of infrared photographic techniques, that form reduces the tendency for the baby's eyes to wander, particularly when scanning in the vertical dimension. Since movement occurred in a form-filled field, and was oriented in the vertical direction, it is quite possible that infants were fixating on some portion of the visual field, and not responding to the field as a whole. The application of photography to the present study would have been useful in determining if this was the case. Such techniques add greatly to the fuller understanding of patterns of looking behavior in infants and, when financially possible, should be employed.

General Discussion

One of the major problems confronting any research worker is to relate the findings of his study to the existing body of empirical data, as well as to current theoretical issues. This becomes a difficult task when, as in the case of the present thesis, the study represents an attempt to investigate an area of research which is virtually unexplored. At best, a study of this nature can provide only preliminary information about specific perceptual capacities of the young infant. Hopefully, it will also furnish guidelines in methodology which might help to ease the path of other researchers interested in pursuing the problem further.

In Chapter 2, it was noted that the bulk of the literature related to movement perception and complexity was concerned with studies on adults. This was particularly true in the case of movement perception where, in addition, the studies were concerned primarily with the measurement of different types of movement thresholds and the critical variables that affect those thresholds. Since the literature contains only one study on movement thresholds using children as subjects (Carpenter and Carpenter, 1958), it would be presumptuous to draw generalized conclusions as to the exact nature of the developmental trend in the perception of real movement. This is particularly true when one approaches the infant end of the developmental continuum, where studies involved with the measurement of thresholds are virtually non-existent. Due to methodological limitations, the results of the present study cannot be considered as yielding measures of threshold sensitivities. Nevertheless, the study does provide some evidence that there is an age progression in the response to speed of movement, with older babies responding to a wider range of speeds than younger babies. It would appear also that the older babies are better able to discriminate slower speeds of movement. These findings are in keeping with the results from Carpenter and Carpenter's study (1958), where it was demonstrated that the threshold of movement perception was higher for children than adults.

The empirical data from infants and children is presently too sparse to relate the findings of this thesis to any meaningful discussion of the theoretical issues arising from adult studies. However, this does not dismiss the possibility that the same variables that affect adults' perception of real movement are also effective in infants' perception. These variables include, among others, the size and structure of the visual field, the direction of movement, illumination, exposure time, the use of central vs. peripheral vision, and fixation and pursuit. It is considered prudent to control for these variables until their exact role in infants' perception of movement is understood. If anything, the paucity of such information points to fruitful areas for future research.

Since the literature on infants' responses to complexity is considerably more extensive than that on movement perception, there is more opportunity to relate the results of the present study to it. One of the major theoretical problems in the discussion of stimulus complexity lies in its definition. As pointed out in the historical review in Chapter 2, the only results that can be generalized are from studies that have used explicit definitions of complexity based on contour, or number of parts. The results from this study, as well as from other studies on infants using similar definitions of complexity, give some supportive evidence for Dember and Earl's "pacer" theory (1957). Since it was believed, on the basis of work by Brennan, Ames, and Moore (1966), that the stimuli used in the present research were below the "pacer" levels of the infants used, it was hypothesized that more complex stimuli would elicit more looking from the infants. This hypothesis was supported for both the moving and non-moving stimuli.

It is acknowledged, however, that an extensive test of Dember and Earl's theory would have to utilize younger infants and more complex stimuli, in order to span a broad age range and complexity continuum. In this way, it would be possible to determine whether age differences in visual attention are a function of stimulus complexity, whether the maximum level of attention shifts to higher levels of complexity with increasing age, and whether the level of attention drops off, once the "pacer" level has been surpassed.

One of the major problems confronting developmental psychologists is finding response measures that will enable one to make meaningful age comparisons of the perceptual capacities of infants and children. This becomes particularly important when one wishes to establish age norms with which the development of individual children can be compared. The major contribution of this thesis has been in demonstrating the importance of using response measures which are appropriate to the age range being investigated. Some studies in the current literature have failed to take into account these changes in the visual fixation response and, as a result, have made questionable age comparisons. It is suggested that, with the aid of modern technological advances, it is desirable to study different aspects of the visual fixation response over a large age range. Perhaps from studies such as these, it will be possible to derive a measure, or set of measures, that will reflect a response continuum that is truly sensitive to developmental change, and which can be used to make meaningful age comparisons in the response to visual stimulation.

BIBLIOGRAPHY

Abelson, R. P., & Tukey, J. W. Efficient utilization of non-numerical information in quantitative analysis: General theory and the case of simple order. *Ann. Math. Statist.*, 1963, *34*, 1347-1369.

Ahrens, R. Beitrag zur Entwicklung des Physiognomie und Mimikerkennens. *Z. f. exp. u. angew. Psychol.*, 1954, *2*, 599-633. (a)

Ahrens, R. Das Verhalten des Säuglings in der Zeit zwischen erstem und siebentem Monat. *Z. f. exp. u. angew. Psychol.*, 1954, *2*, 412-454. (b)

Ambrose, J. A. The development of the smiling response in early infancy. In B. M. Foss (Ed.), *Determinants of infant behavior*. New York: Wiley, 1961, Pp. 179-196.

Ames, Elinor W., & Silfen, Carole K. Methodological issues in the study of age differences in infants' attention to stimuli varying in movement and complexity. Paper read at biennial meeting of the Soc. for Res. in Child Develpm., Minneapolis, March, 1965.

Attneave, F. Symmetry, information, and memory for patterns. *Am. J. Psychol.*, 1955, *68*, 209-222.

Attneave, F. Physical determinants of the judged complexity of shapes. *J. exp. Psychol.*, 1957, *53*, 221-227.

Beasley, W. C. Visual pursuit in 109 white and 142 negro newborn infants. *Child Develpm.*, 1933, *4*, 106-120.

Berlyne, D. E. The influence of complexity and novelty in visual figures on orienting responses. *J. exp. Psychol.*, 1958, *55*, 289-296. (a)

Berlyne, D. E. The influence of the albedo and complexity of stimuli on visual fixation in the human infant. *Br. J. Psychol.*, 1958, *49*, 315-318. (b)

Berlyne, D. E. *Conflict, arousal, and curiosity*. New York: McGraw-Hill, 1960.

Brennan, Wendy M. Age differences in infants' attention to stimuli varying in complexity. Unpublished master's thesis, University of British Columbia, 1965.

Brennan, Wendy M., Ames, Elinor W., & Moore, R. W. Age differences in infants' attention to patterns of different complexities. Science, 1966, 151, 354-356.

Brown, J. F. The thresholds for visual movement. Psychol. Forsch., 1931, 14, 249-268. (a)

Brown, J. F. The visual perception of velocity. Psychol. Forsch., 1931, 14, 199-232. (b)

Brown, R. H. Some methodological considerations in measuring visual thresholds of velocity. Percept. mot. Skills, 1960, 11, 111-122.

Brown, R. H. Visual sensitivity to differences in velocity. Psychol. Bull., 1961, 58, 89-103.

Brown, R. H. & Conklin, J. E. The lower threshold of visible movement as a function of exposure time. Am. J. Psychol., 1954, 67, 104-110.

Cantor, G. N. Responses of infants and children to complex and novel stimulation. In L. P. Lipsitt & C. C. Spiker (Eds.), Advances in child development and behavior, Vol. 1, New York: Academic Press, 1963. Pp. 1 - 30.

Carpenter, B. & Carpenter, Janeth T., The perception of movement by young chimpanzees and human children. J. comp. physiol. Psychol., 1958, 51, 782-784.

Chase, W. P. Color vision in infants. J. exp. Psychol., 1937, 20, 203-222.

Cohen, L. B. Observing responses, visual preferences, and habituation to visual stimuli in infants. Unpublished doctoral dissertation, Univ. of California, Los Angeles, 1965.

Crook, M. N. Visual discrimination of movement. J. Psychol., 1937, 3, 541-558.

Dayton, G. O., Jr., & Jones, Margaret H. Analysis of characteristics of fixation reflex in infants by use of direct current electro-oculography. Neurology, 1964, 14, 1152-1156.

Dayton, G. O., Jr., Jones, Margaret H., Aiu, P., Rawson, R. A., Steele, B., & Rose, M. Developmental study of coordinated eye movements in the human infant: I. Visual acuity in the newborn human: a study based on induced optokinetic nystagmus recorded by electro-oculography. Arch. Opthal., 1964, 71, 865-870.

Dayton, G. O., Jr., Jones, Margaret H., Steele, B. & Rose, M. Developmental study of coordinated eye movements in the human infant: II. An electro-oculographic study of the fixation reflex in the newborn. Arch. Opthal., 1964, 71, 871-875.

DeSilva, H. R. An analysis of the visual perception of movement. Brit. J. Psychol., 1929, 19, 268-305.

Deese, J. Complexity of contour in the recognition of visual form. USAF WADC Tech. Rep., 1956, no. 56-60.

Dember, W. N. & Earl, R. W. Analysis of exploratory, manipulatory, and curiosity behaviors. Psychol. Rev., 1957, 64, 91-96.

Fantz, R. L. Pattern vision in young infants. Psychol. Rec., 1958, 8, 43-47.

Fantz, R. L. The origin of form perception. Sci. Am., 1961, 204, no. 5, 66-72.

Fantz, R. L. Pattern vision in newborn infants. Science, 1963, 140, 296-297.

Fantz, R. L. Visual experience in infants: decreased attention to familiar patterns relative to novel ones. Science, 1964, 146, 668-670.

Fantz, R. L. & Ordy, J. M. A visual acuity test for infants under six months of age. Psychol. Rec., 1959, 9, 159-164.

Fantz, R. L., Ordy, J. M. & Udelf, M. S. Maturation of pattern vision in infants during the first six months. J. comp. physiol. Psychol., 1962, 55, 907-917.

Fehrer, E. V. An investigation of the learning of visually perceived forms. Am. J. Psychol., 1935, 47, 187-221.

Fiske, D. W. & Maddi, S. (Eds.), Functions of varied experience. Homewood, Ill.: Dorsey Press, 1961.

French, R. S. Identification of dot patterns from memory as a function of complexity. J. exp. Psychol., 1954, 47, 22-31.

Fröbes, J. Lehrbuch der experimentellen Psychologie. 1923, 1, 395-413.

Gibson, Eleanor & Olum, Vivian. Experimental methods of studying perception in children. In P. H. Mussen (Ed.), Handbook of research methods in child development. New York: Wiley, 1960. Pp. 311-373.

Gibson, J. J., Smith, O. W., Steinschneider, A., & Johnson, C. W. The relative accuracy of visual perception of motion during fixation and pursuit. Am. J. Psychol., 1957, 70, 64-68.

Gordon, D. A. The relation between the thresholds of form, motion and displacement in parafoveal and peripheral vision at a scotopic level of illumination. Am. J. Psychol., 1947, 60, 202-225.

Gorman, J. J., Cogan, D. G., & Gellis, S. S. A device for testing visual acuity in infants. Sight Saving Rev., 1959, 28, 80-84.

Graham, C. H. On some aspects of real and apparent visual movement. J. Opt. Soc. Am., 1963, 53, 1019-1025.

Gottsdanker, R. M. The ability of human operators to detect acceleration of target motion. Psychol. Bull., 1956, 53, 477-487.

Haith, M. M. The response of the human newborn to visual movement. J. exp. Child Psychol., 1966, 3, 235-243.

Haynes, H., White, B. L., & Held, R. Visual accommodation in human infants. Science, 1965, 148, 528-530.

Hershenson, M. Visual discrimination in the human newborn. J. comp. physiol. Psychol., 1964, 58, 270-276.

Hershenson, M., Munsinger, H. & Kessen, W. Preference for shapes of intermediate variability in the human newborn. Science, 1965, 147, 630-631.

Hick, W. E. The threshold for sudden changes in the velocity of a seen object. Quart. J. exp. Psychol., 1950, 2, 33-41.

Hick, W. E. & Bates, J. A. V. The human operator of control mechanisms. London: Ministry of Supply, 1950.

Hunt, J. McV. *Intelligence and experience.* New York: Ronald Press, 1961.

Jones, Mary C. The development of early behavior patterns in young children. *J. genet. Psychol.*, 1926, *33*, 537-585.

Kagan, J. & Lewis, M. Studies of attention in the human infant. *Merrill-Palmer Quarterly*. 1965, *11*, 95-127.

Karmel, B. Z. The effect of complexity, amount of contour, element size, and element arrangement on visual preference behavior in the hooded rat, domestic chick, and human infant. Unpublished doctoral dissertation, The George Washington University, 1966.

Kennedy, J. L. The nature and physiological basis of visual movement discrimination in animals. *Psychol. Rev.*, 1936, *43*, 494-521.

Korte, A. Kinematoskopische Untersuchungen. *Z. Psychol.*, 1915, *72*, 193-296.

Lewis, M., Kagan, J., Campbell, Helen, & Kalafat, J. The cardiac response as a correlate of attention in infants. *Child Develpm.*, 1966, *37*, 63-72.

Lewis, M., Meyers, W. J., & Kagan, J. Attention to visual patterns in infants. Paper read at meeting of the Am. Psychol. Assn., August, 1963.

Ling, Bing Chung. A genetic study of sustained visual fixation and associated behavior in the human infant, from birth to six months. *J. genet. Psychol.*, 1942, *61*, 227-277.

McGinnis, J. M. Eye-movements and optic nystagmus in early infancy. *Genet. Psychol. Monog.*, 1930, *8*, 321-430.

Mandriota, F. J., Mintz, D. E. & Notterman, J. M. Visual velocity discrimination: effects of spatial and temporal cues. *Science*, 1962, *138*, 437-438.

Mashhour, Madjid. *Psychophysical relations in the perception of velocity*. Stockholm: Almqvist & Wiksell, 1964.

Meyer, J. L. *Fundamentals of experimental design*. Boston: Allyn and Bacon, 1966.

Meyers, W. J., & Cantor, G. N. Infants' observing and heart period responses as related to novelty of visual stimuli. *Psychon. Sci.*, 1966, *5*, 239-240.

Moffett, Adrienne M. Stimulus complexity as a determinant of visual attention in infants. Unpublished master's thesis, McMaster University, 1963.

Morgan, Barbara. Infant visual fixation of motion pictures of the human face. Unpublished master's thesis, Brown University, 1965.

Rheingold, Harriet L. The effect of environmental stimulation upon social and exploratory behavior in the human infant. In B. M. Foss (Ed.) Determinants of infant behavior. New York: Wiley, 1961. Pp. 143-171.

Ryan, T. A. Multiple comparisons in psychological research. Psychol. Bull., 1959, 56, 26-47.

Saayman, G., Ames, Elinor W. & Moffett, Adrienne. Response to novelty as an indicator of visual discrimination in the human infant. J. exp. Child Psychol., 1964, 1, 189-198.

Salapatek, P. & Kessen W. Visual scanning of triangles by the human newborn. J. exp. Psychol., 1966, 3, 155-167.

Schwarting, B. H. Testing infants' vision. Am. J. Opthal., 1954, 38, 714-715.

Silfen, Carole K., & Ames, Elinor W. Visual movement preference in the human infant. Paper read at East. Psychol. Assn., Philadelphia, April, 1964.

Smith, O. W. & Sherlock, Louise. A new explanation of the velocity-transposition phenomenon. Am. J. Psychol., 1957, 70, 102-105.

Spears, W. C. Assessment of visual preference and discrimination in the four-month-old infant. J. comp. physiol. Psychol., 1964, 57, 381-386.

Spitz, R. A. The smiling response: a contribution to the ontogenesis of social relations. Genet. Psychol. Monogr., 1946, 34, 57-125.

Staples, Ruth. The response of infants to color. J. exp. Psychol., 1932, 15, 119-142.

Stechler, G. Newborn attention as affected by medication during labor. Science, 1964, 144, no. 3616, 315-317.

Stechler, G. Attention and arousal in the infant. Paper read at biennial meeting of Soc. for Res. in Child Develpm., Minneapolis, March, 1965.

Thomas, H. Visual-fixation responses of infants to stimuli of varying complexity. Child Develpm., 1965, 36, 629-638.

Walk, R. D. & Dodge, Sue H. Visual depth perception of a 10-month-old monocular human infant. Science, 1962, 137, 529-530.

Walk, R. D., & Gibson, Eleanor J. A comparative and analytical study of visual depth perception. Psychol. Monogr., 1961, 75, no. 519.

Walker, E. L. Psychological complexity as a basis for a theory of motivation and choice. In D. Levine (Ed.), Nebraska symposium on motivation. Lincoln: Univ. of Nebraska Press, 1964.

Wallach, H. On constancy of visual speed. Psychol. Rev., 1939, 46, 541-552.

Walters, R. H., & Parke, R. D. The role of the distance receptors in the development of social responsiveness. In Lipsett, L. P., & Spiker, C. C. (Eds.), Advances in child development and behavior. Vol. 2. New York: Academic Press, 1965. Pp. 59 - 96.

Watson, J. S. Evidence of discriminative operant learning within thirty seconds by infants 7 to 26 weeks of age. Paper presented at biennial meeting of Soc. for Res. in Child Develpm., Minneapolis, March, 1965.

Wertheimer, M. Experimentelle Studien über das Sehen von Bewegung. Z. Psychol., 1912, 61, 161-265. English translation in T. Shipley (Ed.), Classics in psychology. New York: Philosophical Library, 1961. Pp. 1032-1089.

White, B. L. Plasticity in perceptual development during the first six months of life. Paper read to Am. Assoc. for the Adv. of Sci., Cleveland, December, 1963.

Whiteside, T. C. D. Visual perception of movement. Ann. Roy. Coll. Surg. Engl., 1963, 33, 267-281.

Winer, B. J. Statistical principles in experimental design. New York: McGraw-Hill, 1962.

Wolff, P. H. Observations on the early development of smiling. In B. M. Foss (Ed.), Determinants of infant behavior. II. New York: Wiley, 1963, Pp. 113-134.

Wolff, P. H., & White, B. L. Visual pursuit and attention in young infants. *J. Am. Acad. of Child Psychiat.*, 1965, 4, 473-484.

APPENDIX

RAW DATA

SOUND CONTROL

Data for sound control. Numbers represent total time, in seconds, spent looking at stimulus pattern on the side where motor sound was located. Subjects were eleven 16 week-old infants looking at Level 3 of Complexity.

Speed of Motor

Subjects	SS	S	F	FF
97	23.70	25.05	26.25	33.70
98	26.50	19.70	23.75	30.65
99	10.60	4.35	13.45	3.40
100	18.15	14.40	10.60	25.60
101	31.25	33.80	44.40	23.70
102	22.50	26.85	25.60	16.85
103	26.30	25.60	26.25	25.65
104	24.35	31.25	23.75	37.45
105	10.60	16.90	17.75	8.10
106	26.80	27.80	39.65	31.25
107	23.75	21.20	21.25	31.90

STATIONARY TRIALS

Total time in seconds spent looking at both stimulus patterns, over four levels of complexity, when both stimuli were stationary. Numbers represent total taken over two trials for each subject in 8 week-old groups.

Degree of Complexity

Level 1	Level 2	Level 3	Level 4
36.85	46.25	19.35	50.00
17.40	41.90	43.70	41.25
25.65	46.20	39.95	55.60
40.65	26.25	55.60	49.35
16.55	41.30	47.50	36.85
47.45	51.25	32.55	44.95
15.60	49.40	59.40	53.10
36.90	54.35	50.00	51.85

STATIONARY TRIALS

Total time in seconds spent looking at both stimulus patterns, over four levels of complexity, when both stimuli were stationary. Numbers represent total taken over two trials for each subject in 16 week-old groups.

Degree of Complexity

Level 1	Level 2	Level 3	Level 4
26.90	31.30	48.10	33.20
32.50	34.65	23.15	25.30
19.95	37.50	48.10	28.15
13.70	36.25	26.90	40.05
10.00	6.20	48.15	11.25
33.40	39.40	45.90	41.90
6.25	44.70	45.00	34.40
14.40	43.45	24.35	20.55

STATIONARY TRIALS

Total time in seconds spent looking at both stimulus patterns, over four levels of complexity, when both stimuli were stationary. Numbers represent total taken over two trials for each subject in 24 week-old groups.

Degree of Complexity

Level 1	Level 2	Level 3	Level 4
18.10	18.15	41.85	14.30
.60	11.85	22.10	18.80
20.00	18.40	44.40	18.75
25.00	15.05	31.30	20.60
10.00	21.90	5.00	25.00
33.80	16.85	17.50	9.35
6.85	18.80	6.25	31.85
11.85	17.55	9.95	26.20

COMPLEXITY LEVEL 1

8-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
1	.47	.71	.70	.79
2	.54	.54	.61	.80
3	.49	.69	.80	.99
4	.52	.41	.54	.75
5	.35	.51	.79	.75
6	.68	.70	.88	.84
7	.46	.40	.61	.93
8	.61	.54	.56	.71

COMPLEXITY LEVEL 1

16-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

	Speed			
Subject	SS	S	F	FF
9	.64	.69	.70	.63
10	.40	.67	.44	.53
11	.53	.87	.96	.89
12	.98	.75	.93	.99
13	.52	.88	.77	.51
14	.53	.70	.74	.95
15	.32	.75	.81	.84
16	.71	.82	.85	.77

COMPLEXITY LEVEL 1

24-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
17	.42	.76	.99	.97
18	.24	.26	.75	.74
19	.56	.67	.60	.68
20	.64	.86	.88	.91
21	.87	.72	.90	.97
22	.71	.74	.92	.85
23	.64	.25	.46	.49
24	.64	.87	.92	.96

COMPLEXITY LEVEL 2

8-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
25	.47	.53	.80	.91
26	.74	.73	.75	.95
27	.54	.47	.63	.67
28	.52	.55	.51	.63
29	.61	.66	.67	.88
30	.51	.63	.50	.60
31	.49	.50	.50	.50
32	.56	.59	.74	.79

COMPLEXITY LEVEL 2

16-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
33	.51	.83	.78	.77
34	.53	.62	.96	.97
35	.50	.62	.94	.96
36	.55	.73	.90	.87
37	.39	.88	.90	.89
38	.66	.83	.95	.93
39	.60	.76	.91	.88
40	.57	.76	.94	.82

COMPLEXITY LEVEL 2

24-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
41	.73	.86	.83	.86
42	.47	.75	.84	.79
43	.46	.68	.72	.69
44	.76	.91	.82	.87
45	.51	.85	.87	.93
46	.53	.77	.63	.67
47	.82	.89	.96	.94
48	.97	.88	.81	.96

COMPLEXITY LEVEL 3

8-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
49	.57	.86	.90	.97
50	.53	.49	.68	.91
51	.72	.73	.64	.81
52	.64	.75	.72	.56
53	.44	.44	.55	.73
54	.62	.51	.33	.61
55	.50	.50	.50	.50
56	.40	.50	.50	.50

COMPLEXITY LEVEL 3

16-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
57	.38	.53	.89	.85
58	.58	.61	.87	.91
59	.68	.81	.81	.95
60	.48	.58	.80	.87
61	.51	.64	.90	.99
62	.68	.87	.97	.98
63	.51	.72	.81	.90
64	.55	.81	.87	.93

COMPLEXITY LEVEL 3

24-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

	Speed			
Subject	SS	S	F	FF
65	.62	.71	.78	.81
66	.51	.64	.92	.90
67	.60	.84	.68	.94
68	.57	.50	.67	.63
69	.56	.73	.81	.78
70	.61	.80	.85	.89
71	.60	.91	.95	.96
72	.35	.84	.80	.83

COMPLEXITY LEVEL 4

8-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

	Speed			
Subject	SS	S	F	FF
73	.68	.68	.86	.92
74	.60	.40	.85	.97
75	.50	.65	.79	.89
76	.49	.58	.55	.75
77	.57	.88	.93	.87
78	.56	.58	.42	.55
79	.40	.57	.75	.73
80	.56	.56	.93	.88

COMPLEXITY LEVEL 4

16-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
81	.44	.76	.95	.89
82	.60	.77	.91	.94
83	.70	.72	.81	.94
84	.49	.60	.75	.87
85	.51	.77	.84	.98
86	.57	.40	.37	.82
87	.41	.60	.79	.86
88	.41	.62	.85	.85

COMPLEXITY LEVEL 4

24-WEEK-OLD INFANTS

The percent of total looking time that was spent looking at the moving stimulus pattern, as compared to the non-moving stimulus pattern. The numbers represent the percent looking time, totalled over four 30-second trials.

Speed

Subject	SS	S	F	FF
89	.60	.66	.95	.88
90	.74	.81	.73	.86
91	.39	.81	.96	.98
92	.61	.56	.63	.79
93	.40	.54	.59	.66
94	.52	.65	.92	.81
95	.62	.80	.91	.92
96	.78	.85	.94	.95

COMPLEXITY LEVEL 1

8-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
1	37.50	56.20	40.00	58.10	40.60	18.10	18.75	14.95
2	32.45	45.00	55.00	75.60	38.75	32.45	36.20	14.40
3	38.80	58.75	71.85	104.40	18.75	18.75	14.40	1.85
4	49.40	36.25	35.65	78.75	43.75	48.70	36.90	25.00
5	16.25	30.60	62.50	62.50	17.80	14.70	12.50	2.50
6	59.95	64.35	73.10	81.85	22.50	28.45	6.90	14.40
7	33.40	24.00	48.10	76.25	36.30	34.95	30.00	4.95
8	39.35	50.00	43.10	57.50	26.20	40.00	29.35	23.75

COMPLEXITY LEVEL 1

16-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
9	33.75	39.35	28.80	34.95	17.55	13.70	6.55	16.20
10	37.50	40.60	26.25	50.65	48.75	33.20	36.25	14.35
11	25.65	47.45	54.35	81.20	15.00	8.10	3.10	7.80
12	38.15	33.75	34.40	83.80	.30	1.85	.90	.30
13	25.60	37.50	46.85	39.35	14.95	3.15	8.15	12.45
14	40.65	63.75	67.55	90.05	31.90	22.80	25.65	4.40
15	3.10	31.25	41.25	45.00	20.00	8.10	9.40	6.25
16	38.20	63.75	71.85	56.90	7.80	12.45	11.30	16.30

COMPLEXITY LEVEL 1

24-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
17	28.45	29.95	82.50	50.05	28.10	11.90	.60	3.70
18	3.70	5.60	3.40	46.90	10.60	19.05	.60	.90
19	19.40	31.85	46.85	48.75	21.25	15.00	27.55	20.65
20	38.75	70.65	67.50	64.40	16.25	8.20	6.90	5.90
21	35.65	32.50	53.75	59.35	2.45	8.10	4.35	1.20
22	48.05	55.65	70.00	62.50	16.25	21.85	6.85	11.30
23	30.00	5.00	12.45	27.50	9.40	9.40	9.35	6.90
24	34.40	57.55	62.50	65.05	16.25	6.85	6.90	3.10

COMPLEXITY LEVEL 2

8-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
25	38.40	47.50	80.65	90.60	41.20	23.17	11.85	8.75
26	35.60	43.70	58.10	87.80	27.50	26.85	12.20	4.95
27	51.85	45.65	64.35	72.50	39.95	54.35	38.10	34.05
28	40.05	36.25	49.35	52.80	36.25	19.30	9.40	11.20
29	51.20	67.50	65.60	92.55	18.80	33.10	35.00	11.90
30	45.70	63.15	48.70	59.40	44.40	36.85	50.00	35.65
31	30.65	36.20	36.20	35.00	38.10	52.50	55.00	55.65
32	60.00	62.50	83.10	85.05	43.05	40.00	28.70	21.30

COMPLEXITY LEVEL 2

16-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

Speed / Subject	Moving Stimulus SS	Moving Stimulus S	Moving Stimulus F	Moving Stimulus FF	Non-Moving Stimulus SS	Non-Moving Stimulus S	Non-Moving Stimulus F	Non-Moving Stimulus FF
33	28.70	58.70	51.90	58.75	19.00	7.55	11.60	12.15
34	44.90	35.35	80.65	103.70	41.25	30.60	3.15	2.80
35	38.75	53.10	90.60	93.10	27.50	18.75	5.30	2.80
36	31.90	23.15	46.20	62.50	28.15	7.15	6.85	9.40
37	6.90	25.05	43.10	55.60	9.35	3.75	4.40	5.65
38	50.60	68.15	90.65	95.55	26.25	13.10	5.00	6.90
39	52.50	75.05	91.25	81.90	42.50	22.50	7.85	10.25
40	35.05	71.90	68.15	75.60	25.00	14.40	1.55	12.55

COMPLEXITY LEVEL 2

24-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
41	47.50	61.20	60.65	60.65	16.20	10.00	12.45	9.40
42	24.40	35.05	29.35	30.00	17.55	7.20	5.00	3.05
43	24.90	38.10	36.30	43.70	28.10	12.55	16.25	18.80
44	41.85	63.10	64.35	70.60	11.90	7.50	17.20	5.60
45	19.95	43.70	68.75	66.85	25.60	5.55	8.75	5.60
46	20.00	60.60	62.50	68.15	18.15	13.75	26.85	19.35
47	12.50	26.90	42.45	38.75	4.65	3.40	1.85	3.80
48	33.75	41.20	44.65	80.65	1.85	3.75	13.80	3.40

COMPLEXITY LEVEL 3

8-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

Speed	Moving Stimulus				Non-Moving Stimulus			
Subject	SS	S	F	FF	SS	S	F	FF
49	31.20	62.50	68.15	66.90	20.00	10.05	8.15	2.15
50	60.65	43.10	73.75	89.40	42.20	56.80	14.95	6.25
51	36.20	59.35	66.85	83.75	26.85	20.65	39.30	13.15
52	70.05	78.15	80.05	63.70	36.60	27.55	31.20	50.05
53	49.30	48.10	64.35	86.25	56.25	49.45	28.20	16.25
54	49.40	47.50	34.35	32.50	24.45	43.10	48.75	26.25
55	60.00	60.00	60.00	60.00	46.90	60.00	60.00	46.30
56	46.85	57.50	60.00	60.00	70.65	58.15	60.00	60.00

COMPLEXITY LEVEL 3

16-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
57	37.55	48.20	100.00	94.35	60.00	25.00	11.90	14.35
58	28.75	33.75	67.60	63.10	31.85	26.55	13.10	4.70
59	74.40	89.95	93.75	105.65	24.95	20.00	16.90	5.00
60	27.50	33.75	49.95	72.45	26.95	23.80	10.60	9.40
61	58.75	67.45	105.70	110.00	54.40	33.15	10.90	1.25
62	38.10	66.85	101.25	103.10	26.80	10.00	3.40	1.85
63	46.85	68.75	79.40	87.50	43.75	25.00	19.40	9.95
64	37.50	53.20	67.50	81.90	15.00	13.10	10.00	5.90

COMPLEXITY LEVEL 3

24-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

	Moving Stimulus				Non-Moving Stimulus			
Speed	SS	S	F	FF	SS	S	F	FF
Subject								
65	50.00	41.25	38.75	40.00	24.40	15.85	11.80	9.95
66	38.10	38.15	55.00	53.75	34.35	6.85	6.85	6.85
67	45.60	75.65	62.50	88.10	30.00	7.50	20.00	6.00
68	29.95	36.90	58.80	61.30	29.35	35.60	29.40	36.90
69	10.60	17.55	28.10	36.25	8.75	5.00	6.85	9.95
70	10.65	27.50	35.05	42.45	15.60	7.50	4.95	3.70
71	13.10	28.70	36.25	46.95	8.70	3.75	1.85	1.80
72	9.95	29.35	21.90	35.05	19.40	5.00	3.70	6.25

COMPLEXITY LEVEL 4

8-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

Speed	Moving Stimulus				Non-Moving Stimulus			
Subject	SS	S	F	FF	SS	S	F	FF
73	63.05	69.40	87.55	96.85	30.00	33.15	13.75	8.10
74	47.55	36.25	83.15	79.95	32.45	56.85	14.95	3.10
75	51.30	57.50	81.25	83.70	45.60	36.25	20.00	10.00
76	47.45	58.75	60.00	81.25	50.00	41.90	50.00	28.10
77	26.95	66.90	91.30	91.80	18.80	8.75	6.85	13.75
78	39.35	52.50	43.80	47.55	46.25	41.20	36.25	41.90
79	41.85	52.50	86.85	76.30	61.25	46.25	27.50	26.85
80	58.80	57.55	105.00	93.10	45.05	46.20	6.90	12.50

COMPLEXITY LEVEL 4

16-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

Speed	Moving Stimulus				Non-Moving Stimulus			
	SS	S	F	FF	SS	S	F	FF
Subject								
81	41.25	59.40	88.75	78.80	25.05	15.05	4.35	9.95
82	25.60	43.10	63.05	84.40	13.75	11.55	6.30	3.75
83	48.15	68.40	74.35	81.85	18.75	10.90	15.25	5.00
84	29.30	46.25	61.20	64.95	36.20	20.00	17.50	8.75
85	12.45	56.25	50.00	86.25	15.00	18.10	13.15	1.20
86	55.60	43.75	31.25	65.00	36.95	56.25	50.65	11.90
87	21.20	42.45	60.65	84.35	31.25	20.00	15.60	13.15
88	21.25	35.70	63.75	61.90	30.65	23.15	11.25	11.55

COMPLEXITY LEVEL 4

24-WEEK-OLD INFANTS

The amount of time spent looking at the moving and non-moving stimulus patterns at each of four speeds of movement. The numbers represent the total number of seconds each infant spent looking at the stimulus patterns over four 30-second trials.

Speed	Moving Stimulus				Non-Moving Stimulus			
Subject	SS	S	F	FF	SS	S	F	FF
89	27.55	36.90	92.50	80.65	16.20	19.95	3.75	10.65
90	29.40	48.70	45.65	50.60	7.45	10.00	8.70	7.45
91	17.50	48.15	84.35	86.90	25.00	11.25	3.05	1.80
92	36.85	34.05	43.80	52.45	18.75	18.15	12.50	11.85
93	21.90	33.15	32.50	42.45	17.50	18.15	21.85	24.35
94	31.20	20.60	79.40	70.00	22.50	9.35	3.75	15.60
95	40.65	43.75	53.80	68.10	23.80	10.60	5.95	6.25
96	32.55	28.70	67.60	63.75	9.40	5.65	4.70	23.85

COMPLEXITY LEVEL I

The total number of times the moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
1	21	22	20	25	9	22	22	19	17	17	15	14	14	24
2	11	9	11	11	10	11	8	8	6	18	4	4	3	7
3	8	13	14	11	11	18	22	14	10	19	19	14	18	25
4	6	11	11	8	12	12	14	7	14	20	16	14	14	16
5	7	16	10	16	13	11	8	11	7	21	11	14	20	18
6	8	12	17	11	14	11	15	13	9	22	14	27	16	24
7	20	24	23	21	15	4	11	17	15	23	7	3	11	5
8	28	24	25	24	16	8	21	17	15	24	16	25	27	25

COMPLEXITY LEVEL 2

The total number of times the moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

8-Week-Olds

Subject	SS	S	F	FF
25	15	19	15	17
26	10	9	10	10
27	20	11	10	9
28	5	11	9	9
29	16	14	19	8
30	20	9	26	13
31	10	6	8	4
32	11	9	9	17

16-Week-Olds

Subject	SS	S	F	FF
33	9	14	20	19
34	15	9	18	11
35	15	18	15	14
36	20	19	26	18
37	6	18	22	20
38	18	15	19	15
39	17	19	18	20
40	17	14	12	16

24-Week-Olds

Subject	SS	S	F	FF
41	25	27	25	28
42	11	17	16	9
43	17	19	24	23
44	24	19	16	11
45	13	18	22	22
46	17	16	18	15
47	15	24	19	23
48	13	18	15	13

COMPLEXITY LEVEL 3

The total number of times the moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
49	34	32	20	15	57	21	20	12	16	65	23	20	18	17
50	13	17	13	18	58	21	22	27	23	66	13	13	20	25
51	17	17	18	12	59	25	19	10	11	67	20	16	18	23
52	21	18	19	20	60	26	23	22	17	68	21	22	18	22
53	12	9	13	5	61	11	13	12	10	69	13	14	24	30
54	9	5	5	11	62	16	18	14	14	70	10	13	15	19
55	3	2	2	2	63	30	30	34	18	71	20	27	29	25
56	5	5	3	2	64	22	30	24	23	72	11	17	15	15

COMPLEXITY LEVEL 4

The total number of times the moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
73	22	17	11	11	81	29	22	15	27	89	14	16	17	18
74	24	19	15	10	82	20	26	25	22	90	21	18	17	20
75	10	14	10	7	83	29	18	21	26	91	15	23	15	20
76	23	18	10	4	84	37	30	29	31	92	21	20	20	38
77	32	24	10	11	85	14	13	15	11	93	15	16	20	24
78	8	13	4	12	86	17	11	18	22	94	10	10	11	16
79	7	5	3	7	87	23	16	27	23	95	32	37	40	35
80	10	10	7	6	88	23	38	26	38	96	19	17	28	26

COMPLEXITY LEVEL 1

The total number of times the non-moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

	8-Week-Olds					16-Week-Olds					24-Week-Olds			
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
1	21	14	14	16	9	19	20	13	20	17	16	9	1	2
2	15	12	12	7	10	19	9	12	12	18	10	5	2	3
3	10	10	14	3	11	13	14	4	7	19	12	17	20	22
4	8	18	9	6	12	1	4	2	1	20	16	14	10	10
5	10	10	7	1	13	8	2	5	12	21	6	6	7	4
6	5	7	13	7	14	12	13	7	6	22	10	15	8	19
7	16	20	15	8	15	11	11	9	7	23	5	11	10	8
8	25	27	24	22	16	6	10	8	10	24	9	12	5	4

COMPLEXITY LEVEL 2

The total number of times the non-moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
25	16	19	10	13	33	12	9	14	12	41	24	13	18	15
26	5	5	5	6	34	12	11	2	3	42	15	8	9	5
27	24	15	9	9	35	18	14	5	3	43	18	15	15	20
28	11	13	5	8	36	13	10	7	10	44	16	12	9	7
29	19	13	18	14	37	10	5	7	9	45	13	9	15	9
30	18	10	26	17	38	15	12	9	9	46	15	9	17	15
31	8	5	5	5	39	12	17	13	19	47	9	6	4	7
32	11	11	7	11	40	12	8	3	7	48	2	5	10	8

COMPLEXITY LEVEL 3

The total number of times the non-moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
49	24	17	14	5	57	30	25	9	16	65	18	18	11	8
50	16	10	7	7	58	20	15	9	4	66	17	13	7	8
51	7	12	13	12	59	27	18	11	8	67	16	9	16	9
52	18	14	16	17	60	35	26	15	14	68	19	19	17	15
53	17	12	17	6	61	11	14	5	3	69	15	9	14	25
54	12	6	7	7	62	9	8	4	3	70	8	12	6	5
55	4	2	2	5	63	35	33	27	12	71	17	13	7	5
56	5	6	2	3	64	15	18	15	8	72	14	7	5	9

COMPLEXITY LEVEL 4

The total number of times the non-moving stimulus was fixated by each subject. The numbers represent the total number of looks for each infant, over four 30-second trials.

Speed	8-Week-Olds SS	S	F	FF		16-Week-Olds SS	S	F	FF		24-Week-Olds SS	S	F	FF
Subject					Subject					Subject				
73	18	16	10	7	81	25	15	6	12	89	7	10	4	9
74	21	20	12	4	82	17	13	6	9	90	8	8	10	8
75	12	13	11	3	83	25	13	16	9	91	16	15	5	6
76	24	17	11	3	84	25	27	21	25	92	19	18	13	18
77	25	14	5	6	85	14	14	12	3	93	19	17	23	29
78	8	9	9	14	86	22	16	20	15	94	10	8	2	7
79	9	5	2	4	87	39	16	21	17	95	33	12	14	13
80	8	11	4	5	88	33	35	22	21	96	11	7	7	8

COMPLEXITY LEVEL 1

The average length of fixation of each individual look at the moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

Speed	8-Week-Olds SS	S	F	FF		16-Week-Olds SS	S	F	FF		24-Week-Olds SS	S	F	FF
Subject					Subject					Subject				
1	1.79	2.55	2.00	2.32	9	1.53	1.79	1.52	2.06	17	1.90	2.14	5.89	2.09
2	2.95	5.00	5.00	6.87	10	3.41	5.08	3.28	8.44	18	.93	1.40	1.13	6.70
3	4.85	4.52	5.13	9.49	11	1.43	2.16	3.88	8.12	19	1.02	2.28	2.60	1.95
4	8.23	3.29	3.24	9.84	12	3.18	2.41	4.91	5.99	20	2.42	5.05	4.82	4.03
5	2.32	1.91	6.25	3.91	13	2.33	4.69	4.26	5.62	21	3.24	2.32	2.69	3.30
6	7.49	5.36	4.30	7.44	14	3.70	4.25	5.20	10.01	22	3.43	2.06	4.38	2.60
7	1.67	1.00	2.09	3.63	15	.80	2.84	2.43	3.00	23	4.29	1.67	1.13	5.50
8	1.41	2.08	1.72	2.40	16	4.78	3.04	4.23	3.79	24	2.15	2.30	2.31	2.60

COMPLEXITY LEVEL 2

The average length of fixation of each individual look at the moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
25	2.56	2.50	5.38	5.33	33	3.19	4.19	2.60	3.09	41	1.90	2.27	2.43	2.17
26	3.56	4.86	5.81	8.78	34	2.99	3.93	4.48	9.43	42	2.22	2.06	1.83	3.33
27	2.59	4.15	6.44	8.06	35	2.58	2.95	6.04	6.65	43	1.46	2.01	1.51	1.90
28	8.01	3.30	5.48	5.87	36	1.60	1.22	1.78	3.47	44	1.74	3.32	4.02	6.42
29	3.20	4.82	3.45	11.57	37	1.15	1.39	1.96	2.78	45	1.53	2.43	3.13	3.04
30	2.29	7.02	1.87	4.57	38	2.81	4.54	4.77	6.37	46	1.18	3.79	3.47	4.54
31	3.07	6.03	4.53	8.75	39	3.09	3.95	5.07	4.10	47	.83	1.12	2.23	1.68
32	5.45	6.94	9.23	5.00	40	2.06	5.14	5.68	4.73	48	2.60	2.29	2.98	6.20

COMPLEXITY LEVEL 3

The average length of fixation of each individual look at the moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

8-Week-Olds

Subject	SS	S	F	FF
49	.92	1.95	3.41	4.46
50	4.67	2.54	5.67	4.97
51	2.13	3.49	3.71	6.98
52	3.34	4.34	4.21	3.19
53	4.11	5.34	4.95	17.25
54	5.49	9.50	6.87	2.95
55	20.00	30.00	30.00	30.00
56	9.37	11.50	20.00	30.00

16-Week-Olds

Subject	SS	S	F	FF
57	1.79	2.41	8.33	5.90
58	1.37	1.53	2.50	2.74
59	2.98	4.73	9.38	9.60
60	1.06	1.47	2.27	4.26
61	5.34	5.19	8.81	11.00
62	2.38	3.71	7.23	7.36
63	1.56	2.29	2.34	4.86
64	1.70	1.77	2.81	3.56

24-Week-Olds

Subject	SS	S	F	FF
65	2.17	2.06	2.15	2.35
66	2.93	2.93	2.75	2.15
67	2.28	4.73	3.47	3.83
68	1.43	1.68	3.27	2.79
69	.82	1.25	1.17	1.21
70	1.07	2.11	2.34	2.23
71	.65	1.06	1.25	1.88
72	.90	1.73	1.46	2.34

COMPLEXITY LEVEL 4

The average length of fixation of each individual look at the moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

	8-Week-Olds					16-Week-Olds					24-Week-Olds			
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
73	2.87	4.08	7.96	8.80	81	1.42	2.70	5.92	2.92	89	1.97	2.31	5.44	4.48
74	1.98	1.91	5.54	8.00	82	1.28	1.66	2.52	3.84	90	1.40	2.71	2.69	2.53
75	5.13	4.11	8.13	11.96	83	1.66	3.80	3.54	3.15	91	1.17	2.09	5.62	4.35
76	2.06	3.26	6.00	20.31	84	.79	1.54	2.11	2.10	92	1.75	1.70	2.19	1.38
77	.84	2.79	9.13	8.35	85	.89	4.33	3.33	7.84	93	1.46	2.07	1.63	1.77
78	4.92	4.04	10.95	3.96	86	3.27	3.98	1.74	2.95	94	3.12	2.06	7.22	4.38
79	5.98	10.50	28.95	10.90	87	.92	2.65	2.25	3.67	95	1.27	1.18	1.35	1.95
80	5.88	5.76	15.00	15.52	88	.92	.94	2.45	1.63	96	1.71	1.69	2.41	2.45

COMPLEXITY LEVEL 1

The average length of fixation of each individual look at the non-moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

	8-Week-Olds					16-Week-Olds					24-Week-Olds			
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
1	1.93	1.29	1.34	.93	9	.92	.69	.50	.81	17	1.76	1.32	.60	1.85
2	2.58	2.70	3.02	2.06	10	2.57	3.69	3.02	1.20	18	1.06	3.81	.30	.30
3	1.88	1.88	1.03	.62	11	1.15	5.79	.77	1.11	19	1.77	.88	1.38	.94
4	5.47	2.71	4.10	4.17	12	.30	.46	.45	.30	20	1.02	.59	.69	.59
5	1.78	1.47	1.79	2.50	13	1.87	1.58	1.63	1.04	21	.41	1.35	.62	.30
6	4.50	4.06	.53	2.06	14	2.66	1.75	3.66	.73	22	1.63	1.46	.86	.59
7	2.27	1.75	2.00	.62	15	1.82	.74	1.04	.89	23	1.88	.85	.94	.86
8	1.05	1.48	1.22	1.08	16	1.30	1.25	1.41	1.63	24	1.81	.57	1.38	.78

COMPLEXITY LEVEL 2

The average length of fixation of each individual look at the non-moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

8-Week-Olds					16-Week-Olds					24-Week-Olds				
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
25	2.58	1.25	1.19	.67	33	1.58	.84	.83	1.01	41	.68	.77	.69	.63
26	5.50	5.37	2.44	.83	34	3.44	2.78	1.58	.93	42	1.17	.90	.55	.61
27	1.66	3.62	4.23	3.78	35	1.53	1.34	1.06	.70	43	1.56	.84	1.08	.94
28	3.30	1.48	1.88	1.40	36	2.17	.72	.98	.94	44	.74	.63	1.97	.80
29	.99	2.55	1.94	.85	37	.94	.75	.63	.63	45	1.97	.62	.58	.62
30	2.47	3.69	1.92	2.10	38	1.75	1.09	.56	.77	46	1.21	1.53	1.58	1.29
31	4.76	10.50	11.00	11.13	39	3.54	1.32	.60	.54	47	.52	.57	.46	.54
32	3.92	3.64	4.10	1.94	40	2.08	1.80	.52	1.79	48	.93	.75	1.38	.43

COMPLEXITY LEVEL 3

The average length of fixation of each individual look at the non-moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

	8-Week-Olds					16-Week-Olds					24-Week-Olds			
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
49	.83	.59	.58	.43	57	2.00	1.00	1.32	.90	65	1.36	.88	1.07	1.24
50	2.64	5.68	2.14	.89	58	1.59	1.77	1.46	1.18	66	2.02	.53	.98	.86
51	3.84	1.72	3.02	1.10	59	.92	1.11	1.54	.63	67	1.88	.83	1.25	.67
52	2.03	1.97	1.95	2.94	60	.77	.92	.71	.67	68	1.54	1.87	1.73	2.46
53	3.31	4.12	1.66	2.71	61	4.95	2.37	2.18	.42	69	.58	.56	.49	.40
54	2.04	7.18	6.96	3.75	62	2.98	1.25	.85	.62	70	1.95	.63	.83	.74
55	11.73	30.00	30.00	9.26	63	1.25	.76	.72	.83	71	.51	.29	.27	.36
56	14.13	9.69	30.00	20.00	64	1.00	.73	.67	.74	72	1.39	.71	.74	.69

COMPLEXITY LEVEL 4

The average length of fixation of each individual look at the non-moving stimulus. The numbers represent the average span of looking time in seconds for each subject. The average span is defined as the total fixation time divided by the total number of looks.

	8-Week-Olds					16-Week-Olds					24-Week-Olds			
Speed	SS	S	F	FF		SS	S	F	FF		SS	S	F	FF
Subject					Subject					Subject				
73	1.67	2.07	1.38	1.16	81	1.00	1.00	.73	.83	89	2.31	2.00	.94	1.18
74	1.55	2.84	1.25	.78	82	.81	.89	1.05	.42	90	.93	1.25	.87	.93
75	3.80	2.79	1.82	3.33	83	.75	.84	.95	.56	91	1.56	.75	.61	.30
76	2.08	2.46	4.55	9.37	84	1.45	.74	.83	.35	92	.99	1.01	.96	.66
77	.75	.63	1.37	2.29	85	1.07	1.30	1.10	.40	93	.92	1.07	.95	.84
78	5.78	4.58	4.03	2.99	86	1.68	3.52	2.53	.79	94	2.25	1.17	1.88	2.23
79	6.81	9.25	13.75	6.71	87	.80	1.25	.74	.77	95	.72	.88	.43	.48
80	5.63	4.20	1.73	2.50	88	.93	.66	.51	.55	96	.85	.81	.67	.51