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Concurrent Motion in Infant Event Perception

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Infant sensitivity to motion relationships specifying certain complex events, such as a person walking, has recently been demonstrated, but the perceptual principles underlying early event perception are not well understood. Retinal motion toward a common point (concurrent motion) specifies translation in depth to adult perceivers in the absence of conflicting information (Börjesson & von Hofsten, 1973). We tested this principle of event perception with 28 16-week-old infants. One group was habituated in a dark room to a concurrent motion: three points of light moving in a frontoparallel plane toward and away from a central point (not seen). After habituation, the room was illuminated, and looking time was tested to alternate presentations of two displays. In one display (depth motion), three lights were attached to a triangle actually moving in depth; in the other display (surface motion), the three lights moved visibly along the surface of a frontoparallel stationary triangle. If concurrent motion, in the absence of conflicting information, specifies motion in depth to infants, they were expected to look longer after habituation at the surface motion display. A control group tested infants' relative interest in the two test displays with no prior habituation period.

Control-group infants marginally preferred the depth movement display. The habituation group responded three times as much to the surface motion display, suggesting that motion in depth had been perceived during habituation. Specification of motion in depth by concurrency of relative proximal stimulus motions seems to be an operative principle in infants' perception; moreover, at least some principles of early event perception are unrelated to person perception or biological motion. The relation of these results to recent findings in infant object perception is discussed.

motion perception form perception vector analysis
depth perception point-light displays optical transformations

Adult visual perception in ordinary environments depends greatly on information in optical transformations (Gibson, 1966, 1979). The importance of

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changing stimulation has led Johansson (1975) and others to suggest that visual perception should generally be conceived of as event perception.

An especially useful paradigm in the study of event perception has been the use of moving points of light in a dark surround (Johansson, 1975; Johansson, von Hofsten, & Jansson, 1980). Such displays allow tests of the perceptual effectiveness of motion information about structure and events in the absence of surface and contour information. Experiments with such displays have revealed adults' dramatic sensitivity to information in motion relationships. One example is the now-classic *Johansson effect*. If one attaches small lights to the main joints of a walking person and films the movements of the lights in a dark surround, observers viewing the film will quickly and compellingly perceive a person walking.

Some basic principles underlying perception of events have been identified by Börjesson and von Hofsten (1972, 1973). They developed a vector model that predicts with great accuracy the presence and type of perceived motion in depth in three-dot patterns and other simple displays. Following the earlier suggestion of Johansson (1964), the motion common to all points is extracted, leaving only relative motions. Two kinds of relative motion on the retina are fundamental for perceiving motion in depth. *Concurrent motions* are those in which all vectors are directed toward or away from a common point. This kind of proximal stimulus pattern is perceived as translation in depth. *Parallel motions* are motions toward a common line, and they result in perceived rotation in depth (around the common line).

It is often conjectured that event perception rests on innate mechanisms, but there has been little research to determine specific properties of optical flow patterns which may signify meaningful properties of objects and events to infants. One line of research suggests that infants are sensitive to certain optical changes specifying translation in depth (Ball & Tronick, 1971; Bower, Broughton, & Moore, 1971). Early experiments reported that a rapidly and symmetrically expanding projection of a solid object seems to evoke a defensive response even very early in infancy. Subsequent research raised questions about the interpretation of the observed behaviors, such as head withdrawal, and the conditions under which they occur (see Yonas, 1981, for an excellent review). It now seems clear that blinking and backward head rotation tend to occur when information for object approach is presented (Yonas, 1981; Yonas, Pettersen, & Lockman, 1979). That these responses indicate perceived approach has received further support from the finding that optical expansion patterns characteristic of approaching objects, but not similar ones given by approaching apertures, evoke defensive behavior (Carroll & Gibson, 1981).

An attempt to specify the effective information in such optical expansion displays has been carried out by Yonas, Pettersen, Lockman, and Eisenberg (1980). Following studies of nonhuman species and analyses of particular stimulus variables by Schiff (1965; Schiff & Detweiler, 1979), Yonas et al. found that for 14-week-olds, blinking and backward head rotation depended on patterns accelerating geometrically and filling large (100°) visual fields. Such "explosive" magnification patterns are characteristic of approaching objects when collision is imminent. Citing evidence of reliable blinking by 4-week-olds even to nonexplosive expansion patterns, Yonas (1981) suggested a developmental trend toward distinguishing mere approach from impending collision.

Although detection of impending collision by infants seems well-documented, whether this ability illustrates general principles of event perception is unknown. The present program of research seeks to identify principles underlying infants' use of optical transformations. Specifically, we ask whether the Börjesson and von Hofsten vector analysis identifies basic principles. The study of information in moving-light points may furnish in infant perception, as in adult perception, a useful method of isolating motion information. This program of research thus complements previous research on optical expansion patterns but differs from it in at least two ways. First, point-light displays allow clear tests of event-carried information in the absence of surface information, such as contour, texture, color, projective size, accretion and deletion of background texture, etc. Second, the absence of connected surface information makes point-light displays optimal for studying event specification of the structure (unity and form) of the moving object itself as well as its motion in space.

Recently, studies introducing point-light displays to infant perception research have been reported (Bertenthal, Profitt, Spetner, & Thomas, in press; Fox & McDaniel, 1982). These studies have focused primarily on motion patterns characteristic of moving persons. Results show that infants as young as 3 months of age discriminate such patterns from other patterns (Bertenthal et al., in press; Fox & McDaniel, 1982). By 9 months of age, and perhaps earlier they seem to perceive a person walking from light points (Bertenthal et al., in press). No research has yet attempted to identify the specific perceptual abilities underlying such performance. Of special interest is the question of whether infants' extraction of structure and events from moving-dot displays is restricted to social or animate stimuli (biological motion) or whether it involves more general perceptual principles.

Here, we report a test of one specific event perception principle: concurrent motion as a determinant of perceived translation in depth. To assess infants' perception, we used a habituation-of-looking-time procedure. If concurrent motion of light points, in the absence of other information, specifies unitary translation in depth to the perceiver, then after habituation to concurrent motion, test responding should be greater to a different perceived motion than to a perceived translation in depth.

Our design made use of the following facts: One way to achieve concurrent motion on the retina is with a display in which the visible points move in a frontoparallel plane toward a central point (Börjesson & von Hofsten, 1973). In darkness, such a movement of light points appears unequivocally to adults as translation in depth. However, when surrounded by fully illuminated, textured surfaces, the same motion is clearly (and veridically) seen to be motion in a frontoparallel plane rather than translation in depth. Another way of creating concurrent motion on the retina, and the basis of the ecological validity of this principle, is for the light points to share a rigid translation in depth.

If infants' perception follows that of adults in these respects, then concurrent motion in a frontoparallel plane shown in darkness should be perceived as translation in depth. Thus, it might be seen as similar to a fully illuminated display in which these light points translate in depth. The concurrent motion produced by frontoparallel motion might be perceptually very different, however, in darkness and in full illumination. In full illumination, the display might appear, as it does to adults, as light points converging and diverging in a frontoparallel plane.

METHOD

Subjects

Twenty-eight 13- to 20-week-old infants from Uppsala, Sweden, served as subjects in one of two groups of 14 subjects each. Subjects were recruited through local child health centers, which are visited by all new parents and infants.

Displays and Apparatus

The concurrent motion display (used as the habituation display in the concurrent motion group; see below) consisted of three small lights (5 mm) moved mechanically 2.8 cm in a frontoparallel plane toward and away from a centrally located concurrency point (see Figure 1). At their furthest separation, the lights formed the vertices of an equilateral triangle with side 15.5 cm and at their nearest, 10.7 cm. Lights were viewed in an otherwise dark room and were shielded by opaque tape on the sides to minimize illumination of other surfaces in the room. They traversed the full distance toward or away from the center in 3 s with a .5-s pause at each end. The display was moved by turning a crank at an approximately constant speed, resulting in an approximately constant velocity of the lights. Infants viewed the display at eye level from 40 cm away. The concurrent-motion display appeared to adults as three rigidly connected points translating back and forth in depth.

Two test displays were shown with full room illumination. In both, a triangular panel (equilateral; 24 cm per side) was affixed to the rods holding the three lights so that the lights protruded through slits in the triangle (see Figure 1). The triangle was painted a bright-yellow color with small, randomly distributed red spots. Behind it was a similarly painted background, 75 cm square, 67 cm away from the subject. In one test display (depth movement), the triangular piece and the lights moved in a unitary fashion toward and away from the subject through a range of 17 cm (Figure 1). The display was moved by hand at an approximately constant speed; movement in each direction took 3 s with a .5-s pause at the endpoints. From previous research (Carroll & Gibson,

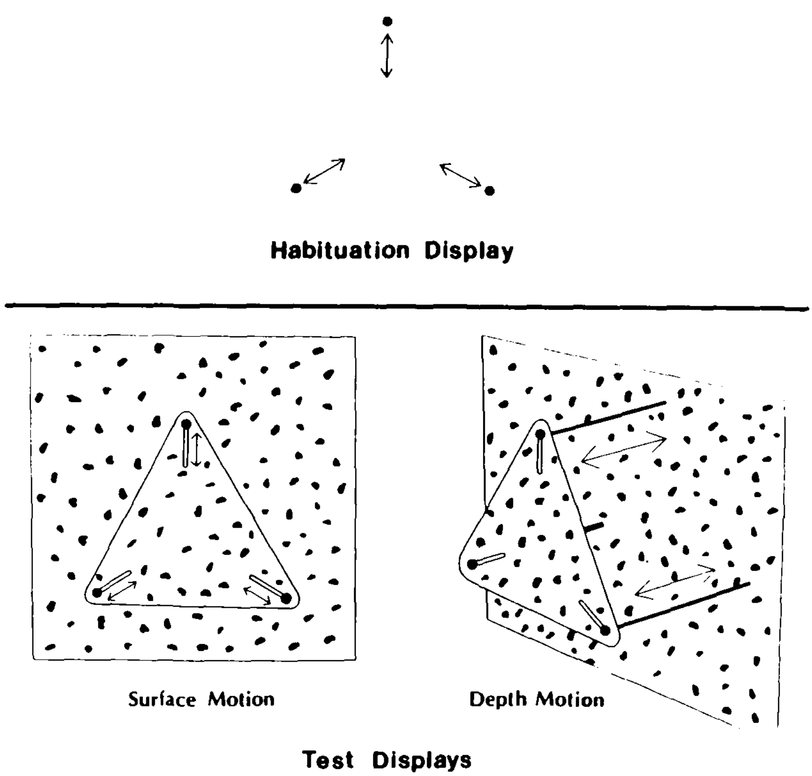

Figure 1. Displays used in the experiment. Black dots indicate 5 mm diameter lights with translucent covers. Arrows indicate motion. (a) Habituation Display. (b) Surface Motion Test Display. (c) Depth Motion Test Display. The depth motion display was oriented toward subjects in the same way as the other displays; it is shown here from the side so that its movement can be indicated.

1981; Yonas, 1981), we assumed that this display would be seen veridically (i.e., as translation in depth) by infants in the age range tested. In the other test display (surface movement), the triangular piece did not move while the lights were moved along the triangle's surface toward and away from the center 2.8 cm. The physical motion of the lights in this display was produced in exactly the same way as in the habituation display. Retinally, the starting points, endpoints, and duration of the movement of the lights were the same in the habituation display and in both test displays. The triangular insert served to emphasize the unity of the three dots in the depth motion display and to make salient the absence of depth motion in the surface motion test display.

Design

Infants in the experimental group were habituated in a very dark room to the concurrent motion display. After habituation, subjects saw the surface motion and depth motion test displays in alternation. Half of the subjects saw each test display first. Infants in the baseline control group saw the two test displays in alternation with no prior habituation period.

If infants perceived the concurrent motion of the three spots during habituation as unitary translation in depth, then they were expected to generalize habituation more to the depth-movement test display than to the surface-movement display. This outcome would require not only that they perceived translation in depth during habituation but that they did *not* see motion in depth from the surface-motion test display. Since the surface-motion test display included the same concurrent motion used in the dark, it was possible that they would also see depth movement in this display, despite ample information for its absence. (Adults did not see any depth motion under full illumination.) The baseline control group was used to assess the relative intrinsic interest of the two test displays, apart from habituation effects.

Procedure

An infant control habituation-of-looking-time procedure was used to assess infants' perception in the concurrent motion group. Each trial began with the sliding away of a cardboard screen. After an initial .5-s fixation, a trial continued until a 2-s look away occurred, up to a maximum of 60 s of looking time. At the end of the trial, the screen was interposed between the infant and the display. An intertrial interval of 6 s was used on all trials. This allowed enough time to change the displays during the test trials. Closing and opening of the screen required an additional 1–2 s each. The concurrent-motion display was shown on repeated trials until a criterion of habituation was met. The criterion was a 50% decline from a subject's initial looking time, calculated over three trial blocks. If total looking time on the first three trials did not exceed 12 s, the habituation criterion was set by the first three consecutive trials on which 12 s was exceeded.

Test trials consisted of alternating presentations of the fully illuminated surface-motion and depth-motion displays, three times each. Test trials were otherwise the same as habituation trials. The baseline group received only the test trials.

Fixation was recorded by a trained observer using a pushbutton input to a microcomputer. Light from the stimulus displays was adequate to allow accurate determination of fixation direction. A second observer was available for some subjects ($n = 12$) and was used to check reliability. Observers were blind to the order of test displays. Observer agreement was measured by sampling both observer buttons every tenth of a second and calculating time of agreement as a proportion of total trial time. For subjects tested with two observers, observer agreement ranged from .84 to .93 and averaged .89.

RESULTS

Figure 2 shows looking times in (a) the concurrent-motion group and (b) the baseline group. After habituation to concurrent motion in darkness, infants

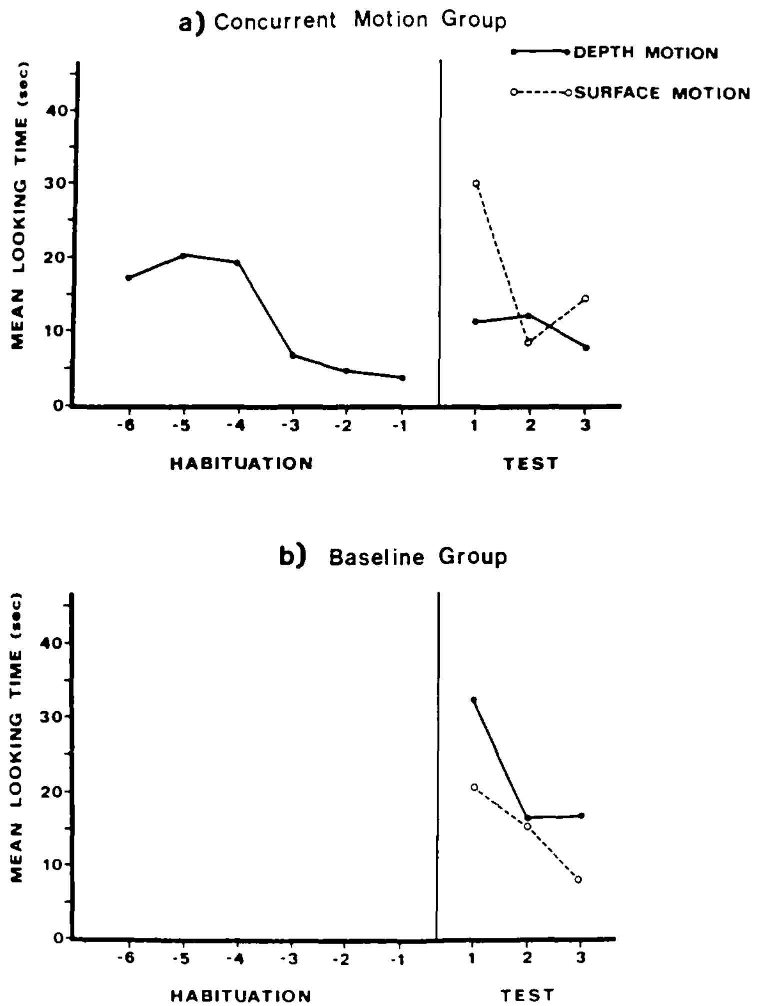

Figure 2. (a) *M* Looking Time during habituation and test trials in the concurrent motion group. Habituation trials are numbered backwards from the trial on which the habituation criterion was met. (b) *M* Looking Time during test trials in the baseline group.

responded much more to the surface-motion display than to the depth-motion display. Baseline-group infants, in contrast, looked more at the depth-motion display. These patterns were confirmed by the analyses. A 2 (Group) × 2 (Test Display) × 3 (Test Trial) ANOVA on the test-trial looking times showed a reliable main effect of Trial, $F(2,52) = 11.2$, $p < .001$, a reliable Group by Test Display interaction, $F(1,26) = 10.70$, $p < .005$, a reliable Group by Test Display by Trial interaction, $F(2,52) = 6.80$, $p < .005$, and no other reliable effects. The main effect of Trials reflects the general decline in looking times over the three test trials. The two interaction effects indicates that the two groups had markedly different looking preferences between the two test displays, with the differences strongest on the first test trial. Subjects in the baseline group looked longer at the depth-movement test display, while subjects in the concurrent-motion group robustly preferred the surface-movement display on the first test trial. Individual comparisons showed that the baseline group's numerical superiority of looking time to the depth-movement test display over the surface-movement test display on the first test trial did not reach significance, $t(13) = 1.22$. Over all three test trials taken together, the depth-movement display was marginally preferred, $t(13) = 1.56$, $.05 < p < .10$. In the concurrent motion group, looking times were much longer to the surface-movement display than to the depth movement display on the first test trial, $t(13) = 5.13$, $p < .001$, and over all three test trials, $t(13) = 5.71$, $p < .001$. All 14 infants in the concurrent-motion group looked longer at the surface-motion display on the first test trial, $p < .001$, binomial test, as opposed to 5 of 14 infants in the baseline group, n.s.

DISCUSSION

These findings suggest that infants perceived translation in depth from the concurrent-motion pattern shown during habituation. The retinal motion of the light points had the same spatial properties throughout the experiment. In habituation, it was physically produced by motion in a frontoparallel plane. When shown this same real motion pattern (surface motion) in full lighting, infants responded greatly. The depth-motion test display, which received greater looking time in the control group, evoked comparatively little responding after habituation to concurrent motion, suggesting that it was perceived as similar to the habituation display.

There was one difference in the concurrent motion produced on a frontoparallel surface and the concurrent motion produced by a display that moved in depth, but it did not concern spatial properties. The proximal velocity patterns were different. The display moved in depth with approximately constant velocity and produced a retinal acceleration as the dots moved away from each other and a deceleration as they approached each other. The surface display, on the other hand, produced a retinal motion of approximately constant velocity. If the second display was perceived as moving in depth, it would also be perceived as accelerating when receding and decelerating when approaching. Even though proximal velocity properties are not totally unimportant for adult perception of motion in space (Hofsten, 1974), they are always overruled by unambiguous spatial properties. This seems to be the case with infants as well.

Sensitivity to change in the pattern of velocity perceived would not favor the obtained results. If the test displays were correctly perceived, they would both have appeared to have approximately constant real velocity. Thus, depending on whether or not the habituation display was perceived as having constant real velocity, *both* test displays would have appeared similar or dissimilar to it in this respect. If all displays in the habituation and test periods were perceived either as moving in the frontoparallel plane or as moving in depth, sensitivity to change in the velocity pattern would favor test responding to the depth display, since this display had a different proximal velocity pattern from the habituation display. On the contrary, subjects responded to the test pattern which was proximally identical to the habituation pattern; habituation to the concurrent motion shown in darkness did not generalize to the identical pattern shown in illuminated surroundings.

Besides indicating the effectiveness of concurrent motion, the results suggest that young infants, like adults, can use other information to override the concurrent-motion principle. Apparently, perception of an adjacent, stationary surface provided veridical information about the movement. This might be because relationships between the lights and the surface provide information or simply because the presence of well-illuminated surroundings allows more precise depth perception.

As in adult perception, concurrent motion seems to specify translation in depth to young infants. These results from a minimal case of concurrent motion are consistent with the possibility that early infant responding to optical expansion patterns (Ball & Tronick, 1971; Bower et al., 1971; Yonas, Pettersen, & Lockman, 1979) depends on such a perceptual principle. However, our displays did not give the explosive magnifications, covering large areas of the visual field, that are most effective in eliciting defensive responding (Yonas et al., 1980), nor did we observe defensive responding in our infants. It seems likely that by several months of age, infants detect translatory motion from concurrent-retinal motion generally but respond defensively only to rapidly accelerating patterns specifying imminent collision (Carroll & Gibson, 1981; Yonas, 1981).

Our results indicate the usefulness of the point-light technique in studying perception of motion and structure. Relative retinal motions of spatially separated points evoked a percept of unitary motion in depth. This finding indicates that at least some principles of event perception operate outside of domains that involve biological motion or person perception. Efforts to identify other principles of early event perception using the point-light paradigm are currently underway.

The present research also bears important relations to research on infants' perception of object unity. Kellman, Spelke, and Short (1986) found that when two visible parts of a partly occluded object shared a common translation in depth, infants detected the unity of the object. This finding parallels the present results in suggesting that certain motion patterns can jointly specify events (such as motion in depth) and persisting structure (such as object unity) in early perception. The studies are complementary in that (Kellman et al., 1986), tested for perception of object unity while more or less assuming detection of the depth motion. The current study tested primarily for perceived motion in depth while inferring perception of the rigid spatial relationships among the light points undergoing depth translation. Further research should elaborate the role of such dual specification of structure and change (Gibson, 1979) in the development of perception. The present results, along with others, suggest that it plays an important role in perception from very early in life.

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