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Where's the Rabbit? 5.5-Month-Old Infants' Representation of the Height of a Hidden Object

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Two experiments examined 5.5-month-old infants' ability to represent the height of a hidden object. The infants saw two test events in which a toy rabbit travelled along a horizontal track; the center of this track was hidden by a screen that had a large window in its upper half. The only difference between the two test events was in the height of the rabbit. In one event (possible event), the rabbit was shorter than the lower edge of the window; in the other (impossible event), the rabbit was taller than the window's lower edge. In both events, the rabbit travelled along the track, disappearing at one end of the screen and reappearing at the other, *without* appearing in the window. The infants looked reliably longer at the impossible than at the possible event, indicating that they (a) believed that the rabbit continued to exist and pursued its trajectory behind the screen; (b) represented the height of the rabbit behind the screen; and therefore (c) expected the tall rabbit to appear in the window and were surprised that it failed to do so. A control condition in which a pretest display suggested that two separate rabbits were used to produce the events (one travelling to the left and the other to the right of the screen) supported this interpretation. The results have implications for research on the development of infants' ability to represent and use information about the physical and spatial properties of hidden objects.

When adults see an object occlude another object, they generally assume that the occluded object continues to exist behind the occluding object and retains the physical and spatial properties it possessed prior to occlusion. Do infants make the same assumptions? Piaget (1954) was the first to examine this question. He concluded that infants' beliefs about occluded objects develop slowly during the

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first year of life. Prior to the age of 9 months, 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 existing anew when they come back into view. At about 9 months of age, infants begin to endow objects with permanence; they become aware that objects 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 and as participating in physical relations with other objects. According to Piaget, it is not until infants are about 12 months of age that they are able to represent and to reason about the physical and spatial properties of occluded objects.

Over the last 20 years, Piaget's description of the development of infants' beliefs about occluded objects has been tested by numerous researchers (see Bremner, 1985; Harris, in press; Schuberth, 1983; Sophian, 1984; and Wellman, Cross, & Bartsch, in press, for recent reviews). Several of these researchers have obtained results that contradict the claim that infants less than 9 months of age do not realize that objects continue to exist when occluded (e.g., Baillargeon, 1987a; Baillargeon, Spelke, & Wasserman, 1985; Hood & Willats, 1986). For example, Baillargeon (1987a) habituated 3.5- and 4.5-month-old infants to a screen that rotated back and forth through a 180° arc, in the manner of a drawbridge. After 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-olds, and the 3.5-month-olds 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 after it was occluded by the screen and (b) expected the screen to stop when it reached the occluded box and were surprised that it failed to do so. Control experiments conducted without the box supported this interpretation. Together, the results of these experiments indicated that infants as young as 3.5 months of age represent the existence of occluded objects.

Investigators have also obtained results that contradict the claim that infants less than 12 months of age do not represent the physical and spatial properties of occluded objects (e.g., Baillargeon, 1986, 1987b; Baillargeon & Graber, 1987; Campos & Bertenthal, in press; Diamond, 1985; Wellman et al., in press). For example, Diamond (1985) reported that 7.5-month-old infants can retrieve an object hidden in one of two locations, provided that they are allowed to search immediately after the object is hidden. Baillargeon (1986) also found evidence that 6.5-month-old infants can represent the location of an object hidden at one of two distances behind a screen. In her experiment, infants aged 6.5 and 8 months sat in front of a small screen; to the left of the screen was a long, inclined ramp. The infants were habituated to the following event: The screen was raised (so that the infants could see 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. After habituation, the infants saw two test events that were identical to the habituation event except that a box now stood behind the screen. 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 tracks, blocking the car's 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 experiment in which the box was placed in *front* (possible event) or on *top* (impossible event) of the car's tracks yielded the same results. Together, the results of these experiments indicated that the infants (a) represented the location of the box behind the screen and (b) expected the car to stop when the box stood in its path and were surprised that it did not do so.

The findings reviewed above are consistent with two alternative claims. The first, weaker claim is that Piaget was correct in stating that infants' beliefs about occluded objects develop through a stage sequence but underestimated by at least 5.5 months the rate at which infants progress through the sequence (infants would begin to represent the existence and the properties of occluded objects at about 3.5 and 6.5 months, respectively, rather than at about 9 and 12 months, as Piaget thought). The second, more radical claim is that Piaget was mistaken in assuming that infants represent first the existence and later the properties of occluded objects. (Infants would realize at one and the same time that objects continue to exist and retain their properties when occluded.)

Evidence that infants younger than 6.5 months of age can represent the properties of occluded objects would argue against the first of these alternative claims. Clearly, the narrower the gap between the ages at which infants are shown to be able to represent the existence and the properties of occluded objects, the less plausible the hypothesis that these two abilities develop sequentially. The present experiment was designed to address this issue. It examined 5.5-month-olds' ability to represent the height of an occluded object.

The infants saw two test events in which a toy rabbit traveled along a horizontal track whose center was occluded by a screen. The midsection of the upper half of the screen had been removed, creating a large window. The only difference between the two test events was in the height of the rabbit. In one event (possible event), the rabbit was shorter than the lower edge of the window; in the other (impossible event), the rabbit was taller than the window's lower edge. In both events, the rabbit traveled along the track, disappearing at one end of the screen and reappearing at the other end, *without* appearing at the window (see Figure 1).

Our reasoning was as follows. If the infants (a) believed that the rabbit continued to exist and pursued its trajectory behind the screen and (b) represented the height of the rabbit behind the screen, then they should be surprised when the tall rabbit reappeared on the other side of the screen without having appeared in

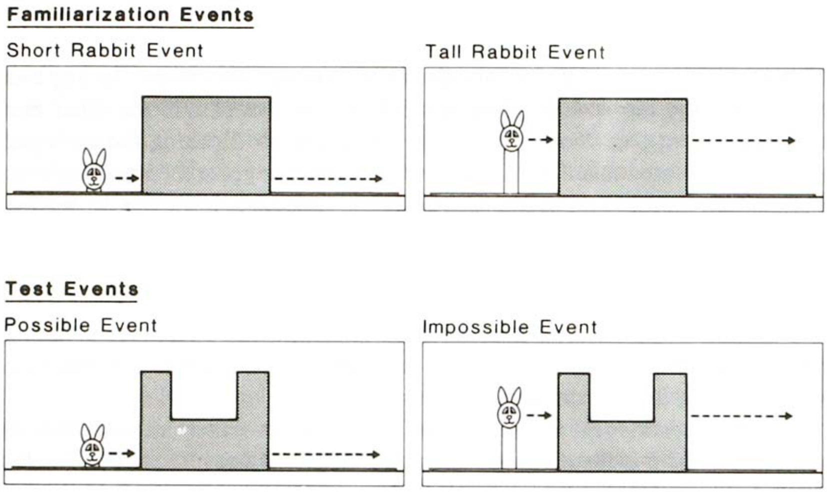

Figure 1. Schematic representation of the familiarization and test events shown to the infants in the tall/short condition in Experiment 1

the window. Because infants typically react to surprising or novel events with prolonged attention, the infants should look longer at the impossible than at the possible event. On the other hand, if the infants (a) did not assume that the rabbit continued to exist and pursued its trajectory behind the screen or (b) did not represent the height of the rabbit behind the screen, then they should look equally at the impossible and the possible events because neither event would seem surprising.

There was one foreseeable difficulty with the design of the experiment. The infants might look longer at the impossible than at the possible event, not because they were surprised that the tall rabbit did not appear in the screen window, but because they found the tall rabbit intrinsically more interesting than the short rabbit. To check this possibility, we presented the infants with two familiarization events before showing them the test events. These familiarization events were identical to the test events except that the screen had no window; hence, neither the tall nor the short rabbit could be visible when passing behind the screen. We reasoned that if the infants looked reliably longer at the tall rabbit during the test but not the familiarization trials, it would provide strong evidence that they expected the tall rabbit to appear in the screen window and were surprised that it did not do so.

EXPERIMENT 1

Design

Because it was unclear how good the infants would be at representing the height of the occluded rabbits, two conditions were included in the experimental design.

For the infants in the *tall/short* condition, the tall rabbit was 11.5 cm taller than the lower edge of the window. For the infants in the *medium/short* condition, the tall rabbit was 7.5 cm taller than the lower edge of the window (in either condition, the short rabbit was 0.5 cm shorter than the lower edge of the window). Because the infants in the medium/short condition were faced with a more difficult discrimination than the infants in the tall/short condition, they were deemed less likely to show the predicted preference for the tall- over the short-rabbit test event.

Method

Subjects. Subjects were 24 full-term infants ranging in age from 5 months, 0 days to 6 months, 1 day (M = 5 months, 13 days). Half of the infants were assigned to the tall/short condition and half to the medium/short condition. Another 6 infants were eliminated from the experiment, 3 because of fussiness, 2 because of equipment failure, and 1 because of procedural error. The infants' names in this experiment and in the following experiment were obtained from birth announcements in a local newspaper. Parents were contacted by letters and followup phone calls. They were offered reimbursement for their travel expenses but were not compensated for their participation.

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 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. 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 either side of the apparatus; in addition, the experimenters listened through headphones to a metronome beating once per second.

During the experiment, identical two-dimensional rabbits were placed on the left and right carriers. These rabbits had heads made of pink construction paper (with brightly colored faces) and bodies made of green plastic strips 7.5 cm wide. Rabbits of three different heights were used: tall, medium, and short. These rabbits had identical heads (14 cm high and 7.5 cm wide), but differed in the heights of their bodies, which were 13, 9, and 1 cm high for the tall, medium, and short rabbits, respectively. Because the carriers stood 0.5 cm above the floor of the apparatus, the rabbits' total heights were 27.5, 23.5, and 15.5 cm, respectively.

Centered between the side walls, at a distance of 5.5 cm from the slit 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 red 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-W lightbulb) were attached to the back and side walls of the apparatus to provide additional light. Two frames, each 180 cm high and 60 cm wide and covered with white muslin, 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 muslin-covered curtain 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/short condition events. In the impossible test event, the blue screen with the large window occluded the center portion of the track, and the tall rabbits stood on the left and right carriers.

At the start of the trial, the rabbit placed on the left carrier stood visible at the left end of the track; the rabbit placed on the right carrier stood just inside the right edge of the screen, hidden from the infant. After a 1-s pause, the first experimenter slid the left rabbit at the speed of about 21 cm/s until it had slid 42 cm and stood just inside the left edge of the screen, hidden from the infant. After a 2-s pause, the right experimenter slid the right rabbit to the right end of the track at the same speed (approximately 21 cm/s), taking about 2 s to complete this movement. After a 1-s pause, the entire process was repeated in reverse. The second experimenter returned the right rabbit back to its starting position behind the right edge of the screen; the first experimenter waited 2 s and then slid the left rabbit from behind the left edge of the screen back to its starting position at the left end of the track. Each event cycle thus lasted approximately 14 s. 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.

The possible test event was identical to the impossible test event except that the tall rabbits were replaced by the short rabbits.

The tall and short rabbit familiarization events were identical to the impossible and possible test events, respectively, except that the red, windowless screen was substituted for the blue screen.

Medium/short condition events. Impossible and possible test events and tall and short rabbit familiarization events were identical to the test and familiarization events shown to the infants in the tall/short condition, except that the medium rabbits were used in the impossible test event and in the tall rabbit familiarization event.

The events were produced so as to create the impression that the rabbit placed on the left carrier travelled the entire length of the track, briefly passing behind the screen and continuing on to the end of the track. One clue, however, was inconsistent with this interpretation of the rabbit's trajectory: The sound of the carrier sliding along the track could be heard during the visible, but not the occluded, portion of the rabbit's trajectory. We chose to produce the events without the carrier sound behind the screen for two reasons. First, several researchers (e.g., Meicler & Gratch, 1980; Nelson, 1971; Piaget, 1954) have found that young infants do not make use of available sound cues to track or locate occluded objects. Hence, it seemed unlikely that the infants would notice the absence of carrier sound behind the screen. Second, if the infants did notice that there was no carrier sound behind the screen and concluded, on this basis, that (a) two separate rabbits were involved or (b) the rabbit magically vanished at one edge of the screen and reappeared at the other edge, they should look equally at the impossible and the possible test events. Having no carrier sound behind the screen thus made it less, rather than more, likely that the infants would look longer at the impossible test event.

Procedure. Prior to the start of the experiment, the infant was allowed to manipulate a tall (or a medium, depending on the infant's condition) and a short rabbit for a few seconds 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. The infant's head was approximately 66 cm from the screen and 96 cm from the back wall. 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 familiarization and test 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 experimental events. Interobserver agreement was calculated on the basis of the number of seconds for which the observers agreed on the direction of the infant's gaze, out of the total number of seconds the trial lasted. Disagreements of less than 0.1 s were ignored. Agreement in this experiment as well as in the following experiment averaged 93% per trial per infant. The looking times recorded by the primary observer were used to determine when a trial had ended.

At the start of the experiment, the infants in the two conditions watched the tall and the short rabbit familiarization events described earlier. These events served two purposes. First, they enabled us to assess whether the infants found the tall rabbit intrinsically more interesting than the short rabbit. Second, they served to acquaint the infants with the rabbits and their trajectories. The infants saw the two events on alternate trials until they had completed two pairs of trials. Half of the infants in each condition saw the tall rabbit event first, and half saw the short rabbit event first. Each trial ended when the infant (a) looked away from the event for 2 consecutive s after having looked at it for at least 6 cumulative s or (b) looked at the event for 60 cumulative s without looking away for 2 consecutive s.

Following the familiarization trials, the infants in the two conditions watched the impossible and the possible test events described earlier on alternate trials until they had completed four pairs of test trials. The infants who saw the tall rabbit familiarization first saw the impossible event first, and the infants who saw the short rabbit familiarization first saw the possible event first. Finally, the criteria used to determine the end of the test trials were the same as for the familiarization trials.

Of the 24 infants who participated in the experiment, 5 completed only three pairs of test trials, 1 because of fussiness, 1 because of drowsiness, 1 because of procedural error, and 2 because of equipment failure. All subjects were included in the data analyses, whether or not they had completed the full complement of four pairs of test trials.

Results

Familiarization Trials. Planned comparisons indicated that the infants in the tall/short condition looked reliably longer at the short ($M = 56.65$) than at the tall ($M = 47.16$) rabbit familiarization event, $F(1, 55) = 5.33, p < .05$, whereas the infants in the medium/short condition looked about equally at the two events (short rabbit event: $M = 52.61$; tall rabbit event: $M = 51.01$), $F(1, 55) = 0.16$.

In addition to these planned comparisons, the infants' looking times to the two familiarization events were analyzed by means of a $2 \times 2 \times 2 \times 2$ mixed model analysis of variance, with Condition (tall/short or medium/short condition) and Order (tall or short rabbit event first) as the between-subjects factors, and with Pair (first or second pair of trials) and Event (tall or short rabbit event) as the within-subjects factors. The only significant effect was that of pair, $F(1, 55) = 5.21, p < .05$, indicating that the infants looked reliably less on the second than on the first pair of trials.

Test Trials. Figure 2 shows the difference in the infants' mean looking times to the impossible and the possible test events. It can be seen that most of the infants in the tall/short and the medium/short conditions looked longer at the impossible event.

Planned comparisons revealed that the infants in both the tall/short and the

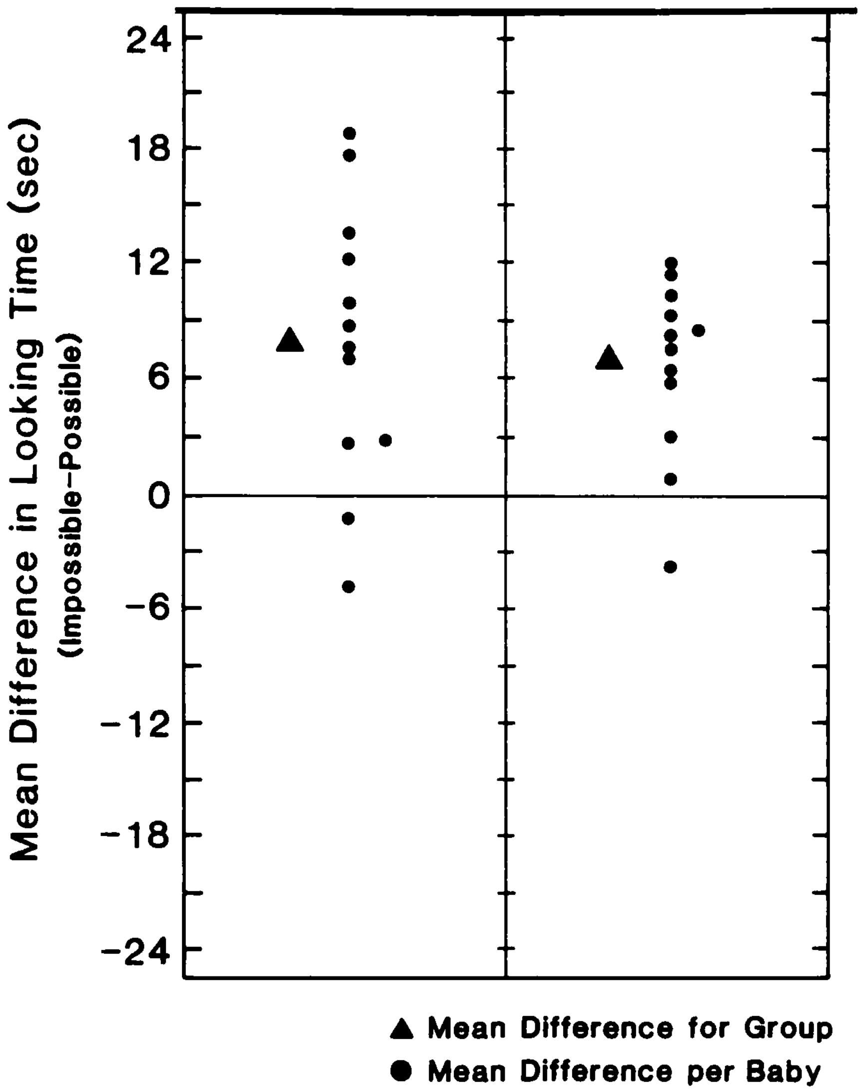

Figure 2. **Difference in the mean looking times of the infants in the tall/short (left pannel) and the medium/short (right pannel) conditions in Experiment 1 to the impossible and the possible events**

medium/short conditions looked reliably longer at the impossible than at the possible event (tall/short condition—impossible event: M = 33.07, possible event: M = 25.11, $F(1, 130) = 6.31$, $p < .05$; medium/short condition—impossible event: M = 34.44, possible event: M = 27.83, $F(1, 130) = 4.07$, $p < .05$).

The infants' looking times to the two test events were also analyzed by means of a 2 × 2 × 4 × 2 mixed model analysis of variance, with Condition (tall/short or medium/short condition) and Order (impossible or possible event first) as the between-subjects factors, and with Test Pair (first, second, third, or fourth pair of test trials) and Event (impossible or 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). As expected, there was a reliable main effect of event, $F(1, 130) = 11.15, p < .002$, indicating that the infants looked reliably longer overall at the impossible ($M = 33.74$) than at the possible ($M = 26.43$) event. There was also a reliable main effect of pair, $F(3, 130) = 25.37, p = .0001$, and a reliable Condition × Pair interaction, $F(3, 130) = 3.88, P < .05$. Post-hoc comparisons revealed that the mean looking times of the infants in the two conditions did not differ reliably on the first (tall/short: $M = 43.11$; medium/short: $M = 50.21$; $F(1, 130) = 2.56, p > .10$), second (tall/short: $M = 25.75$; medium/short: $M = 29.91$; $F(1, 130) = 0.88$), and fourth (tall/short: $M = 20.03$; medium/short: $M = 27.44$; $F(1, 130) = 2.21, p > .10$) test pairs, but did differ reliably on the third test pair (tall/short: $M = 26.72$; medium/short: $M = 15.75$; $F(1, 130) = 6.12, p < .05$). Because these pair effects are of no theoretical interest in the present context, they will not be discussed further.

Discussion

The infants in the tall/short and the medium/short conditions in Experiment 1 looked reliably longer at the tall than at the short rabbit event during the test trials when the screen had a window but not during the familiarization trials when the screen had no window. Together, these results suggest that the infants looked longer at the impossible event, not because they found the tall rabbit intrinsically more interesting than the short rabbit, but because they expected the tall rabbit to appear in the screen window and were surprised that it did not do so.

However, there is another, somewhat unlikely, interpretation for the results of Experiment 1. Although the infants gave no evidence of preferring the tall to the short rabbit during the familiarization trials, they might conceivably have developed such a preference in the course of the test trials (a case of familiarity breeding interest rather than contempt!). Experiment 2 was designed with two purposes in mind: One was to confirm the results of Experiment 1 and the other was to test the alternative interpretation just mentioned.

The infants were assigned to one of two conditions. The infants in the *standard tall/short* condition saw familiarization and test events similar to those shown to the infants in the tall/short condition in Experiment 1. The infants in the *control tall/short* condition saw the same familiarization and test events as the infants in the standard tall/short condition, with one important exception. Prior to the familiarization trials, the infants received two pretest trials in which they saw *two* tall or *two* short rabbits standing motionless on either side of the windowless, red screen. For half of the infants, the pretest trial with the tall rabbits was presented first; for the other half, the pretest trial with the short rabbits was presented first.

We reasoned as follows: If the infants in Experiment 1 looked longer at the impossible than at the possible event because they found the tall rabbit more interesting than the short rabbit, then the infants in the standard and the control tall/short conditions should also look longer at the impossible event. On the other hand, if the infants in Experiment 1 looked longer at the impossible event because they were surprised that the tall rabbit did not appear in the screen window, then only the infants in the standard tall/short condition should look longer at the impossible event. The infants in the control tall/short condition, who were provided with a ready explanation for the nonappearance of the tall rabbit in the screen window (i.e., two separate rabbits were involved), should look equally at the impossible and the possible events.

EXPERIMENT 2

Subjects

Subjects were 24 full-term infants ranging in age from 5 months, 0 days to 5 months, 30 days (M = 5 months, 15 days). Half of the infants were assigned to the standard tall/short condition and half to the control tall/short condition. An additional 7 infants were eliminated from the experiment because of fussiness.

Apparatus, Events, and Procedure

The apparatus and events used in the present experiment were similar to those used in the tall/short condition in Experiment 1, with two exceptions: The rabbits had yellow heads and blue bodies instead of pink heads and green bodies, and the screen used during the test trials was green instead of blue.

The procedure used to test the infants in the standard tall/short condition was identical to that used to test the infants in the tall/short condition in Experiment 1. The procedure used with the infants in the control tall/short condition was identical to that used with the infants in the standard tall/short condition, with one exception. The infants in the control tall/short condition were first given two pretest trials. In one, the infants saw two tall rabbits standing motionless 8 cm to the left and to the right of the windowless, red screen; in the other, the infants saw two short rabbits standing motionless on either side of the screen. Each trial ended when the infant (a) looked away from the display for 2 consecutive s after having looked at it for at least 10 cumulative s or (b) looked at the display for 30 cumulative s without looking away for 2 consecutive s. Half of the infants saw the pretest, familiarization, and test trials involving the tall rabbit(s) first, and half saw the pretest, familiarization, and test trials involving the short rabbit(s) first.

For reasons that are unclear, the infants in the standard tall/short condition were much less likely than the infants in the control tall/short condition to remain calm and alert throughout the test trials. Of the 12 infants in the standard tall/short condition, 4 completed only three pairs of test trials, 3 because of fussiness and 1 because of drowsiness. Further, of the 8 infants who completed a fourth test pair, 4 were judged by the observers to have been slightly or moderately fussy on that pair. Only 1 of the 12 infants in the control tall/short condition did not complete a fourth test pair which was because of equipment failure. Further, only 1 of the 11 infants who completed a fourth test pair was judged to have been fussy on that pair. Because only 4 of the 12 infants in the standard tall/short condition were calm and alert when they received their fourth test pair (as compared with 10 of the 12 infants in the control tall/short condition), we decided to include only the data from the first three test pairs in the data analysis.

Results

Familiarization Trials. Planned comparisons indicated that the mean looking times of the infants in the standard and the control tall/short conditions to the tall and the short rabbit familiarization events did not differ reliably (standard condition—short rabbit event: $M = 54.21$, tall rabbit event: $M = 48.89$, $F(1, 58) = 1.65$, $p > .10$; control condition—short rabbit event: $M = 45.99$, tall rabbit event: $M = 42.42$, $F(1, 58) = 0.78$).

The infants' looking times to the two familiarization events were also analyzed by means of a $2 \times 2 \times 2 \times 2$ mixed model analysis of variance with Condition (standard or control tall/short condition) and Order (tall or short rabbit event first) as the between-subjects factors and with Pair (first or second pair of trials) and Event (tall or short rabbit event) as the within-subjects factors. There was a reliable main effect of pair, $F(2, 38) = 7.28$, $p < .05$, indicating that the infants looked reliably less during the second than during the first pair of familiarization trials. In addition, there was a reliable Order × Event interaction, $F(1, 58) = 4.92$, $p < .05$. Follow-up comparisons revealed that, whereas the infants who saw the tall rabbit event first tended to look equally at the tall ($M = 50.24$) and the short ($M = 48.55$) rabbit events, $F(1, 58) = 0.17$, the infants who saw the short rabbit event first looked reliably longer at the short ($M = 51.53$) than at the tall ($M = 40.73$) rabbit event, $F(1, 58) = 6.81$, $p < .02$.

Test Trials. Figure 3 shows the difference in the mean looking times of the infants in the standard and the control tall/short conditions to the impossible and the possible test events. It can be seen that, whereas most of the infants in the standard tall/short condition tended to look longer at the impossible event, the same was not true of the infants in the control tall/short condition.

Planned comparisons revealed that the infants in the standard tall/short condition looked reliably longer at the impossible ($M = 37.57$) than at the possible ($M = 29.47$) event, $F(1, 100) = 4.65$, $p < .05$, whereas the infants in the control

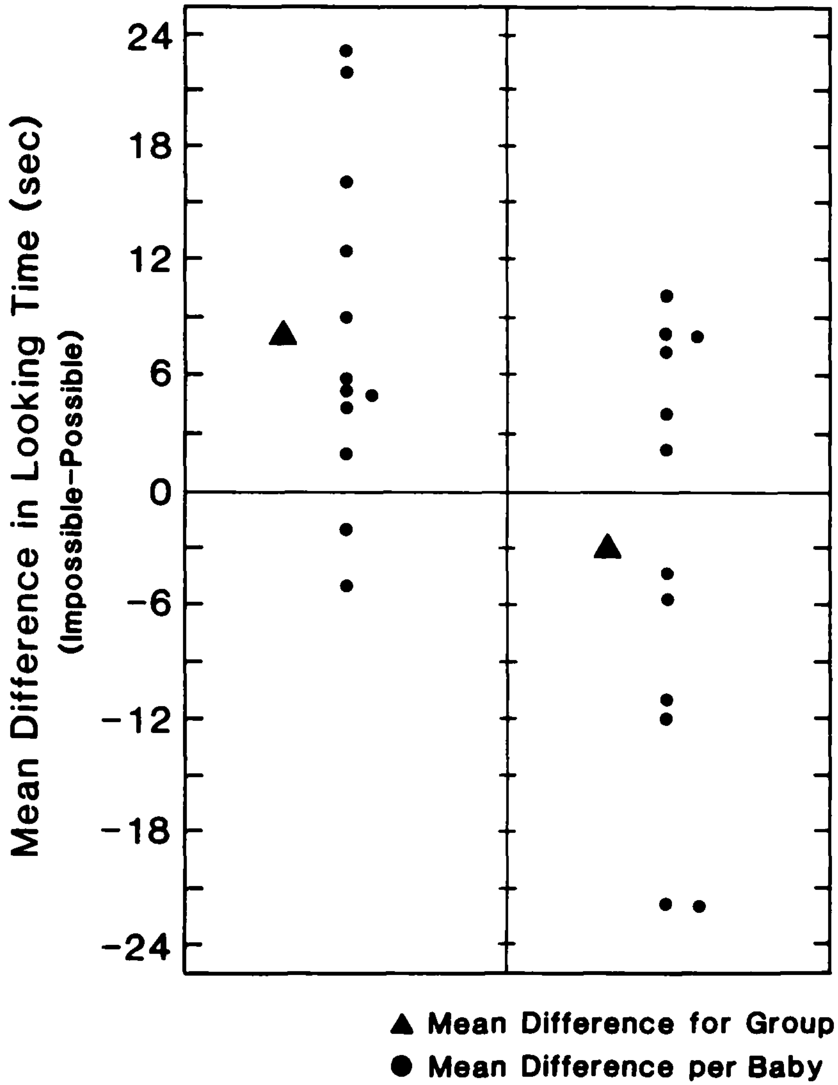

Figure 3. Difference in the mean looking times of the infants in the standard (left pannel) and the control (right pannel) tall/short conditions in Experiment 2 to the impossible and the possible events

tall/short condition looked about equally at the two events, $F(1, 100) = 0.65$ (impossible event: $M = 25.95$; possible event: $M = 28.98$).

The infants' looking times to the test events were also analyzed by means of a $2 \times 2 \times 3 \times 2$ mixed model analysis of variance with Condition (standard or control tall/short condition) and Order (impossible or possible event first) as the between-subjects factors and with Test Pair (first, second, or third pair of test trials) and Event (impossible or possible event) as the within-subjects factors. As expected, the analysis yielded a reliable Condition × Event interaction, $F(1, 100) = 4.40, p < .05$. There was also a reliable main effect of pair, $F(2, 100) = 16.64, p = .0001$, indicating that the infants looked significantly less as the experiment progressed.

Discussion

Like the infants in the tall/short and the medium/short conditions in Experiment 1, the infants in the standard tall/short condition in Experiment 2 looked reliably longer at the impossible than at the possible event. This result suggests that the infants (a) believed that the rabbit continued to exist and pursued its trajectory behind the screen, (b) represented the height of the rabbit behind the screen, and hence (c) were surprised when the tall rabbit reappeared on the other side of the screen without having appeared in the window.

Could the infants in the standard tall/short condition have looked longer at the impossible event simply because they found the tall rabbit more attractive than the short rabbit? This interpretation is unlikely, for two reasons. First, the results of the familiarization trials indicated that the infants tended to look equally at the tall and the short rabbit familiarization events. Second, the results of the test trials showed that the infants in the control tall/short condition looked about equally at the impossible and the possible events. Such a finding provides evidence against the idea that the infants in the standard tall/short condition looked longer at the impossible event because they developed a preference for the tall rabbit over the course of the test trials.

Why did the infants in the control tall/short condition look equally at the impossible and the possible events? The most likely explanation, we would argue, is that the infants were able to take advantage of the information provided in the pretest trials. Specifically, the infants understood that the tall rabbit did not appear at the screen window because it did not in fact travel the distance behind the screen: One rabbit travelled from the left end of the track to the left edge of the screen and stopped just inside this edge; a second, identical rabbit then emerged from behind the right edge of the screen and travelled to the right end of the track.

It should be noted that the present data are insufficient to determine whether the infants in the control tall/short condition perceived (a) all of the familiarization and test events, (b) only the test events, or (c) only the impossible test event, as involving separate rabbits with separate trajectories. The infants could have remained neutral on the issue of whether one or two rabbits were used to produce the tall and the short rabbit familiarization events and the possible test event, because these events (in contrast to the impossible test event) were consistent with either alternative.

GENERAL DISCUSSION

The infants in the tall/short and medium/short conditions in Experiment 1 and the infants in the standard tall/short condition in Experiment 2 (a) looked reliably longer at the impossible than at the possible test event, but (b) did not look reliably longer at the tall than at the short rabbit familiarization event. Together, these results indicate that the infants looked longer at the impossible event, not because they found the tall rabbit more attractive than the short rabbit, but because they were surprised that the tall rabbit did not appear in the screen window. Such a finding suggests that the infants represented the height of the tall and of the short rabbits behind the screen and realized that the tall but not the short rabbit should be visible at the window.

Piaget's (1954) proposal that infants do not represent the existence and the properties of occluded objects until about 9 and 12 months of age, respectively, was based on detailed observations of infants' manual search behavior. In recent years, investigators have called into serious question the validity of manual search as an index of object permanence, claiming that infants' beliefs about occluded objects are only one of many factors that contribute to the emergence and the development of search (e.g., Baillargeon et al., 1985; Mandler, 1986; Wellman et al., in press). Accordingly, investigators have developed new methods to assess infants' beliefs about occluded objects, methods which do not require manual search (e.g., Baillargeon, 1986, 1987a, 1987b). Experiments conducted with these methods (including the present experiments) have yielded two findings which bear critically on Piaget's theory. The first is that the results have not confirmed the 9- and 12-month shifts reported by Piaget. The second is that the results do not call for the postulation of similar qualitative shifts at younger ages. The evidence currently available indicates that infants are able to represent the existence and (at least some of) the properties of occluded objects at 3.5 and 5.5 months of age, respectively. However, it should be kept in mind that these ages reflect not the youngest ages at which these abilities can be successfully demonstrated, but the youngest ages tested to date with nonsearch methods. It seems likely, given the present trend, that these abilities will be found at even younger ages. (Indeed, there is preliminary evidence that 4-month-old infants represent the height [Baillargeon, 1987c] and the trajectory [Spelke & Kestenbaum, 1986, cited in Spelke, in press] of occluded objects.)

We believe the time has come to set aside Piaget's proposal that infants come to represent first the existence and only later the properties of occluded objects. To reiterate, (a) this hypothesis was based on observations now known to be open to other, more likely interpretations; (b) observations collected with less ambiguous methods have not confirmed the 9- and 12-month sequential shifts reported by Piaget; and (c) nothing in the evidence currently at our disposal suggests that these shifts occur at younger ages. Until evidence of such shifts is obtained, it would seem more reasonable, indeed, more parsimonious, to adopt the simpler hypothesis that infants recognize early in the first year that objects both continue to exist and retain their properties when occluded.

One important advantage of adopting this alternative hypothesis, we would argue, is that it focuses investigators' attention away from the issue of when infants come to share adults' beliefs about occluded objects and onto the more general issue of how infants represent and use information about occluded objects and events.

To illustrate, consider the experiments reported in this paper. The infants in these experiments represented the height of the (tall or short) rabbit behind the screen and used this information to predict whether the rabbit would appear in the screen window. This finding raises interesting questions about the nature and the limits of the infants' physical reasoning abilities. First, how did the infants go about deciding whether the rabbit would appear in the window? Did they visually compare the height of the rabbit to that of the window as the rabbit approached or left the screen? Or did they mentally compare the height of the rabbit, as they remembered it, to that of the window? Second, how precise was the infants' reasoning process? We already know that the infants were surprised when rabbits 11.5 cm (tall rabbit) and 7.5 cm (medium rabbit) taller than the window's lower edge did not appear in the window. Would the infants have been surprised if the rabbit had been only 3.5 cm taller than the window? The answer to this last question could well depend on the answer to the first. A direct perceptual comparison of the heights of the rabbit and the window would enable the infants to detect height differences of only a few centimeters. On the other hand, a mental comparison process (e.g., mentally holding the rabbit in front of the screen to see whether it protrudes above the lower edge of the window) would only be as accurate as the infants' representation of the rabbit.

Other interesting questions concern the infants' inferences about the occluded portion of the rabbit's trajectory. Upon seeing an object disappear at one end of an occluder and reappear (after a suitable delay) at the other end, adults typically assume that the object travelled from one end of the occluder to the other. Furthermore, if portions of the occluder are removed, adults expect the object to be visible at every point along its trajectory that is no longer occluded. The infants in Experiment 1 and those in the standard condition in Experiment 2 must have believed that the tall and the short rabbits travelled at least some of the distance behind the screen—otherwise they would not have expected the tall rabbit to appear in the screen window. But how precise was the infants' representation of the rabbits' trajectory behind the screen? If shown a screen with a very narrow window, would the infants have shown surprise if the tall rabbit had failed to appear at the window? Pilot data collected with a screen whose window was one-half as wide as the window used in the present experiments yielded negative results: The infants looked about equally at the impossible and the possible events.[1] However, these negative results are open to at least two differ-

[1] These data were collected with 12 infants ranging in age from 5 months, 0 days to 5 months, 28

ent interpretations. On the one hand, it could be that the infants (a) believed that the rabbits moved continuously from one end of the screen to the other; (b) expected the rabbits to be visible at every point of their trajectories that was not occluded; but (c) failed to notice, on most trials, that the tall rabbit did not in fact appear in the window (to do so, the infants had to have been looking at the window during the fraction of a second when the tall rabbit was to appear). On the other hand, the infants could have noted that the tall rabbit did not appear in the window but had been undisturbed by it because they did not hold assumptions (a) and (b) or because they were quite willing to admit exceptions to these assumptions (e.g., the infants might admit the possibility of there being fleeting gaps in an object's trajectory).

Other interesting questions are raised by the results obtained with the infants in the control condition in Experiment 2. It seems plausible to assume that these infants showed little or no surprise at the impossible event because they understood that two tall rabbits were involved, one covering the left half and the other the right half of the track. It was surprising to us that the infants could make such an inference on the basis of what appeared to be relatively limited information: a single trial at the start of the experiment in which the infants saw two tall rabbits standing motionless on either side of the screen. Did the infants in Experiment 1 and those in the standard condition in Experiment 2 spontaneously conclude, after seeing the impossible event, that two tall rabbits must be involved in the production of the event? If they did, one might expect that the infants would have looked longer at the impossible event on the first and perhaps the second test pair, but not on the subsequent test pair(s). However, in neither Experiment 1 nor in Experiment 2 was the Event × Test Pair interaction statistically reliable, indicating that the infants' looking times to the two test events did not differ significantly across test pairs. These data are interesting in that they suggest that, although the infants could take advantage of the (relatively limited) information made available to them in the pretest to make sense of the tall rabbit's failure to appear at the window, they were unable to *generate* such an explanation themselves. This finding is consistent with data recently reported by Spelke and Kestenbaum (1986, cited in Spelke, in press).

The results of the present experiments suggest that, by 5.5 months of age, infants represent the height of occluded objects and use this information to predict the outcome of simple physical events involving these objects. These results point to remarkable and hitherto largely unsuspected physical reasoning abilities in young infants. Clearly, one important task facing cognitive developmentalists in the future is that of describing (a) the nature of young infants'

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days (M = 5 months, 12 days). The procedure was the same as that used with the infants in the tall/short condition in Experiment 1, except that the screen window was only one-half as wide. The results indicated that the infants looked about equally at the impossible (M = 30.14) and at the possible (M = 29.12) events, $F(1, 56) = 0.32$.

physical knowledge and the processes by which they acquire it and (b) the nature of infants' physical reasoning abilities and the processes by which these develop.

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