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Infants' perception of three-dimensional shape specified by motion-carried information

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The purpose of this study was to replicate Arterberry and Yonas (1988) with an added control group to provide further evidence that infants respond to distal shape specified by motion-carried information. In a habituation procedure, 4-month-old infants were tested for discrimination of a complete and incomplete cube specified in computer-generated, kinetic random-dot displays. Two groups of infants were tested. One group was provided with a full view of the habituation and test displays (called the full-view group). A second group of infants viewed only the central region in which differential motion was located (called the partial-view group). The full-view group provided evidence of discriminating the two objects, whereas the partial-view group did not. These findings suggest that 4-month-old infants do perceive three-dimensional shape specified by motion-carried information.

An important task for the perceiver is perception of the three-dimensional shape of objects. Several studies have addressed the issue of infants' sensitivity to motion-carried information specifying three-dimensional object shape (Arterberry & Yonas, 1988; Kellman, 1984; Kellman & Short, 1987; Owsley, 1983; Shaw, Roder, & Bushnell, 1986; Yonas, Arterberry, & Granrud, 1987). This research provides evidence that young infants within the first 6 months of life perceive some aspect of three-dimensional object shape from motion-carried information. The present study contributes to the evidence by providing a replication and control experiment.

Many types of displays have been used to study infants' perception of three-dimensional shape specified by motion-carried information: shadow-cast displays, wire figures, real objects, videotapes of real objects, and kinetic random-dot displays (see Arterberry & Yonas, 1988, for a review). In these displays, except the random-dot displays, motion-carried information was presented with figural features such as edges, intersections, and/or surfaces that infants may have used to discriminate the objects. Arterberry and Yonas were able to isolate motion-carried information from figural features. Utilizing computer-generated, kinetic random-dot displays, Arterberry and Yonas investigated 4-month-old infants' ability to perceive the difference between two rectilinear forms (Figures 1A, 1B, 1C, and 1D).

The use of kinetic random-dot stimuli to study depth and object perception has a long history in the study of adult motion perception (see Braunstein, 1962, for an example of early work). The use of these displays allows for the testing of sensitivity to motion-carried information in the absence of static information because when these displays are stationary, no information for object shape or depth is present. Instead, in kinetic random-dot displays, figural properties are created by processes operating on optical flow information (Nakayama & Loomis, 1974).

Arterberry and Yonas (1988) tested 4-month-old infants for discrimination between a complete and an incomplete cube in an infant-controlled habituation-of-looking paradigm. Using a method borrowed from Kellman (1984), infants were habituated to either a complete or incomplete cube that oscillated about two different axes (e.g., vertical, diagonal) on alternating trials. Following habituation, infants viewed the habituation object and a new object, both oscillating about a third, new axis (e.g., horizontal). The 4-month-olds provided evidence of perceiving the three-dimensional shape of the kinetic random-dot displays by looking longer at the novel shape than at the familiar shape during the test phase. Arterberry and Yonas concluded that 4-month-olds perceive three-dimensional object shape in the absence of figural information.

However, there is another interpretation for Arterberry and Yonas's (1988) findings. Infants' ability to discriminate between the complete and incomplete cubes could have been based on differences in the extent of the motion of the dots in the central region of the displays. This difference is illustrated in Figures 1E and 1F. In the complete cube (Figure 1E), the dots in the upper central region where the interior corner is located travel a longer distance than do the dots in the same region of the incom-

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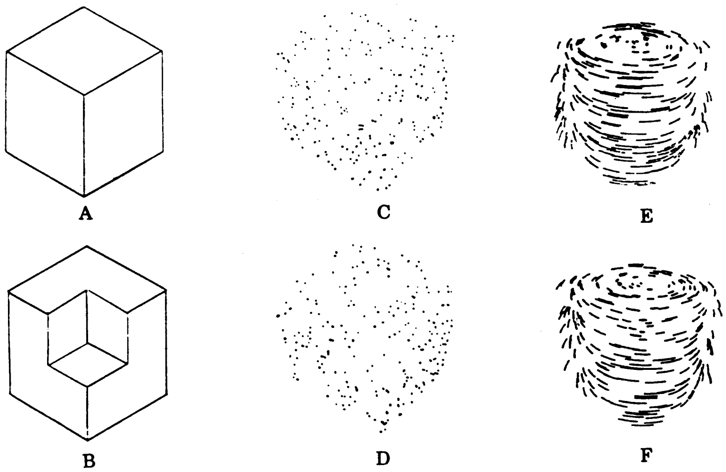

Figure 1. Schematic drawings of the complete (A) and incomplete (B) cubes. These drawings represent the middle frame of each oscillation. C and D depict single frames of the complete and incomplete cubes, respectively. E and F were drawn from time-lapse photographs showing the pattern of texture flow in the complete and incomplete cube displays. In the actual displays, the contrast was reversed.

plete cube (Figure 1F). To discriminate the two objects, infants did not necessarily have to perceive the three-dimensional shape of the objects; instead, they merely needed to attend to the differential motion of the dots in the central region.

The present study provides a replication of Arterberry and Yonas's (1988) previous work, and it provides a control condition to rule out the differential-motion explanation. In the control condition, 4-month-old infants were presented with the same displays used by Arterberry and Yonas, except that the displays were presented behind an aperture that limited the view of the displays. This group of infants, called the partial-view group, viewed only the central region of the displays. Using an infant-control habituation procedure, infants were habituated to a partial view of either the complete or incomplete cube oscillating about two different axes on alternating trials. Following habituation, infants were presented with partial views of both the habituation object and the novel object oscillating about a third, new axis. Infants' looking times were compared to a second group of infants who were presented with a full view of the displays following the same procedure as Arterberry and Yonas.

METHOD

Subjects

Twenty-four 4-month-old infants served as subjects. Twelve were in the full-view group (mean age = 114.7 days, *SD* = 7.1 days, range = 105 to 125 days), and 12 were in the partial-view group (mean age = 113.8 days, *SD* = 7.9 days, range = 106 to 130 days). An additional 55 infants (28 in the partial-view group and 27 in the full-view group) began the procedure but did not complete it because of fussiness (47), experimenter error/equipment failure (2), or parental interference (6). This high attrition rate is comparable to that in Arterberry and Yonas (1988).

Materials, Apparatus, and Procedure

The materials, apparatus, and procedure were the same as those used by Arterberry and Yonas (1988), except in the partial-view condition a 76.2×50.8 cm panel with a 7.6×6.1 cm aperture allowed only a view of the central region of the displays where the central or missing corner was located. Adults viewing the displays in the partial-view condition did not report any perception of three-dimensional structure. Reliability was calculated for 19 randomly chosen subjects using the Kappa statistic (Bartko & Carpenter, 1976). Mean agreement between the two observers was $K = 0.86$.

RESULTS AND DISCUSSION

The infants' looking times on the last six habituation trials and on the test trials are presented in Figure 2. For the initial analysis, the looking times on the two novel test trials and the two familiar test trials were combined. The looking times were analyzed in a 2×2×2×2 mixed-design analysis of variance with group (full view or partial view), habituation object (complete or incomplete cube), and test order (novel or familiar object first) as between-subject factors and novelty (novel or familiar) as a within-subject factor. The analyses revealed a significant main effect for group [$F(1,16) = 7.62, p < .05$], a significant interaction between habituation object and test order [$F(1, 16) = 7.40, p < .05$], and a marginally significant main effect for novelty [$F(1,16) = 3.49, p < .10$]. No other reliable main effects or interactions were found.

Post hoc analyses reveal the main effect of group to be due to significantly more looking at the novel object by the full-view group than by the partial-view group [$t(23) = 14.27, p < .05$]. Moreover, the full-view group looked significantly longer at the novel object than the partial-view group looked at the familiar object [$t(23) = 15.57, p < .05$].

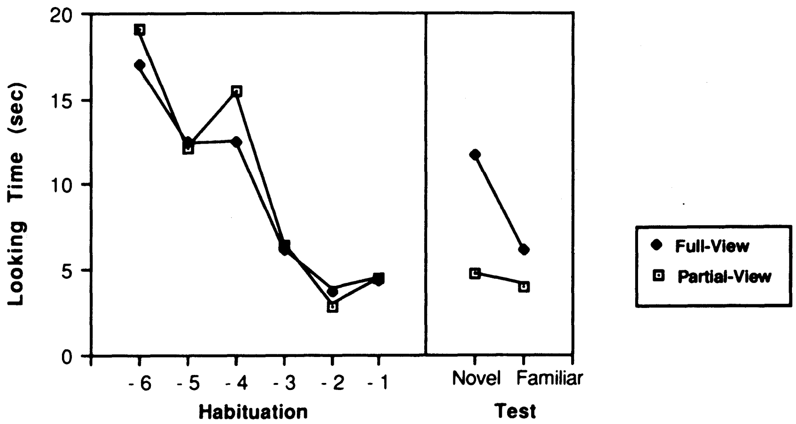

Figure 2. Mean fixation time in habituation and test trials for the full-view and partial-view groups.

The habituation object × test order interaction is due to a high amount of looking at the novel object when the infants were presented with the incomplete cube during habituation and the familiar object first during the test phase (referred to subsequently as the "incomplete-familiar" group). The infants looked significantly longer at the novel object in the incomplete-familiar condition than did the infants who viewed the incomplete cube during habituation and the novel object first during the test phase [$t(5) = 18.31, p < .05$]. This finding suggests that the incomplete-familiar infants looked longer at the novel object when the test trial order positioned the novel object second than did the infants who were habituated to the incomplete cube and viewed the novel object first in the test phase. It is possible that this effect is due to the fact that the infants in the incomplete-familiar group viewed the familiar object on the first test trial, allowing them to habituate further to the familiar object. This possibility is supported by an additional significant difference contributing to this interaction; the infants in the incomplete-familiar condition also looked significantly longer at the novel object than did the infants who viewed the complete cube during habituation and the novel object first during the test phase [$t(5) = 22.04, p < .01$]. Further planned comparisons revealed that the full-view group significantly dishabituated to the novel object on both presentations [$t(11) = 2.43$ for the first presentation, $t(11) = 1.96$ for the second presentation, $ps < .05$]. The full-view group did not significantly dishabituate to the familiar object. In contrast to the full-view group, the partial-view group showed no significant dishabituation (all $ts < 1.09$). These results provide further evidence that the full-view group discriminated the displays, whereas the partial-view group did not.

The 4-month-old infants in the partial-view condition provided no evidence of discriminating the extent of motion of the dots in the central region of the display. This finding suggests that the performance of the 4-month-old infants in the full-view group was not based on responding to proximal cues. Rather, the infants in the full-view group perceived the three-dimensional shape specified by the motion of the random dots. Thus, the findings of this study provide additional support to the claim that 4-month-old infants do perceive three-dimensional shape specified by motion-carried information. When viewing kinetic random-dot displays, the infants in this study responded to the distal shape rather than to proximal information. Moreover, these findings suggest that young infants may perceive three-dimensional shape in a manner similar to adults in that they are able to recover figural features from the relative motions of random dots.

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