

# Object Permanence in Young Infants: Further Evidence

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BAILLARGEON, RENÉE, AND DEVOS, JULIE. *Object Permanence in Young Infants: Further Evidence*. CHILD DEVELOPMENT, 1991, 62, 1227-1246. Recent evidence suggests that 4.5- and even 3.5-month-old infants realize that objects continue to exist when hidden. The goal of the present experiments was to obtain converging evidence of object permanence in young infants. Experiments were conducted using paradigms previously used to demonstrate object permanence in 5.5-month-old infants and 6.5-month-old infants. In one experiment, 3.5-month-old infants watched a short or a tall carrot slide along a track. The track's center was hidden by a screen with a large window in its upper half. The short carrot was shorter than the window's lower edge and so did not appear in the window when passing behind the screen; the tall carrot was taller than the window's lower edge and hence should have appeared in the window but did not. The infants looked reliably longer at the tall than at the short carrot event, suggesting that they (a) represented the existence, height, and trajectory of each carrot behind the screen and (b) expected the tall carrot to appear in the screen window and were surprised that it did not. Control trials supported this interpretation. In another experiment, 4.0-month-old infants saw a toy car roll along a track that was partly hidden by a screen. A large toy mouse was placed behind the screen, either on top or in back of the track. The female infants looked reliably longer when the mouse stood on top as opposed to in back of the track, suggesting that they (a) represented the existence and trajectory of the car behind the screen, (b) represented the existence and location of the mouse behind the screen, and (c) were surprised to see the car reappear from behind the screen when the mouse stood in its path. A second experiment supported this interpretation. The results of these experiments provide further evidence that infants aged 3.5 months and older are able to represent and to reason about hidden objects.

When adults see an object occlude another object, they typically make three assumptions. The first is that the occluded object continues to exist behind the occluding object. The second is that the occluded object retains the physical and spatial properties it possessed prior to occlusion. Finally, the third is that the occluded object is still subject to physical laws: its displacements and interactions with other objects do not become capricious or arbitrary but remain regular and predictable. When do infants begin to share these assumptions? Piaget (1954) was the first to address this question. Detailed analyses of infants' performance in manual search tasks led him to conclude that infants' beliefs about occluded objects develop slowly over the course of infancy. Un-

til about 9 months of age, Piaget maintained, infants do not understand that objects continue to exist when occluded. They believe that objects cease to exist when they cease to be visible and begin to exist anew when they become visible again. At about 9 months of age, infants begin to view objects as permanent entities that continue to exist when masked by other objects. However, this permanence is still limited. Infants do not yet conceive of occluded objects as occupying objective locations in space. Rather, they tend to confer on occluded objects "a sort of absolute position" (p. 46), the first place in which they were found. It is not until about 12 months of age, Piaget held, that infants begin to attend systematically to visible displacements and assume that oc-

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cluded objects reside in whatever locations they occupied immediately prior to occlusion. The final advance in the development of infants' beliefs about occluded objects follows the emergence of symbolic representation, at about 18 months of age. Because of their new representational capacity, infants become able to imagine invisible displacements and hence to infer occluded objects' locations. According to Piaget, objects' appearances and disappearances are then no longer mysterious but follow known, predictable patterns. Occluded objects are understood to be subservient to the same spatial and kinematic laws as visible objects.

Over the past 2 decades, many investigators have tested Piaget's description of the development of infants' beliefs about occluded objects (see Baillargeon, in press-a, in press-b; Bremner, 1985; Gratch, 1975, 1976; Harris, 1987, 1989; Schuberth, 1983; Sophian, 1984; and Wellman, Cross, & Bartsch, 1987, for reviews). In these tests, investigators have used Piaget's manual search tasks as well as novel visual tasks. The introduction of visual tasks stemmed from a concern that young infants might perform poorly on search tasks, not because their concept of object permanence is lacking or incomplete, but because their ability to plan means-end search sequences is limited. The results obtained with visual tasks have substantiated this concern: they indicate that Piaget seriously underestimated young infants' understanding of occlusion events (e.g., Baillargeon, 1986, 1987a, 1987b, 1991, in press-a, in press-b; Baillargeon, DeVos, & Graber, 1989; Baillargeon & Graber, 1987, 1988; Baillargeon, Graber, DeVos, & Black, 1990; Baillargeon, Spelke, & Wasserman, 1985; Spelke, 1988).

One experiment, for example, revealed that infants as young as 6.5 months of age are able to reason about the existence, location, and trajectory of occluded objects (Baillargeon, 1986). The infants sat in front of a small screen; to the left of this screen was a long, inclined ramp. The infants were habituated to the following event: the screen was raised (to show the infants that there was nothing behind it) and lowered, and a toy car rolled down the ramp, passed behind the screen, and exited the apparatus to the right. Following habituation, the infants saw two test events. These were identical to the habituation event except that a box was placed behind the screen. This box was revealed when the screen was raised. In one event (possible event), the box stood in *back* of the

car's tracks; in the other event (impossible event), the box stood on *top* of the car's tracks, blocking its path. The results indicated that the infants looked reliably longer at the impossible than at the possible event, suggesting that they were surprised to see the car reappear from behind the screen when the box stood in its path. A second condition in which the box was hidden in *front* (possible event) or on *top* (impossible event) of the car's tracks yielded the same results. Together, the results of these two conditions indicated that the infants (*a*) realized that the box and the car continued to exist behind the screen, (*b*) believed that the box retained its location behind the screen, (*c*) assumed that the car pursued its trajectory behind the screen, (*d*) understood that the car could not roll through the space occupied by the box, and hence (*e*) were surprised in the impossible event to see the car reappear from behind the screen.

Another experiment provided evidence that infants as young as 5.5 months of age are able to reason about the existence, height, and trajectory of occluded objects (Baillargeon & Graber, 1987). The infants were habituated to a toy rabbit sliding back and forth along a horizontal track whose center was occluded by a screen. On alternate trials, the infants saw a short or a tall rabbit slide along the track. Following habituation, the midsection of the screen's upper half was removed, creating a large window. The infants saw two test events. In one (possible event), the short rabbit moved back and forth along the track; this rabbit was shorter than the window's lower edge and so did not appear in the window when passing behind the screen. In the other event (impossible event), the tall rabbit moved back and forth along the track; this rabbit was taller than the window's lower edge and hence should have appeared in the window but did not. The results indicated that the infants looked equally at the short and the tall rabbit habituation events but looked reliably longer at the impossible than at the possible test event, suggesting that they (*a*) realized that each rabbit continued to exist behind the screen, (*b*) believed that each rabbit retained its height behind the screen, (*c*) assumed that each rabbit pursued its trajectory behind the screen, and hence (*d*) expected the tall rabbit to appear in the screen window and were surprised that it did not. This interpretation was supported by the results of a second condition that was identical to the experimental condition with one important

exception: prior to the habituation trials, the infants received two pretest trials in which they saw *two* short or *two* tall rabbits standing motionless on either side of the windowless habituation screen. Half of the infants saw the two short rabbits in the first trial and the two tall rabbits in the second trial; the other infants saw the rabbits in the opposite order. Unlike the infants in the experimental condition, the infants in this pretests condition looked equally at the impossible and the possible events. These results suggested that the infants were able to use the information presented in the pretest trials to make sense of the impossible event. Specifically, the infants understood that the tall rabbit did not appear in the screen window because it did not in fact travel the distance behind the screen: instead, one rabbit traveled along the left half of the track and another rabbit along the right half.

Yet another experiment provided evidence that 4.5- and even 3.5-month-old infants are able to reason about the existence of an occluded object (Baillargeon, 1987a). The infants were habituated to a screen that rotated back and forth through a 180° arc, in the manner of a drawbridge. Following habituation, a box was placed behind the screen, and the infants saw two test events. In one (possible event), the screen rotated until it reached the occluded box; in the other (impossible event), the screen rotated through a full 180° arc, as though the box were no longer behind it. The results indicated that the 4.5-month-old infants, and the 3.5-month-old infants who were fast habituators, looked reliably longer at the impossible than at the possible event, suggesting that they (a) believed that the box continued to exist behind the screen, (b) understood that the screen could not rotate through the space occupied by the box, and hence (c) expected the screen to stop in the impossible event and were surprised that it did not. Support for this interpretation came from a control condition that was identical to the experimental condition except that *no box* was placed behind the screen. Unlike the infants in the experimental condition, the infants in this control condition tended to look equally at the shorter (112° arc) and the longer (180° arc) screen rotations. Together, these results indicated that infants as young as 3.5 months of age are aware that objects continue to exist when occluded.

The goal of the present research was twofold. The first goal was to obtain converging evidence for Baillargeon's (1987a) con-

clusion that 3.5-month-old infants are able to represent and to reason about the existence of occluded objects. The second goal was to determine whether young infants can represent and reason about not only the existence but also some of the properties—such as the height, location, and trajectory—of occluded objects. Subjects were 3 to 4 months of age. Infants were tested with either the sliding rabbit task Baillargeon and Graber (1987) used successfully with 5.5-month-old infants (Experiments 1 and 2), or with the rolling car task Baillargeon (1986) used successfully with 6.5-month-old infants (Experiments 3, 3A, and 4). We reasoned that evidence that young infants performed successfully in these two tasks would have important implications for models of the development of object permanence in infancy.

### Experiment 1

Subjects in Experiment 1 were 3.5-month-old infants. The method of this experiment was similar to that used by Baillargeon and Graber (1987) with 5.5-month-old infants. The only departure from the description given above was that carrots were used instead of rabbits (see Fig. 1). In pilot work, some infants were found to be scared of the rabbits so they were replaced with less threatening-looking carrots.

### METHOD

#### Subjects

Subjects were 32 healthy, full-term infants ranging in age from 3 months, 5 days to 3 months, 27 days ( $M = 3$  months, 15 days). An additional 19 infants were excluded from the experiment because they failed to complete at least two pairs of test trials (see below), 13 due to fussiness, 3 due to drowsiness, and 3 due to procedural error. The infants' names in this experiment and in the following experiments were obtained from birth announcements in the local newspaper. Parents were contacted by letters and follow-up phone calls. They were offered reimbursement for their travel expenses but were not compensated for their participation.

Half of the infants were assigned to the experimental condition ( $M = 3$  months, 18 days) and half to the pretests condition ( $M = 3$  months, 12 days).

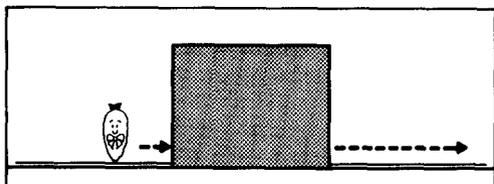
#### Apparatus

The apparatus consisted of a large wooden box 180 cm high, 136 cm wide, and 66 cm deep. The infant faced an opening 47

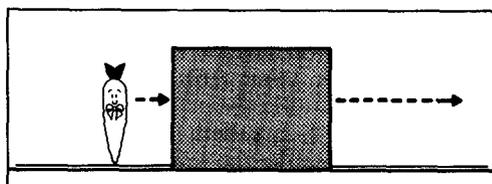
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### Habituation Events

#### Short Carrot Event

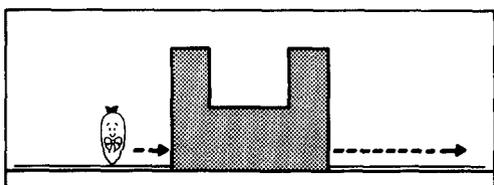


#### Tall Carrot Event



### Test Events

#### Possible Event



#### Impossible Event

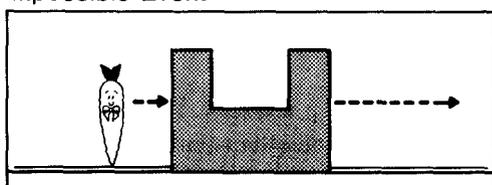


FIG. 1.—Schematic representation of the habituation and test events shown to the infants in the experimental condition in Experiment 1.

cm high and 108 cm wide in the front wall of the apparatus. The back and side walls of the apparatus were covered with colorful contact paper; the floor was painted black.

In the floor of the apparatus, parallel to the back wall and centered between the side walls, was a narrow track 126 cm long. Two carriers moved back and forth along this track, one along the left half and the other along the right half. Each carrier consisted of a styrofoam strip 9.5 cm high, 2 cm wide, and 1.5 cm thick. Inserted into the strip was a metal rod 9 cm high and 0.5 cm in diameter. The lower portion of this rod was attached underneath the floor of the apparatus to a cubical metal base 2 cm a side that slid along a metal guide rod 136 cm long and 0.75 cm in diameter. The base of each carrier was connected by a thin cable to a pulley and balance weight system on the side of the apparatus (left side for the left carrier and right side for the right carrier). Lowering the balance weight of a carrier down the side of the apparatus caused the carrier to slide from the center of the apparatus toward the side wall; conversely, raising the balance weight of a carrier caused it to slide back toward the center of the apparatus. To help the experimenters raise and lower the balance weights of the carriers at an even pace, a column of equally spaced marks was placed on each side of the apparatus; in addition, the experimenters listened through headphones to a metronome beating once per second.

Identical tall or short flat carrots were placed on the left and right carriers. These carrots were made of thick orange cardboard and were decorated with small, black-inked features and green cardboard bow ties; they also had leaves at their upper, larger ends made of green cardboard and decorated with green pom-poms. The tall carrots were 27 cm high, 0.6 cm thick, and 6.25 cm wide at their widest point; the short carrots were 15 cm high, 0.6 cm thick, and 6.25 cm wide at their widest point. Because the carriers stood 0.5 cm above the floor of the apparatus, the tall and the short carrots' total heights were 27.5 and 15.5 cm, respectively. Strips of Velcro were glued to the back of the carrots to attach them to the carriers.

Centered between the side walls, at a distance of 5.5 cm from the track and 29.5 cm from the back wall, was a three-sided metal frame consisting of two vertical bars, each 30.5 cm high and 2.5 cm wide, standing 26 cm apart, and connected at their base by a metal bar 1.5 cm high and 33.5 cm long. A cardboard screen could be attached to the vertical bars by strips of Velcro. Two screens were used in the experiment: a yellow screen 32 cm high and 42 cm wide and a blue screen also 32 cm high and 42 cm wide but with a window 16 cm high and 21 cm wide in the center of its upper half.

The infant was tested in a brightly lit room. Four clip-on lights (each with a

40-watt lightbulb) were attached to the back and side walls of the apparatus to provide additional light. These lights were arranged so as to prevent tell-tale shadows. Two frames, each 180 cm high and 60 cm wide and covered with blue cloth, stood at an angle on either side of the apparatus. These frames served to isolate the infant from the experimental room. At the end of each trial, a curtain consisting of a muslin-covered frame 52 cm high and 108 cm wide was lowered in front of the opening in the front wall of the apparatus.

### Events

Two experimenters worked in concert to produce the events; the first operated the left carrier and the second operated the right carrier.

*Tall carrot habituation event.*—In the tall carrot habituation event, the windowless yellow screen occluded the center of the track and the tall carrots stood on the left and right carriers.

At the start of the trial, the carrot placed on the left carrier stood visible at the left end of the track; the carrot placed on the right carrier stood just inside the right edge of the screen, hidden from the infant. After a 1-sec pause, the first experimenter slid the left carrot at the speed of about 21 cm/sec until it had slid 42 cm and stood just inside the left edge of the screen, hidden from the infant. After a 2-sec pause, the second experimenter slid the right carrot at the same speed of about 21 cm/sec until it had slid 42 cm and stood at the right end of the track. After a 1-sec pause, the entire process was repeated in reverse. The second experimenter returned the right carrot to its starting position behind the screen's right edge; the first experimenter waited 2 sec and then slid the left carrot from behind the screen's left edge back to its starting position at the left end of the track. Each event cycle thus lasted about 14 sec. Cycles were repeated until the computer signaled that the trial had ended (see below). When this occurred, the second experimenter lowered the curtain in front of the apparatus.

*Short carrot habituation event.*—The short carrot habituation event was identical to the tall carrot habituation event except that the short carrots were substituted for the tall carrots on the carriers.

*Impossible and possible test events.*—The impossible and the possible test events were identical to the tall and the short carrot habituation events, respectively,

except that the windowless yellow screen was replaced by the blue screen with the large window. We hoped that the change in the screen's color would draw the infants' attention to the screen, thus making them more likely to notice the presence of the window.

### Procedure

Prior to the experiment, each infant was allowed to manipulate a tall and a short carrot for a few minutes while his or her parent filled out consent forms. During the experiment, the infant sat on the parent's lap in front of the apparatus, facing the screen. The infant's head was approximately 66 cm from the screen and 96 cm from the back wall of the apparatus. The parent was asked not to interact with the infant during the experiment and to close his or her eyes during the test trials.

The infant's looking behavior was monitored by two observers who viewed the infant through peepholes in the cloth-covered frames on either side of the apparatus. The observers could not see the events from their viewpoints and they did not know the order in which the events were presented. Each observer held a button box linked to a MICRO/PDP-11 computer and depressed the button when the infant attended to the events. Each trial was divided into 100-msec intervals, and the computer determined in each interval whether the two observers agreed on the direction of the infant's gaze. Interobserver agreement was calculated for each trial on the basis of the number of intervals in which the computer registered agreement, out of the total number of intervals in the trial. Agreement in this experiment and in the following experiments averaged 91% or more per trial per infant. The looking times recorded by the primary observer were used to determine when a trial had ended (see below).

The infants in the *experimental* condition participated in a two-phase procedure consisting of a habituation phase and a test phase. During the habituation phase, the infants saw the tall and the short carrot habituation events described above on alternate trials. These trials served two purposes: they served to acquaint the infants with the carrots and their trajectories, and they made it possible to assess whether the infants found the tall carrot intrinsically more interesting than the short carrot. Each trial ended when the infant (*a*) looked away from the event for 2 consecutive sec after having looked at it for at least 6 cumulative sec or (*b*) looked

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at the event for 60 cumulative sec without looking away for 2 consecutive sec. Habituation trials continued until the infant (*a*) satisfied a criterion of habituation of a 50% or greater decrease in looking time on three consecutive trials, relative to the infant's looking time on the first three trials, or (*b*) completed nine habituation trials. Therefore, the minimum number of habituation trials an infant could receive was six, and the maximum number was nine. During the test phase, the infants saw the impossible and the possible test events described above on alternate trials until they had completed three pairs of test trials.<sup>1</sup> The criteria used to determine the end of each test trial were the same as for the habituation trials. The 6-sec minimum value was chosen to ensure that the infants had sufficient information to distinguish between the impossible and the possible test events. Half of the infants saw the habituation and test events with the tall carrot first; the other infants saw the habituation and test events with the short carrot first.

The infants in the *pretests* condition participated in a three-phase procedure comprising a pretest phase, a habituation phase, and a test phase. The habituation and test phases were identical to those in the experimental condition. During the pretest phase, the infants received a trial in which they saw *two tall carrots* standing motionless on either side of the windowless habituation screen, and a trial in which they saw *two short carrots* standing motionless on either side of the same screen. The carrots were positioned about halfway between the edges of the screen and the ends of the track. Analysis of the infants' looking times during these trials revealed no preference for the tall ( $M = 22.4$ ) over the short ( $M = 23.8$ ) carrots,  $F(1,15) = 0.46$ . Half of the infants saw the pretest, habituation, and test events with the tall carrot(s) first, and half with the short carrot(s) first.

Of the 32 infants in the experiment, 18 completed nine habituation trials without satisfying the criterion of habituation; the other infants took an average of 6.57 trials to reach the criterion. Four infants failed to complete the full complement of three pairs of test trials. These infants completed only two pairs, three because of fussiness and one

because of drowsiness. All subjects (in this experiment as well as in the subsequent experiments) were included in the data analyses, whether or not they had completed all three pairs of test trials. Preliminary analyses revealed no significant effect of order or sex on the infants' looking times at the impossible and the possible events during the three pairs of test trials, all  $F$ 's  $< 1.61$ ,  $p > .05$ . The data were therefore collapsed in subsequent analyses.

### RESULTS

Figure 2 shows the mean looking times of the infants in the experimental and the pretests conditions during the last three pairs of habituation trials and the three pairs of test trials. The infants' looking times during these trials were analyzed by means of a  $2 \times 2 \times 3 \times 2$  mixed-model analysis of variance with condition (experimental or pretests condition) as the between-subjects factor and with block (habituation or test trials), pair (first, second, or third pair of trials), and event (tall carrot/impossible or short carrot/possible event) as the within-subjects factors. Because the design was unbalanced, the SAS GLM procedure was used to calculate the analysis of variance (SAS Institute, 1985). There was a significant main effect of event,  $F(1,176) = 3.97$ ,  $p < .05$ , and a significant condition  $\times$  block  $\times$  event interaction,  $F(1,176) = 3.88$ ,  $p = .05$ . Planned comparisons revealed that the infants in the experimental condition looked about equally at the tall ( $M = 32.9$ ) and the short ( $M = 32.4$ ) carrot habituation events,  $F(1,176) = 0.03$ , but looked reliably longer at the impossible ( $M = 34.1$ ) than at the possible ( $M = 26.0$ ) test event,  $F(1,176) = 5.69$ ,  $p < .02$ . In contrast, no reliable difference was found between the looking times of the infants in the pretests condition at the tall ( $M = 34.5$ ) and the short ( $M = 29.2$ ) carrot habituation events,  $F(1,176) = 2.53$ ,  $p > .05$ , or at the impossible ( $M = 29.9$ ) and the possible ( $M = 30.7$ ) test events,  $F(1,176) = 0.05$ .

The initial analysis of variance also revealed a significant main effect of pair,  $F(2,176) = 19.49$ ,  $p < .0001$ , indicating that the infants looked reliably less as the habituation and test phases of the experiment progressed.

<sup>1</sup> Baillargeon and Graber (1987) gave their subjects four pairs of test trials but were unable to use the data from the fourth test pair because many of their subjects were fussy on that pair. We therefore decided to use only three test pairs in our experiment.

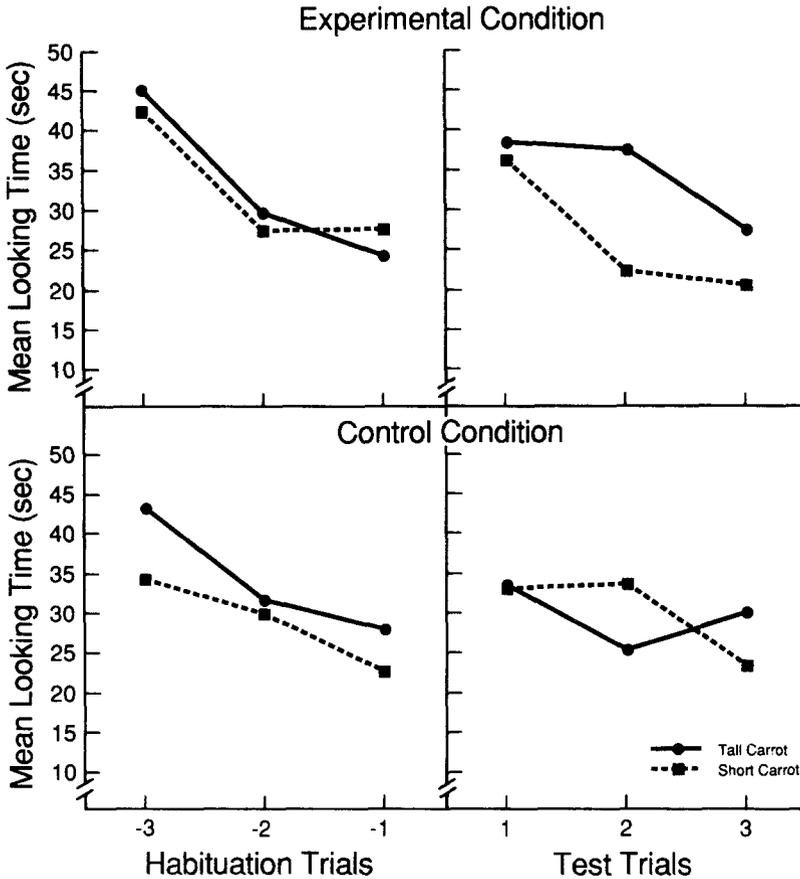


FIG. 2.—Mean looking times of the infants in the experimental and the pretests conditions in Experiment 1 at the habituation and test events.

## DISCUSSION

The infants in the experimental condition tended to look equally at the tall and the short carrot habituation events, but looked reliably longer at the impossible than at the possible test event. These results indicate that the infants (a) realized that each carrot continued to exist after it slid behind the screen, (b) assumed that each carrot retained its height behind the screen, (c) believed that each carrot pursued its trajectory behind the screen, and therefore (d) expected the tall carrot to be visible in the screen window and were surprised that it was not. These results confirm Baillargeon's (1987a) conclusion that infants as young as 3.5 months of age are aware that objects continue to exist when occluded. In addition, the results extend Baillargeon's (1987a) conclusion in that they indicate that 3.5-month-old infants can represent and reason about not only the existence but also the height and trajectory of occluded objects.

In contrast to the infants in the experimental condition, the infants in the pretests condition looked about equally at the impossible and the possible test events. At least two interpretations can be offered for this finding. One interpretation is that the infants made use of the information conveyed in the pretest trials to generate an explanation for the impossible event. Specifically, the infants understood that the tall carrot did not appear in the screen window in the impossible event because the tall carrot did not in fact travel the distance behind the screen. Instead, two separate carrots traveled along the track: one carrot traveled from the left end of the track to the left edge of the screen and stopped just inside this edge; a second, identical carrot then emerged from behind the right edge of the screen and traveled to the right end of the track. This interpretation, if valid, would provide strong additional support for the conclusion that 3.5-month-old infants are able to reason about

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the existence as well as the trajectory of occluded objects.

The other, less impressive interpretation for the results of the pretests condition is that the pretest trials biased the infants to attend to the two sides of the screen simultaneously, causing them to scan the habituation and the test events inappropriately. According to this explanation, the infants in the pretests condition looked equally at the impossible and the possible events, not because they realized that two carrots were used to produce each event, but because they were too confused to distinguish between the events. There are, however, several reasons to doubt this alternative interpretation. First, if the infants had been confused when watching the habituation events, one might have expected this confusion to have had some effect on their looking behavior. Yet statistical analyses revealed no differences (*a*) between the number of habituation trials completed by the infants in the experimental ( $M = 7.8$ ) and the pretests ( $M = 8.1$ ) conditions,  $F(1,28) = 0.60$ ; (*b*) between the total looking time during the habituation trials of the infants in the experimental ( $M = 247.3$ ) and the pretests ( $M = 240.4$ ) conditions,  $F(1,28) = 0.03$ ; (*c*) between the mean looking time during the habituation trials of the infants in the experimental ( $M = 33.5$ ) and the pretests ( $M = 31.1$ ) conditions,  $F(1,28) = 0.30$ ; (*d*) between the mean looking times during the first six habituation trials of the infants in the experimental ( $M = 34.6$ ) and the pretests ( $M = 31.5$ ) conditions,  $F(1,28) = 0.38$ ; and finally (*e*) between the mean looking time during the last six habituation trials of the infants in the experimental ( $M = 32.6$ ) and the pretests ( $M = 31.9$ ) conditions,  $F(1,28) = 0.04$ . The marked similarity between the habituation patterns of the infants in the experimental and the pretests conditions is inconsistent with the notion that one group had a straightforward interpretation of the events, while the other group was hopelessly confused by them. Second, even if the infants in the pretests condition had experienced some initial confusion left undetected by the aforementioned analyses, it is difficult to believe that the infants would still

have been confused by the events at the end of the habituation phase, after witnessing the carrots slide along the track over 30 times on the average (if the infants had watched the habituation events for a total of 240.4 consecutive sec across trials, they would have seen the carrots move from one end of the track to the other 34.3 times, since each half cycle lasted 7 sec). It seems highly unlikely that the infants would have failed after 30 observations to appreciate the simple translation patterns they were shown, especially in light of Haith's (in press) findings that infants this age can readily detect far more complex event regularities. A final reason for doubting the hypothesis that the infants in the pretests condition scanned the habituation and test events inappropriately is that it is inconsistent with observers' descriptions of the infants' performance. Observers reported that most infants in the experimental and the pretests conditions rapidly settled into following each carrot from left to right and right to left across the apparatus. Indeed, parents often mistakenly assumed that the true goal of the experiment was to establish how quickly their infants engaged in this following pattern.

In light of these arguments, it seems likely that the infants in the pretests condition looked equally at the impossible and the possible test events, not because they never fully perceived these events and so could not distinguish between them, but because they understood that two carrots were used to produce each event. In the absence of more direct supportive evidence,<sup>2</sup> however, this conclusion must remain tentative.

### Experiment 2

Would results similar to those of Experiment 1 be obtained with infants less than 3.5 months of age? To answer this question, 3.0-month-old infants were tested in Experiment 2 using the same method as in Experiment 1.

#### METHOD

##### Subjects

Subjects were 29 healthy, full-term infants ranging in age from 2 months, 14 days

<sup>2</sup> Such evidence could take several forms, such as (*a*) videotape data indicating that the looking behavior of infants in the experimental and the pretest conditions did not differ reliably, or (*b*) looking time data indicating that infants still showed a reliable preference for the impossible event when given two pretest trials with a tall and a short carrot standing motionless on either side of the screen (in this case, infants would no longer be given a "clue" as to how the impossible event was produced but would presumably still be biased to attend to the two sides of the screen simultaneously).

to 3 months, 4 days ( $M = 2$  months, 26 days). An additional 21 infants were eliminated from the experiment because they failed to complete at least two test pairs, 15 due to fussiness, 4 due to drowsiness, 1 due to equipment failure, and 1 due to the primary observer's inability to follow the direction of the infant's gaze. Sixteen infants were assigned to the experimental condition ( $M = 2$  months, 27 days) and 13 to the pretests condition ( $M = 2$  months, 24 days).

*Apparatus, Events, and Procedure*

The apparatus, events, and procedure used in Experiment 2 were identical to those in Experiment 1. Analysis of the looking times of the infants in the pretests condition during the two pretest trials revealed no preference for the tall ( $M = 22.1$ ) over the short ( $M = 23.2$ ) carrots,  $F(1,12) = 0.48$ . Of the 29 infants in the experimental and the pretests conditions, 13 failed to satisfy the

habituation criterion within nine trials; the other infants took an average of 7.44 trials to reach the criterion. Four infants completed only two pairs of test trials, one because of fussiness, one because of equipment failure, and two because the primary observer could not follow the direction of their gaze. Preliminary analyses revealed no significant effect of order or sex on the infants' looking times at the impossible and the possible events during the three pairs of test trials, all  $F$ 's  $< 2.04$ ,  $p > .05$ . The data were therefore collapsed in subsequent analyses.

RESULTS

Figure 3 shows the mean looking times of the infants in the experimental and the pretests conditions during the last three pairs of habituation trials and the three pairs of test trials. The infants' looking times were analyzed as in Experiment 1. The main ef-

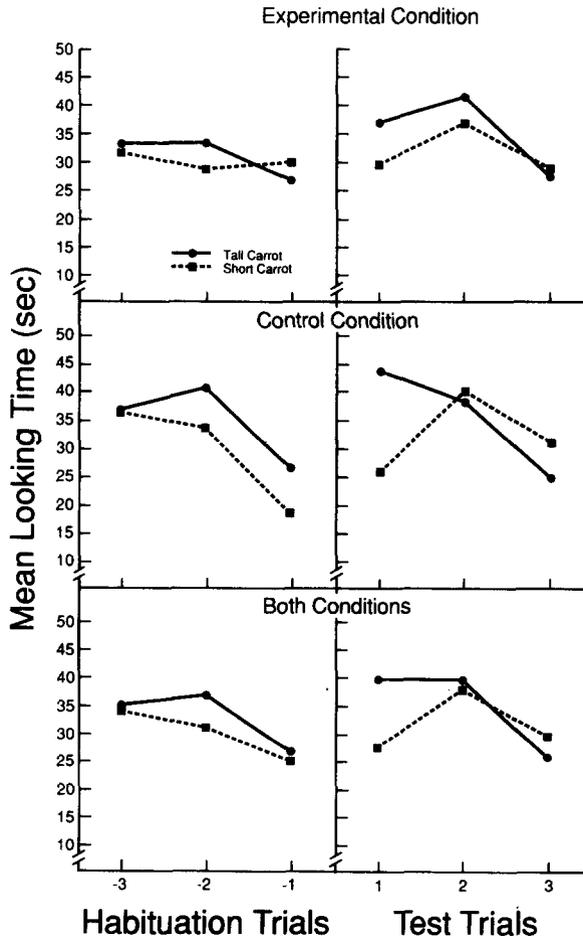


FIG. 3.—Mean looking times of the infants in the experimental and the pretests conditions in Experiment 2 at the habituation and test events.

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fects of condition,  $F(1,27) = 0.01$ , and event,  $F(1,208) = 3.18$ ,  $p > .05$ , were not significant, nor were any of the interactions involving these factors, all  $F$ 's  $< 2.42$ ,  $p > .05$ . There were thus no reliable differences between the looking times of the infants in the experimental and the pretests conditions at the tall and the short carrot habituation events or at the impossible and the possible test events.

### DISCUSSION

Unlike the 3.5-month-old infants in the experimental condition in Experiment 1, the 3.0-month-old infants in the experimental condition in Experiment 2 did not show a reliable preference for the impossible over the possible test event. As is often the case with negative results, this finding is open to several different interpretations. To illustrate, the infants' failure to show a reliable preference for the impossible event could be taken to suggest that the infants lacked a notion of object permanence and so did not realize that each carrot continued to exist, retained its height, and pursued its trajectory behind the screen. Alternatively, it could be proposed that the infants possessed a notion of object permanence but were prevented from detecting the violation embedded in the impossible event by procedural limitations. One such limitation might have been that the infants could perceive the surprising aspect of the impossible event only if they looked at the screen window during the 1 sec (per half cycle) the tall carrot was to have appeared there. Further research is necessary to determine which, if either, of these accounts best explains the poor performance of the infants in the experimental condition in Experiment 2.

Like the 3.5-month-old infants in the pretests condition in Experiment 1, the 3.0-month-old infants in the pretests condition in Experiment 2 showed no reliable preference for the impossible over the possible event. Because the 3.0-month-old infants in the experimental condition in Experiment 2 also failed to look reliably longer at the impossible than at the possible event, however, no clear conclusions can be drawn about the results of the pretests condition.

### Experiment 3

The results of Experiment 1 indicated that a paradigm used to demonstrate 5.5-month-old infants' ability to reason about the existence and properties of occluded objects (Baillargeon & Graber, 1987) could also be

used successfully with 3.5-month-old infants. Given this finding, we were encouraged to ask whether another paradigm, first used to reveal 6.5-month-old infants' understanding of occlusion events (Baillargeon, 1986), would also yield positive results with younger infants.

Subjects in Experiment 3 were 4.0-month-old infants. The method of this experiment was similar to that used by Baillargeon (1986). The only departure from the description given in the introduction was that a large toy mouse, rather than a box, was placed on top or in back of the car's path (see Fig. 4).

### METHOD

#### *Subjects*

Subjects were 32 healthy, full-term infants ranging in age from 3 months, 23 days to 4 months, 13 days ( $M = 3$  months, 29 days). Four additional infants were excluded from the experiment because they failed to complete at least two pairs of test trials, two due to fussiness and two due to procedural problems.

#### *Apparatus*

The apparatus consisted of a large unpainted wooden box 89 cm high, 152 cm wide, and 60 cm deep. The infant faced an opening 45 cm high and 150 cm wide in the front wall of the apparatus. The back wall of the apparatus was covered with blue cloth.

A wooden ramp 61 cm long and 13 cm wide was centered against the left wall of the apparatus below an opening 15 cm high and 15 cm wide. The ramp was 15 cm high at its highest point and sloped downward at a 16° angle. There was a rail 1 cm high and 0.5 cm wide on either side of the ramp. Two wooden tracks, each 91 cm long, 1 cm high, and 1 cm thick, lay 6 cm apart between the lower end of the ramp and an opening 13 cm high and 20 cm wide in the right wall of the apparatus. A toy car 8 cm high, 17 cm long, and 8 cm wide could roll onto the ramp through the opening in the left wall. The car rolled down the ramp, between the rails, and then rolled across the apparatus, along the tracks, until it disappeared through the opening in the right wall. The car was painted white and was decorated with red strips and green pom-poms. Black felt covered the ramp and tracks to minimize the car's noise. White muslin curtains hid the openings in the side walls of the apparatus; these curtains opened as the car went through and closed behind it.

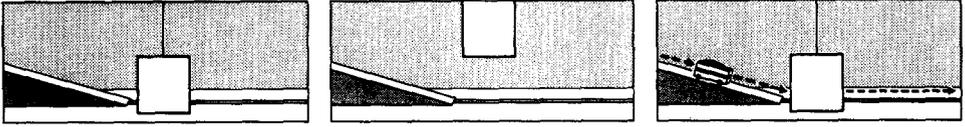
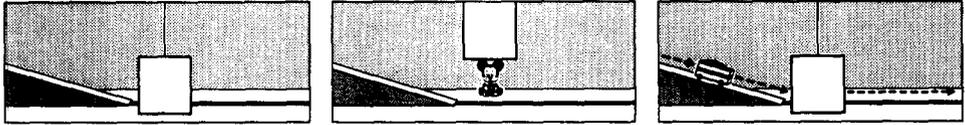
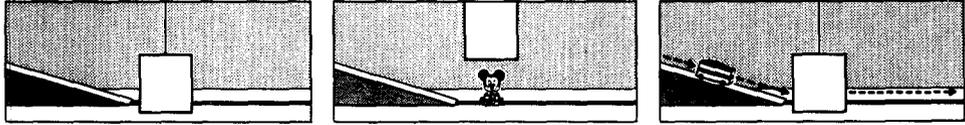
**HABITUATION EVENT****TEST EVENTS****Possible Event****Impossible Event**

FIG. 4.—Schematic representation of the habituation and test events shown to the infants in Experiment 3.

A yellow plastic screen 28 cm high and 26 cm wide stood 23 cm in front of the tracks at a distance of 61 cm from the left wall and 65 cm from the right wall. A wooden handle 91 cm high, 1.5 cm wide, and 1 cm thick was affixed to the back of the screen and protruded through the ceiling of the apparatus. The top portion of the handle fit into a vertical slit mounted inside the front wall of the apparatus. By raising and lowering the handle within this slit (from above), an experimenter could raise and lower the screen.

A brightly colored plastic toy mouse, approximately 17 cm high, 13 cm wide, and 10 cm thick, could be introduced into the apparatus through a hidden opening in the back wall. This toy represented a smiling Mickey Mouse, in a sitting position, playing with alphabet blocks.

The infant was tested in a brightly lit room. Four lights (each with a 40-watt light bulb) were attached to the front and side walls of the apparatus to provide additional light. These lights were arranged so as to eliminate tell-tale shadows. Two wooden frames, each 183 cm high and 70 cm wide and covered with blue cloth, stood at an angle on either side of the apparatus. These frames isolated the infant from the experimental room. At the end of each trial, a curtain consisting of a muslin-covered frame 63 cm high and 152 cm wide was lowered in front of the opening in the front wall of the apparatus.

**Events**

*Habituation event.*—Two experimenters worked in concert to produce the habituation event. The first operated the screen and the second operated the car. To start, the first experimenter lifted the screen 27 cm, taking about 1 sec to complete this action; she paused for about 2 sec, and then lowered the screen to its initial position, again taking about 1 sec to perform this action. After a 2.5-sec pause, the second experimenter pushed the car through the curtain at the top of the inclined ramp. The car then rolled down the ramp and across the apparatus, passing behind the screen, and finally exiting the apparatus to the right. The car took about 2.5 sec to roll in and out of the apparatus. About 2 sec after the car emerged from the apparatus, the first experimenter again lifted the screen, beginning a new event cycle. Each cycle thus lasted approximately 11 sec. Cycles were repeated without stop until the computer signaled the ending of the trial (see below). When this occurred, the second experimenter lowered the curtain in front of the apparatus.

*Impossible test event.*—The impossible test event was identical to the habituation test event with two exceptions. First, the mouse was placed on top of the car's tracks, centered behind the screen; the mouse was revealed when the screen was raised at the start of each event cycle. Second, after the screen was lowered, a third experimenter

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surreptitiously reached through the hidden opening in the apparatus's back wall and removed the mouse from the car's path. After the car rolled past the screen, this same experimenter quickly replaced the mouse on top of the tracks so that when the screen was next raised, the mouse stood intact in the same location as before. As in the habituation event, each cycle lasted approximately 11 sec, and the mouse was totally occluded for the last 7 of these 11 sec. The delay between the occlusion of the mouse and the reappearance of the car from behind the screen was about 4.5 sec.

*Possible test event.*—The possible test event was identical to the impossible test event except that the mouse was placed 10 cm behind the car's tracks. As in the impossible event, the third experimenter reached into the apparatus after the screen was lowered and grasped the mouse. This insured that any faint sounds associated with the mouse's surreptitious movement during the impossible event were also present during the possible event.

### *Procedure*

Prior to the experiment, the infant was allowed to manipulate the car and the mouse for a few minutes while his or her parent filled out consent forms. During the experiment, the infant sat on the parent's lap in front of the apparatus, facing the screen. The infant's head was approximately 60 cm from the screen and 117 cm from the back wall of the apparatus.

Each infant participated in a three-phase procedure consisting of a familiarization phase, a habituation phase, and a test phase. During the familiarization phase, the infant received two trials designed to acquaint him or her with the mouse's two possible locations. The screen remained lifted throughout these trials. In one trial, the mouse stood on top of the tracks; in the other trial, it stood behind the tracks. Each trial ended when the infant either (a) looked away from the display for 2 consecutive sec after having looked at it for at least 4 cumulative sec or (b) looked at the display for 60 cumulative sec without looking away for 2 consecutive sec.

Following the familiarization trials, each infant was habituated to the habituation event described above. The main purpose of this habituation phase was to acquaint the infant with the movements of the screen and car. Each habituation trial ended when the infant (a) looked away from the

event for 2 consecutive sec after having looked at it for at least 9 cumulative sec or (b) looked at the event for 60 cumulative sec without looking away for 2 consecutive sec. Habituation trials continued until the infant either (a) met a habituation criterion of a 50% or greater decrease in looking time on three consecutive trials, relative to the infant's looking time on the first three trials, or (b) completed nine habituation trials. Of the 32 infants in the experiment, 14 completed nine trials without satisfying the habituation criterion; the remaining infants took an average of 7.22 trials to meet the criterion.

During the test phase, the infants saw the impossible and the possible test events described above on alternate trials until they had completed four pairs of test trials. At the beginning of each test trial, the first experimenter waited to lower the screen until the computer signaled that the infant had looked at the mouse for 3 cumulative sec. This ensured that the infant had noted the presence and the location of the mouse behind the screen. Each test trial ended when the infant (a) looked away from the event for 2 consecutive sec after having looked at it for at least 6 cumulative sec (beginning at the end of the pretrial, when the first experimenter lowered the screen in front of the toy) or (b) looked at the event for 60 cumulative sec without looking away for 2 consecutive sec. Like the 9-sec value in the habituation trial, the 6-sec value was chosen to ensure that the infant had the opportunity to see the car reappear from behind the screen. Half of the infants saw the mouse on top of the tracks first during the familiarization and test trials; the other infants saw the mouse behind the tracks first.

Eleven of the 32 infants in the experiment completed fewer than four pairs of test trials. Four infants completed only three pairs, three because of fussiness and one because of drowsiness; the other infants completed only two pairs, six because of fussiness and one because of procedural error. Preliminary analyses revealed no significant effect of order on the infants' looking times at the impossible and the possible events during the four pairs of test trials, all  $F$ 's < 0.98. The data were therefore collapsed in subsequent analyses.

### RESULTS

The infants' looking times at the test events were analyzed by means of a  $4 \times 2$  mixed-model analysis of variance with pair

(first, second, third, or fourth pair of test trials) and event (impossible or possible event) as the within-subject factors. The main effect of event was not significant,  $F(1,181) = 0.80$ , indicating that the infants did not look reliably longer at the impossible ( $M = 27.4$ ) than at the possible ( $M = 25.8$ ) event. No other result was significant.

*Sex differences.*—Examination of the data suggested that the pattern revealed by the preceding analysis—statistically equal looking times at the impossible and the possible events—represented the average of two distinct looking patterns. Specifically, it appeared that the female infants ( $n = 16$ ,  $M = 4$  months, 0 day) in the experiment tended to look longer at the impossible than at the possible event, whereas the male infants ( $n = 16$ ,  $M = 3$  months, 29 days) tended to look equally at the two events (see Fig. 5).

An additional analysis was therefore carried out comparing the looking times of the male and female infants at the test events. This analysis was a  $2 \times 4 \times 2$  mixed-model analysis of variance with sex as the between-subjects factor, and with pair and

event as the within-subjects factors, as in the preceding analysis. The only significant effect was the interaction between sex and event,  $F(1,174) = 5.18$ ,  $p < .05$ . Follow-up analyses confirmed that the female infants looked reliably longer at the impossible ( $M = 31.1$ ) than at the possible event ( $M = 23.7$ ),  $F(1,174) = 4.15$ ,  $p < .05$ , whereas the male infants looked about equally at the two events,  $F(1,174) = 1.07$ ,  $p > .05$  (impossible:  $M = 24.1$ , possible:  $M = 27.6$ ).

Upon the obtention of these results, further analyses were undertaken comparing the responses of the male and female infants to the familiarization and habituation events. The results of these analyses indicated that the male and female infants in the experiment did not differ significantly in (a) their looking times at the two familiarization events,  $F(1,30) = 0.58$ ; (b) the number of habituation trials they received,  $F(1,30) = 1.30$ ,  $p > .05$ ; (c) their total looking times during the habituation trials,  $F(1,30) = 0.17$ ; (d) their mean looking times during the habituation trials,  $F(1,30) = 0.08$ ; and (e) their looking times during their last six habituation trials,  $F(1,30) = 0.53$ . The male and female infants in Experiment 3 thus differed

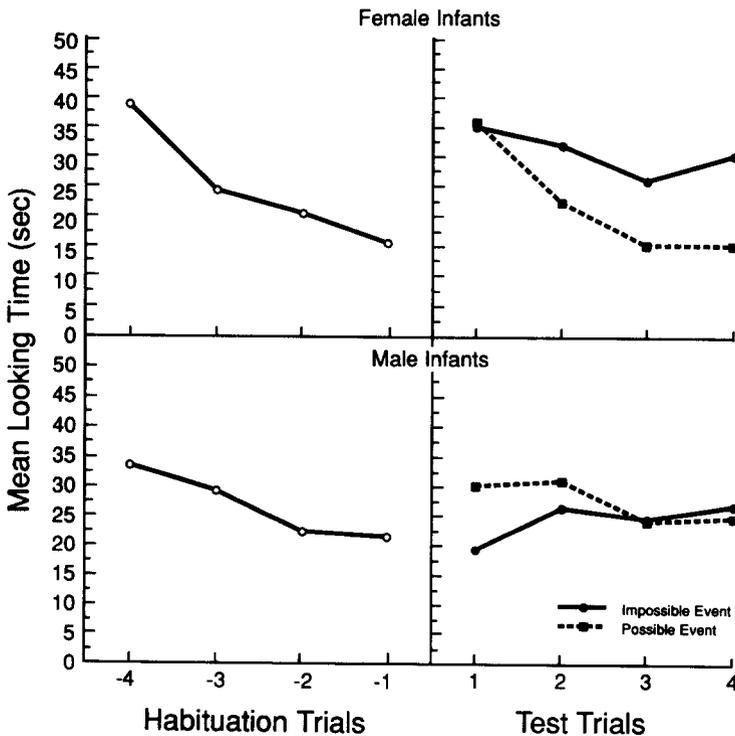


FIG. 5.—Mean looking times of the male and female infants in Experiment 3 at the habituation and test events.

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in their reactions to the test but not the familiarization and habituation events, as assessed by these measures.

The female infants' reliable preference for the impossible over the possible test event suggested that they were surprised to see the car reappear from behind the screen when the mouse stood on top of the tracks. However, another possible interpretation for this finding was that the female infants found the mouse especially attractive and so looked longer when it stood closer to them. Analysis of the female infants' responses to the two familiarization events provided evidence against this interpretation: the female infants' looking times did not differ reliably when the mouse stood on top ( $M = 27.6$ ) or in back ( $M = 31.3$ ) of the tracks,  $F(1,15) = 0.46$ . To provide further evidence against this alternative interpretation, and at the same time confirm female infants' surprise at the impossible test event, an additional group of 4.0-month-old female infants was run in Experiment 3A. This experiment's method was identical to that of Experiment 3 except that the mouse was placed in front rather than in back of the tracks in the possible test event (see Baillargeon, 1986). We reasoned that if the female infants in Experiment 3 looked longer at the impossible event because the mouse stood closer to them, then the infants in Experiment 3A should look longer at the possible (front) than at the impossible (top) event.

The performance of the male infants in Experiment 3 will be discussed after the presentation of the results of Experiments 3A and 4.

### Experiment 3A

#### METHOD

##### *Subjects*

Subjects were 16 healthy, full-term, female infants ranging in age from 3 months, 23 days to 4 months, 14 days ( $M = 4$  months, 2 days). Three additional infants were eliminated from the experiment because of fussiness.

##### *Apparatus, Events, and Procedure*

The apparatus, events, and procedure used in Experiment 3A were identical to those in Experiment 3 except that the mouse was positioned 10 cm in front instead of in back of the tracks in the familiarization and test events.

Analysis of the infants' looking times at the two familiarization events indicated that

they looked about equally when the mouse was positioned on top ( $M = 29.4$ ) or in front ( $M = 30.5$ ) of the tracks,  $F(1,15) = 0.03$ . Four infants completed nine habituation trials without satisfying the habituation criterion; the other infants took an average of 7.17 trials to reach the criterion. Three infants completed fewer than four pairs of test trials. Two infants completed only three pairs, one because of fussiness and one because the primary observer could not follow the direction of the infant's gaze; the remaining infant completed only two pairs, because of fussiness. Preliminary analyses revealed no significant effect of order on the infants' looking times at the impossible and the possible events during the four pairs of test trials, all  $F$ 's  $< 1.55$ ,  $p > .05$ . The data were therefore collapsed in subsequent analyses.

#### RESULTS

Figure 6 shows the infants' mean looking times at the impossible and the possible events. For purposes of comparison, the mean looking times of the female infants in Experiment 3 are also presented. It can be seen that both groups of infants tended to look longer at the impossible event.

The looking times of the infants in Experiment 3A were compared to those of the female infants in Experiment 3 by means of a  $2 \times 4 \times 2$  mixed-model analysis of variance with experiment (3 or 3A) as the between-subjects factor and with pair (first, second, third, or fourth test pair) and event (impossible or possible event) as the within-subjects factors. The main effect of event was significant,  $F(1,104) = 9.67$ ,  $p < .003$ , indicating that the infants looked reliably longer overall at the impossible ( $M = 34.6$ ) than at the possible ( $M = 28.4$ ) event. The effect of condition was not significant,  $F(1,30) = 2.78$ ,  $p > .05$ , nor was any of the interactions involving this factor, all  $F$ 's  $< 2.64$ ,  $p > .05$ , indicating that there were no reliable differences between the looking times of the female infants in Experiments 3 and 3A at the impossible and the possible events (Experiment 3: impossible,  $M = 31.1$ , possible,  $M = 23.7$ ; Experiment 3A: impossible,  $M = 37.7$ , possible,  $M = 32.4$ ). No other result was significant.

#### DISCUSSION

Like the female infants in Experiment 3, the female infants in Experiment 3A looked reliably longer at the impossible than

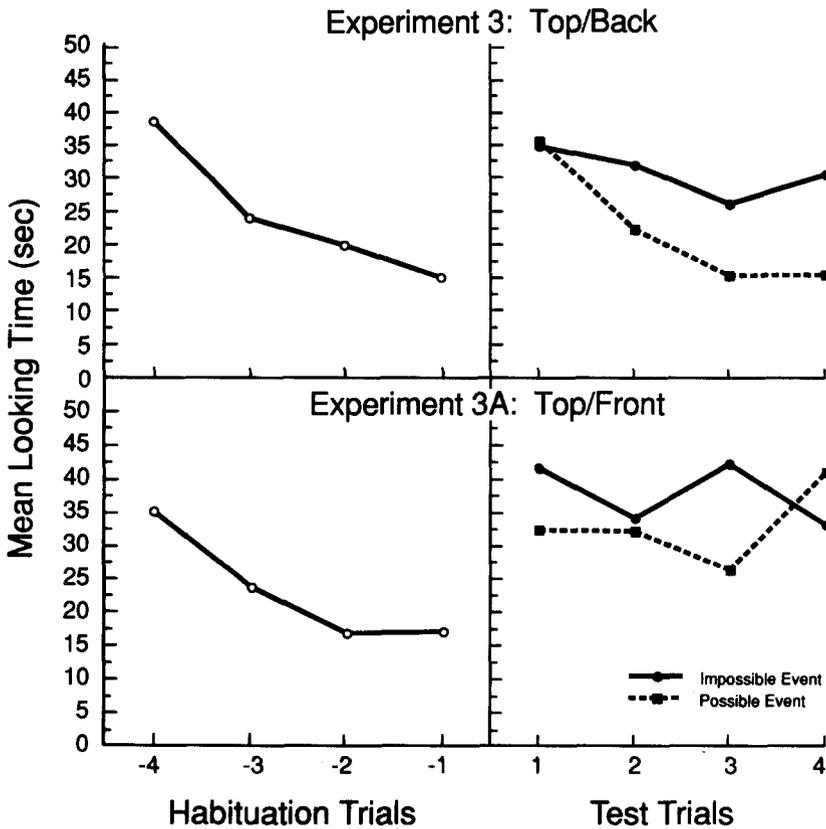


FIG. 6.—Mean looking times of the female infants in Experiments 3 and 3A at the habituation and test events.

at the possible event. Together, these results suggest that the female infants in these two experiments (*a*) realized that the mouse and the car continued to exist behind the screen, (*b*) believed that the mouse retained its location behind the screen, (*c*) assumed that the car pursued its trajectory behind the screen, (*d*) understood that the car could not roll through the space occupied by the mouse, and hence (*e*) were surprised to see the car reappear from behind the screen when the mouse stood on top of the tracks. The results of Experiments 3 and 3A are thus consistent with those of Experiment 1 in suggesting that young infants can represent and reason about not only the existence but also some of the properties—such as the location and trajectory—of occluded objects.

#### Experiment 4

Would results similar to those obtained with the female infants in Experiment 3 also be obtained with younger female infants? To find out, 3.5-month-old female infants were tested using the same procedure as in Experiment 3.

#### METHOD

##### Subjects

Subjects were 20 healthy, full-term infants ranging in age from 3 months, 6 days to 3 months, 22 days ( $M = 3$  months, 16 days). One additional infant was excluded from the experiment because she failed to complete at least two pairs of test trials due to fussiness.<sup>3</sup>

<sup>3</sup> The reader may be puzzled by the fact that the attrition rate due to fussiness in Experiments 3, 3A, and 4 was so much smaller than that in Experiments 1 and 2, despite the general similarity of the subjects' ages. There were 32 infants in Experiment 3, and two additional infants were eliminated because of fussiness. The corresponding figures for the other experiments were: 3A, 16 and 3; 4, 20 and 1; 1, 32 and 13; and 2, 29 and 15. We are not entirely clear as to the reasons for this difference. The infants generally loved the car experiment, but seemed more

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### *Apparatus, Events, and Procedure*

The apparatus, events, and procedure used in Experiment 4 were identical to those in Experiment 3. During the two familiarization trials, the infants looked about equally when the mouse stood on top ( $M = 31.2$ ) and in front ( $M = 28.5$ ) of the tracks,  $F(1,19) = 0.28$ . Ten of the 20 infants in the experiment completed nine habituation trials without reaching the habituation criterion; the remaining infants took an average of 7.30 trials to reach the criterion. Eight infants failed to complete the full complement of four pairs of test trials. Four infants completed only three pairs, three because of fussiness and one because of drowsiness; the other infants completed only two pairs, one because of fussiness, one because of drowsiness, and two because of procedural error. Preliminary analyses revealed no significant effect of order on the infants' looking times at the impossible and the possible events during the four pairs of test trials, all  $F$ 's  $< 0.78$ . The data were therefore collapsed in subsequent analyses.

### RESULTS

Figure 7 presents the infants' mean looking times at the impossible and the possible test events. The data were analyzed by means of a  $4 \times 2$  mixed-model analysis of variance with pair (first, second, third, or fourth test pair) and event (impossible or possible event) as within-subject factors. The main effect of event was not significant,  $F(1,64) = 2.41$ ,  $p > .05$ , indicating that the infants did not look reliably longer at the impossible ( $M = 30.9$ ) than at the possible ( $M = 27.4$ ) event. No other result was significant.

### DISCUSSION

Like the 4.0-month-old male infants in Experiment 3, the 3.5-month-old female infants in Experiment 4 failed to show a reliable preference for the impossible over the possible event, suggesting that they were not surprised to see the car roll past the screen when the mouse stood in its path.

How can we explain the discrepancy between these negative findings and the positive findings obtained with the 4.0-month-old female infants in Experiments 3 and 3A? Given the results of Experiment 1 and those of Baillargeon (1987a), it is plausible that the 4.0-month-old male infants in Experiment 3 and the 3.5-month-old female infants in Experiment 4 (a) believed that the mouse continued to exist behind the screen, (b) assumed that the car continued to exist and pursued its trajectory behind the screen, and (c) understood that the car could not roll through the space occupied by the mouse. Nevertheless, the infants may have lacked some other conceptual ability necessary for detecting the surprising character of the impossible event, such as the ability to keep track of the mouse's location on each trial, or the ability to reason about the interaction of two simultaneously occluded objects, such as the mouse and the car.

Another explanation for the infants' failure to notice the violation embedded in the impossible event is that this failure stemmed not from a conceptual but from a perceptual limitation. Clearly, if the infants lacked the visual skills necessary to determine that the mouse stood on top or in back of the car's tracks, they could not have distinguished between the impossible and the possible events. Recent research on the development of stereopsis may be relevant here (e.g., Birch, Gwiazda, & Held, 1982; Gwiazda, Bauer, & Held, 1989a, 1989b; Held, Birch, & Gwiazda, 1980; Held, in press). Investigators have found that following the onset of coarse stereopsis (30 or more min of disparity), sensitivity to disparity rapidly increases to 1 min of arc (Birch et al., 1982; Held et al., 1980). In these developments, male infants lag behind female infants by several weeks. For example, Gwiazda et al. (1989a) found the mean age of onset of stereopsis to be 9.1 weeks for female infants, as compared with 12.1 weeks for male infants. These and related findings suggest the following speculation. It may be that the 4.0-month-old female infants in Experiments 3 and 3A had achieved sufficient stereoacuity to assess ac-

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ambivalent about the carrot experiment. One reason for this difference may have been that the car events were more complex and thus more engaging. Another reason may have been that the infants were troubled by the conflict between the animate and inanimate features of our carrots (e.g., they possessed facial features and moved in some respects like animate organisms, stopping and reversing direction without obvious external forces being applied; yet they were clearly toylike objects). This second reason is consistent with observers' comments that the infants who did not complete Experiments 1 and 2 often appeared scared of the carrots. Researchers interested in replicating these experiments might be better served by using less animate-like stimuli, such as simple geometric shapes.

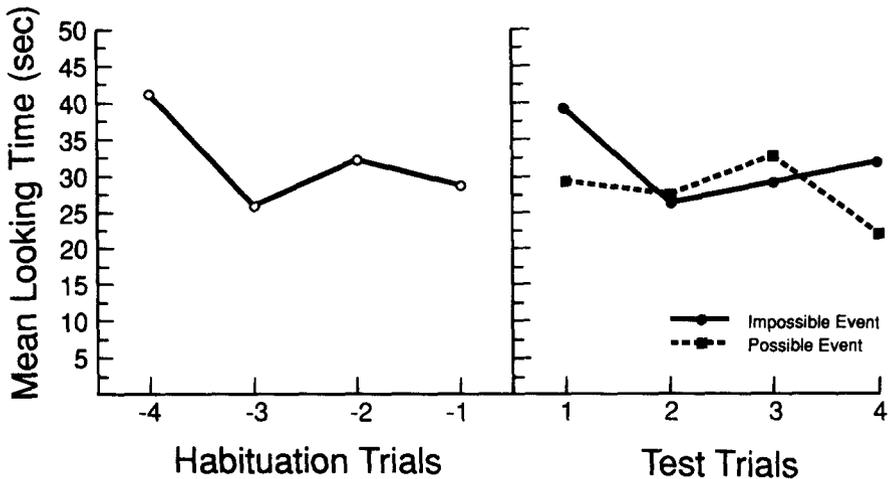


FIG. 7.—Mean looking times of the female infants in Experiment 4 at the habituation and test events.

curately the location of the mouse relative to the car's tracks, but that the 3.5-month-old female infants in Experiment 4 and the 4.0-month-old male infants in Experiment 3 had not. As already mentioned, if these infants were unable to determine whether the mouse stood in or out of the path of the car, they could not have distinguished between the possible and the impossible events since these events were identical in all other respects. This explanation could perhaps be tested by altering our current experimental procedure so as to provide infants with better or richer depth information. Such alterations might include (a) increasing the distance between the mouse and the car's tracks in the possible event, to make this distance more salient and hence more easily detectable; (b) rocking the infant gently back and forth in front of the display when the mouse is in view, to enhance kinetic depth information; and/or (c) moving the mouse gently back and forth in its location when in view, for the same reason.

### Conclusion

When adults see an object occlude another object, they typically make three assumptions. The first is that the occluded object continues to exist behind the occluding object. The results of the present experiments indicate that young infants also share this assumption. Thus, the 3.5-month-old infants in Experiment 1 believed that each carrot continued to exist after it slid behind the screen. Similarly, the 4.0-month-old female infants in Experiments 3 and 3A believed that (a) the mouse continued to exist after it

was occluded by the screen and (b) the car continued to exist after it rolled behind the screen. These results are consistent with and provide converging evidence for Baillargeon's (1987a) claim that infants as young as 3.5 months of age represent the continued existence of occluded objects.

The second assumption adults generally hold about occluded objects is that they retain the physical and spatial properties they possessed prior to occlusion. The present results suggest that young infants also share this second assumption. The 3.5-month-old infants in Experiment 1 realized that each carrot retained its height behind the screen, and the 4.0-month-old female infants in Experiments 3 and 3A believed that the mouse retained its location behind the screen.

Finally, the third assumption adults hold about occluded objects is that they remain subject to physical laws: their displacements and interactions with other objects do not become capricious or arbitrary but follow the same regular patterns as visible objects. The results of the present experiments cannot tell us whether young infants have any conception of physical laws; indeed, it seems highly unlikely that young infants could appreciate the necessary character of such laws. However, the present results do suggest that young infants expect occluded objects to behave in the same predictable manner as visible objects. Thus, the 3.5-month-old infants in the experimental condition in Experiment 1 believed that each carrot pursued a spatially continuous trajectory behind the screen, just as it did on either side of the screen. Similarly, the 4.0-month-

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old female infants in Experiments 3 and 3A assumed that the car rolled along a continuous path behind the screen, just as it did before and after its passage behind the screen. Furthermore, the 4.0-month-old female infants in Experiments 3 and 3A appreciated that the occluded car could not roll through the space occupied by the occluded mouse. This last result is consistent with Baillargeon's (1987a) observation that infants aged 3.5 months and older understand that a rigid screen cannot rotate through the space occupied by a box placed behind the screen. Together, these results suggest that young infants have general expectations about objects' displacements and interactions and believe, very sensibly, that these expectations apply to visible as well as to occluded objects.

Piaget (1954) described the development of object permanence in terms of the slow amalgamation of two initially separate worlds. To start, Piaget maintained, infants distinguish between the visible world, filled with solid entities whose behaviors can be known and understood, and the occluded world, a void which objects, like occult spirits, enter and leave without any discernible design (pp. 11–13). By the end of the second year, however, infants regard occluded objects as substantial entities that obey the same laws as visible objects.

The present results, together with those of Baillargeon (1987a), provide little support for Piaget's characterization of the development of the object concept in infancy. On the contrary, the present results suggest that, from very early on, infants conceive of occluded objects in the same general manner as adults, as inhabiting the same world and as conforming to the same patterns as visible objects.

To say that infants *conceive* of occluded objects as adults do—because they share the same three basic assumptions about these objects—is not to say that infants always *reason* about occluded objects as adults do. Young infants' ability to represent and to reason about occluded objects is clearly more limited than that of adults and must develop through infancy and childhood. To illustrate, consider the habituation and test events shown to the infants in the experimental condition in Experiment 1. Adults might have noticed from the start that the noise that accompanied the movement of each carrot to the left or the right of the screen stopped abruptly when the carrot slid behind the screen. On the basis of this cue,

adults might have concluded that two separate carrots were used in producing the habituation and test events, thereby accounting for the tall carrot's failure to appear in the screen window in the impossible test event. The results of the experimental condition in Experiment 1 suggest that the 3.5-month-old infants in this condition, like the 5.5-month-old infants tested by Baillargeon and Graber (1987), did not attend to or failed to comprehend the implications of these auditory cues.

There already have been attempts at charting some of the ways in which infants' ability to reason about occluded objects develops over time (e.g., Baillargeon, 1991, in press-a, in press-b; Baillargeon & DeVos, 1991). One hypothesis to emerge from this research is that infants succeed in solving occlusion problems requiring *qualitative* reasoning strategies before they succeed in solving occlusion problems requiring *quantitative* strategies. Reasoning strategies are referred to as quantitative if they require infants to reason about specific quantities, and as qualitative if they do not.

This distinction gives rise to interesting speculations about the way in which the infants in the present experiments solved the problems they were given. To solve the rolling car problem used in Experiments 3, 3A, and 4, the infants did not need to represent and to reason about specific quantities: all they had to do was to note the location of the mouse relative to the path of the car. However, in order to solve the sliding carrot problem used in Experiments 1 and 2, the infants could use one of two strategies. One quantitative strategy involved mentally comparing the height of each carrot, after it slid behind the screen, to that of the window's lower edge to see whether the former was greater than the latter. This strategy is referred to as quantitative because it required the infants to represent the specific height of each carrot. The other, qualitative strategy involved visually comparing each carrot as it approached the screen to determine whether the carrot was taller than the window's lower edge. This strategy is said to be qualitative because it did not necessitate the representation of specific quantities, only the encoding of relative quantities. All that the infants needed to do was to note whether the carrot was taller than the window: the two objects' specific heights were irrelevant.

The present data are insufficient to determine whether the 3.5-month-old infants in Experiment 1 used a quantitative or a

qualitative strategy to reason that the tall carrot should appear in the screen window. However, data collected by Baillargeon (1991), using the rotating screen paradigm, suggest that the latter possibility is more likely. In a series of experiments, Baillargeon found that it was not until 6.5 months of age that infants could predict quantitatively at what point a rotating screen should contact the box placed behind it and stop (i.e., by using their representation of the occluded box's height and location). At 4.5 months of age, infants could only predict the screen's stopping point qualitatively, by using as reference point a second, identical box placed to the side of the occluded box, out of the path of the screen. It seems likely that, like the 4.5-month-old infants in Baillargeon's experiments, the 3.5-month-old infants in Experiment 1 were using a qualitative, visual alignment strategy to predict whether each carrot should be visible in the screen window.

Beyond the theoretical issues addressed in the previous discussion, the results of the present experiments also have important methodological implications. One such implication is that the present results reinforce the previously noted (e.g., Baillargeon, in press-a; Baillargeon et al., 1985, 1990) discrepancy between investigations of infants' physical world that have relied on visual tasks as opposed to manual search tasks. The results of the present experiments suggest that by 3.5 to 4.0 months of age, infants are able to represent the existence and location of occluded objects. Yet it is not until several months later that infants (a) begin to search for objects they have observed being hidden and (b) correctly search for objects hidden in one of two locations (e.g., Diamond, 1985; Piaget, 1954; Wellman et al., 1987). The reader is referred to Baillargeon (in press-a; Baillargeon et al., 1989, 1990) for an account of the late emergence and slow development of infants' manual search in terms of the limitations of infants' problem-solving skills.

Another methodological implication of the present results and of those found by Baillargeon (1987a) concerns researchers' selection of object permanence tests for use with young infants. These results make clear that whether a test yields positive findings very much depends on which test is used; all tests are not created equal. The rotating screen paradigm used by Baillargeon (1987a) provided evidence of object permanence in 4.5-month-old infants and in fast but not in slow habituating 3.5-month-old

infants. The sliding carrot paradigm used in Experiment 1 yielded positive evidence with 3.5-month-old infants. Finally, the rolling car paradigm used in Experiments 3, 3A, and 4 generated negative results with 3.5-month-old infants, albeit positive results with 4.0-month-old female infants. Detailed task analyses are needed to determine why certain tasks prove more difficult for infants than others, and why these difficulties result at times in differences between fast and slow habituators and at times in differences between male and female infants.

In conclusion, the results of the present experiments point to remarkable knowledge and abilities on the part of young infants. Young infants are aware that objects (a) cannot exist at two successive points in time without having existed during the interval between them, (b) cannot appear at two separate points in space without having traveled the distance between them, and (c) cannot move through the space occupied by other objects. Furthermore, infants are able to use this knowledge to make (qualitative and perhaps quantitative) predictions about objects' displacements and interactions with other objects. Though unexpected from the point of view of traditional developmental theory, these findings are nevertheless consistent with recent investigations of other facets of young infants' physical world (e.g., Baillargeon, 1991; Baillargeon & Hanko-Summers, 1990; Needham & Baillargeon, 1991). Together, these results underscore the richness and sophistication of young infants' physical world and raise important questions about the origins and development of this world.

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