Why do young infants fail to search for hidden objects?*

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Abstract

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Recent evidence indicates that infants as young as 3.5 months of age understand that objects continue to exist when hidden (Baillargeon, 1987a; Baillargeon & DeVos, 1990). Why, then, do infants fail to search for hidden objects until 7 to 8 months of age? The present experiments tested whether 5.5-month-old infants could distinguish between correct and incorrect search actions performed by an experimenter. In Experiment 1, a toy was placed in front of (possible event) or under (impossible event) a clear cover. Next, a screen was slid in front of the objects, hiding them from view. A hand then reached behind the screen and reappeared holding the toy. The infants looked reliably longer at the impossible than at the possible event, suggesting that they understood that the hand's direct reaching action was sufficient to retrieve the toy when it stood in front of but not under the clear cover. The same results were obtained in a second condition in which a toy was placed in front of (possible event) or behind (impossible event) a barrier. In Experiment 2, a toy was placed under the right (possible event) or the left (impossible event) of two covers. After a screen hid the objects, a hand reached behind the screen's right edge and reappeared first with the right cover and then with the toy. The infants looked reliably longer at the impossible than at the possible event, suggesting that they realized that the hand's sequence of action was sufficient to retrieve the toy when it stood under the right but not the left cover. A control condition sup-

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ported this interpretation. Together, the results of Experiments 1 and 2 indicate that by 5.5 months of age, infants not only represent hidden objects, but are able to identify the actions necessary to retrieve these objects. The implications of these findings for a problem solving explanation of young infants' failure to retrieve hidden objects are considered.

1. Introduction

There is general agreement in the developmental literature that infants less than 7 to 8 months of age do not search for objects they have observed being hidden (e.g., Diamond, 1985; Harris, 1987, in press; Piaget, 1954; Schuberth, 1983; Sophian, 1984; Willatts, 1984). The traditional explanation for this finding has been that put forth by Piaget (1954). According to this explanation, young infants do not search for hidden objects because they do not realize that objects continue to exist when masked by other objects. Piaget speculated that, for young infants, objects are not permanent entities that continue to exist when out of sight, but transient entities that cease to exist when they cease to be visible and begin to exist anew when they become visible again.

Piaget's explanation for young infants' failure to search for hidden objects has recently been questioned. A number of investigators have obtained evidence that infants less than 7 to 8 months of age do appreciate that objects continue to exist when hidden (e.g., Baillargeon, 1987a, in press-a, in press-b; Baillargeon & DeVos, 1990; Baillargeon & Graber, 1987; Baillargeon, Spelke, & Wasserman, 1985; Hood & Willatts, 1986; Rochat, Clifton, Litovsky, & Perris, 1989; Spelke, in press). For example, Baillargeon (1987a; Baillargeon et al., 1985) habituated 4.5- and 5.5-month-old infants 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 infants looked reliably longer at the impossible than at the possible event, suggesting that they (a) believed that the box continued to exist, in its same location, after it was occluded by the screen and (b) expected the screen to stop when it reached the box and were surprised that it did not. Control experiments conducted without a box behind the screen supported this interpretation.

Baillargeon and DeVos (1990) recently obtained evidence of object permanence in even younger infants. They habituated 3.5-month-old infants to a toy carrot 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 carrot travel 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* carrot moved back and forth along the track; this carrot was shorter than the window's lower edge and did not appear in the window when passing behind the screen. In the other event (impossible event), the *tall* carrot traveled back and forth along the track; this carrot was taller than the window's lower edge and hence should have appeared in the window but did not in fact do so. The infants looked 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 indicated that the infants (a) believed that each carrot continued to exist, and pursued its trajectory, after it disappeared behind the screen and (b) expected the tall carrot to appear in the window and were surprised that it did not.

Together, these experiments provide strong evidence that infants less than 7 to 8 months of age are able to represent and to reason about the existence of hidden objects. Such a finding contradicts the traditional Piagetian claim that young infants do not search for hidden objects because they do not understand that objects continue to exist when masked by other objects.

To what, then, should one attribute young infants' failure to search for hidden objects? One possibility is suggested by observations on the development of action in infancy. Researchers have noted (e.g., Diamond, 1981, 1987, in press; Piaget, 1952; Willatts, in press) that it is not until infants are 7 to 8 months of age that they begin to coordinate actions directed at separate objects into means–end sequences. In these sequences, infants apply one action to one object so as to create conditions under which they can apply another action to another object. Examples of such sequences include pulling the near end of a cloth to bring within reach a toy placed on the far end of the cloth, pushing aside a cushion to get a toy visible on the other side of the cushion, or reaching around to the opening of a transparent box to get a toy placed inside the box. Thus, young infants could fail to search for hidden objects simply because this task typically requires them to coordinate separate actions on separate objects (e.g., lifting a cloth to get a toy hidden under the cloth).

Support for this hypothesis comes from reports that infants *do* search for hidden objects when they can find the objects by performing direct, as opposed to means–end, actions. First, a number of authors (e.g., Hood & Willatts, 1986; Rochat et al., 1989) have found that young infants readily search for objects "hidden" by darkening the room. For example, Hood and Willatts (1986) presented 5-month-old infants with an object on the left or the right side within reaching distance; the infants were restrained from reaching for the object. Next, the room lights were turned off, the object was removed, and the infants' hands were released. Infrared recordings indicated that the infants reached reliably more often to the side where they had seen the object than to the opposite side.

Second, Piaget (1954) noted that when infants aged 4 months and older hold an object out of sight and accidentally let go of it, they often stretch their arm to recapture it. One of Piaget's observations involved his son Laurent: "As early as 0;4(6) Laurent searches with his hand for a doll he has just let go. He does not look at what he is doing but extends his arm in the direction toward which it was oriented when the object fell" (p. 23).

Finally, Baillargeon has observed that young infants who are shown impossible events involving objects hidden behind a screen sometimes lean to the side and attempt to look behind the screen, as if to verify for themselves the continued presence of the objects (e.g., Baillargeon, 1986; Baillargeon & DeVos, 1990).

Thus, it appears that even young infants search for hidden objects, when they can search without producing means-end sequences - by groping for objects "hidden" by the dark or dropped out of sight, or by peering around screens that block their line of vision.

2. Why do young infants fail to produce means-end sequences?

Let us assume that we are correct in claiming that young infants do poorly on most search tasks because these tasks typically require them to produce means-end sequences. The question we must then address is: Why do infants less than 7 to 8 months of age have difficulty producing means-end sequences? Two general hypotheses come to mind. One is that infants are unable to *perform* such sequences because of poor motor control; the other is that infants are unable to *plan* such sequences because of limited problem solving ability.

Studies of young infants' actions provide little support for the first hypothesis. The actions involved in the examples of means-end sequences listed in the previous section (e.g., reaching for, grasping, pulling, pushing, lifting, and releasing objects) fall well within the behavioral repertoire of 4- to 7-month-old infants (e.g., Bushnell, 1985; Granrud, 1986; Newell, Scully, McDonald, & Baillargeon, in press; Piaget, 1952, 1954; von Hofsten, 1980). Furthermore, infants this age seem to have little difficulty performing series of actions in rapid succession. Piaget (1952) described in meticulous and delightful detail how his children, beginning at 3.5 months of age, would repeatedly kick, pull, swing, shake, or strike objects suspended from their bassinet hoods, at times systematically varying the speed and vigor of their actions, and at other times playfully intermingling bouts of different actions such as pulling and shaking or striking and shaking. Such observations are inconsistent with the hypothesis that young infants' failure to produce means-end sequences stems from inadequate motor skills.

The second hypothesis proposed above was that young infants are unable to plan means–end sequences because of problem solving difficulties. We now turn to a discussion of the potential source of these difficulties.

3. Why do young infants have difficulty planning means–end sequences?

Problem solving is frequently described in cognitive psychology in terms of searching a *problem space*, which consists of various states of a problem. The goal pursued by the problem solver is referred to as the *goal state* and the initial situation that faces the problem solver as the *initial state*; *operators* are actions carried out by the problem solver to generate each successive *intermediate state* on the way to the goal (e.g., Anderson, 1985; Mayer, 1983; Newell & Simon, 1972).

Having established this terminology, let us consider a typical search problem situation: A young infant watches an experimenter hide an attractive toy under a cover. To what should we attribute the infant's failure to search for the toy? A first possibility is that the infant's goal in the situation differs from that the experimenter has in mind. Instead of seeking to retrieve the toy, the infant may be pursuing a different, unrelated goal. A second possibility is that the infant's representation of the situation's initial state is inaccurate or incomplete, making it impossible for the infant to find a sequence of operators to retrieve the toy. For example, the infant may represent the existence but not the location of the hidden toy.

We believe that neither of these two possibilities is very likely. With respect to the first possibility, there is ample evidence that young infants reach readily for objects that are "hidden" by the dark, as we saw earlier (e.g., Hood & Willatts, 1986; Rochat et al., 1989), as well as for objects that are only partially visible (e.g., Piaget, 1954). Furthermore, young infants are sometimes distressed when desired objects are hidden before them and attempt to grasp the objects as soon as they are even partially uncovered (e.g., Piaget, 1954). Such observations are inconsistent with the hypothesis that young infants do not search for hidden objects because they have no wish to possess them. With respect to the second possibility, it is difficult, given the evidence collected by Baillargeon (1986, 1987a, 1987b, in press-a, in press-b; Baillargeon & DeVos, 1990; Baillargeon & Graber, 1987; Baillargeon et al., 1985), Hood and Willatts (1986), Spelke (in press), and others, to believe that young infants' representation of the initial conditions of search situations could be seriously flawed. The infants in the Baillargeon (1987a; Baillargeon & DeVos, 1990; Baillargeon et al., 1985) experiments described above were clearly able to represent the existence and the location of hidden objects, and to reason about these objects in sophisticated, adult-like ways. Such findings are not easily reconciled with the proposal that young infants fail to retrieve objects hidden behind obstacles because their representation of the objects, the obstacles, or the relations between them is deficient.

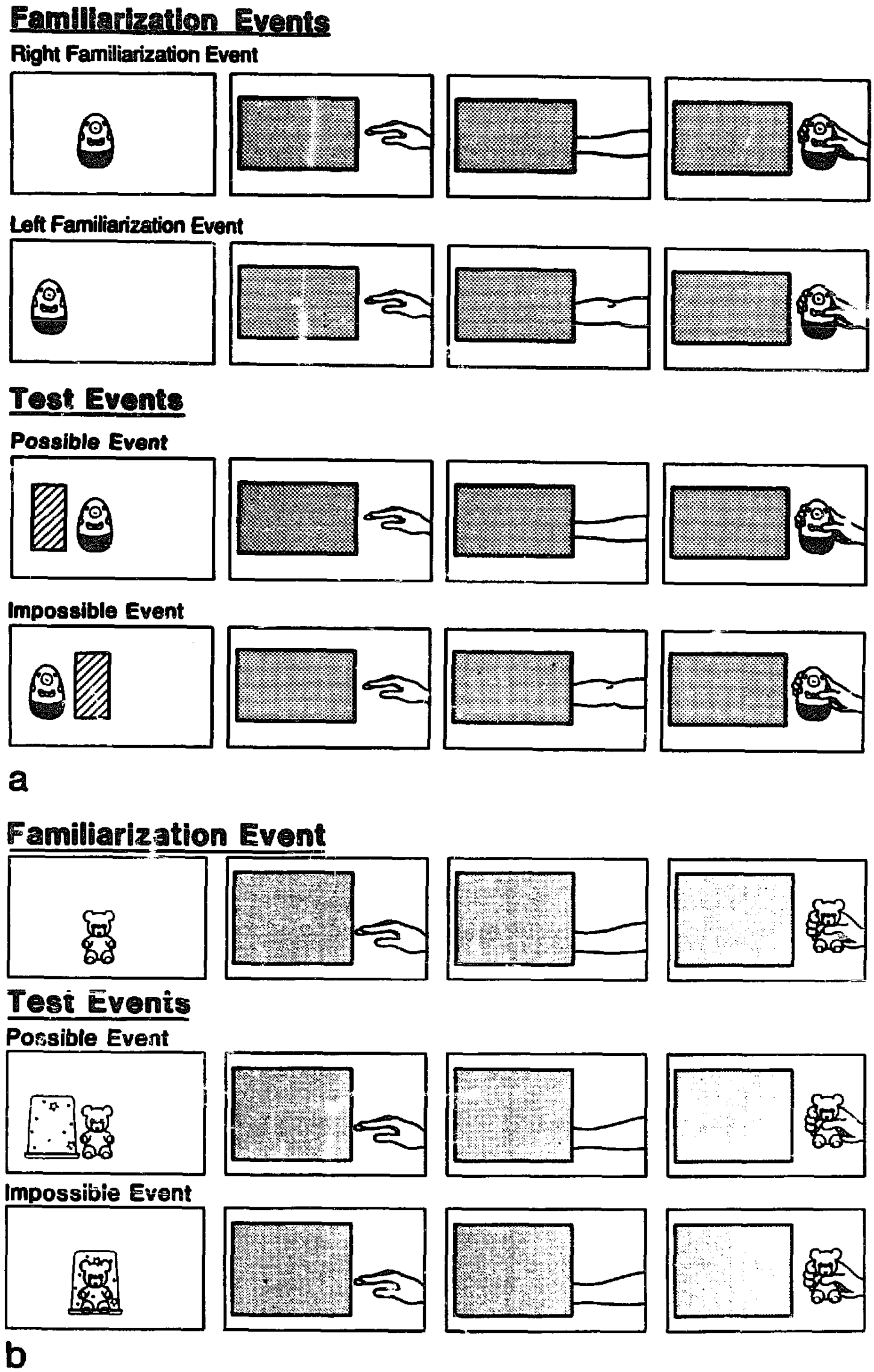
Young infants' representation of the goal state and initial state of means–end problem situations thus seems unlikely to be responsible for their lack of success in these situations. Another, more likely possibility is that this lack of success reflects difficulties in reasoning about operators – about the actions that are applied to transform the initial state into the goal state. Two general hypotheses can be distinguished. First, it may be that infants perform poorly in means–end situations because their knowledge of the relevant operators is lacking or incomplete. Infants may not be fully aware of the preconditions necessary for the application of an operator, or of the effects of an operator. For example, infants may realize that grasping an object will result in their possession of the object, but not that it will *also* alter the location of the object relative to other objects in the situation. Infants would thus be unable to appreciate why grasping the cover placed over a toy would bring them closer to achieving their goal of recovering the toy – to their minds, grasping the cover would result only in their holding the cover, not in their freeing access to the toy. Second, it may be that infants are unable to select or chain appropriate sequences of operators to achieve their goals, even when the relevant operators and their preconditions and effects are well-known to them. We return to this second hypothesis in the Conclusion section.

The present experiments examined the first of the two hypotheses just mentioned, namely, that young infants are unable to plan means–end sequences such as search sequences because they lack sufficient knowledge about the operators or actions involved in these sequences. In the experiments, 5.5-month-old infants were shown events in which a toy was placed in front of, behind, or under an obstacle. The experiments tested whether the infants could distinguish between actions (performed by an experimenter's hand) that could result in the toy's retrieval and actions that could not. We reasoned that evidence that the infants could identify correct and incorrect actions for the toy's retrieval would argue against the hypothesis that young infants cannot plan search sequences because their knowledge of the relevant actions is lacking or incomplete.

4. Experiment 1

Experiment 1 examined whether 5.5-month-old infants are aware that a direct reaching action is sufficient to retrieve a toy placed in front of an obstacle, but is not sufficient to retrieve a toy placed behind (barrier condition) or under (cover condition) an obstacle.

Figure 1. *Schematic representation of the familiarization and test events shown to the infants in the barrier (1a) and the cover (1b) conditions in Experiment 1.*



The infants in the barrier condition were shown two test events (see Figure 1a). At the start of each event, the infants saw a toy bird and a barrier standing side by side at the center of a display box. After a few seconds, a screen was pushed in front of the objects, hiding them from view. Next, a hand reached behind the screen's right edge and reappeared holding the bird. The only difference between the two events was in the relative positions of the bird and the barrier at the start of the events. In one event (possible event), the barrier was on the left and the bird was on the right, directly accessible to the hand; in the other event (impossible event), the bird was on the left and the barrier was on the right, blocking the hand's access to the bird. The events shown to the infants in the cover condition were similar to those shown to the infants in the barrier condition except that the bird and the barrier were replaced by a bear and a clear rigid cover (see Figure 1b). In the possible event, the cover was on the left and the bear was on the right, where it could be retrieved by the hand; in the impossible event, the bear was under the cover and should therefore have been inaccessible to the hand.

We reasoned as follows. If the infants (a) represented the existence and the location of the toy (bird, bear) and the obstacle (barrier, cover) behind the screen and (b) understood that the hand's direct reaching action could result in the retrieval of the toy when it stood in front of, but not behind (barrier condition) or under (cover condition), the obstacle, then they should be surprised in the impossible event when the hand reached behind the screen and reappeared holding the toy. Since an infant's surprise at an event typically manifests itself by prolonged attention to this event, the infants should look reliably longer at the impossible than at the possible event. On the other hand, if the infants (a) did not represent the toy and the obstacle behind the screen or (b) believed that the hand's action was sufficient to retrieve the toy when it stood in front of, behind, or under the obstacle, then they should look equally at the impossible and the possible events because neither event would appear surprising.

4.1. Method

4.1.1. Subjects

Subjects were 28 healthy, full-term infants ranging in age from 5 months 0 days to 5 months 24 days (M = 5 months 12 days). An additional six infants were eliminated from the experiment, five because of fussiness and one because of drowsiness. The infants' names in this experiment and in the next experiment were obtained from birth announcements in the local newspaper. Parents were contacted by letters and follow-up phone calls. They were not compensated for their participation but were offered reimbursement for their travel expenses.

Of the 28 infants in the experiment, 16 were assigned to the barrier condition (M = 5 months 10 days) and 12 to the cover condition (M = 5 months 15 days).

4.1.2. Apparatus

The apparatus consisted of a wooden display box 191 cm high, 100 cm wide, and 40 cm deep. The infant faced an opening 43 cm high and 94 cm wide in the front wall of the apparatus. The floor of the apparatus was painted yellow, the back wall was made of thick green cardboard, and the side walls were covered with brightly patterned contact paper.

Inside the apparatus stood a purple cardboard screen 31 cm wide and either 19 (barrier condition) or 24 (cover condition) cm high. This screen was positioned 38 cm from the left wall, 31 cm from the right wall, and 23 cm from the front edge of the apparatus. The screen could be pulled toward the left wall by means of a yellow wooden handle 1.3 cm high and 77 cm long. The right end portion of the handle was affixed to the back of the screen's lower edge; the left end portion fit between two yellow wooden runners, each 1.3 cm high and 38 cm long, and protruded through the left wall of the apparatus.

During the experiment, two objects were placed behind the screen. In the barrier condition, these objects were: (1) an oval-shaped plastic toy bird, 13 cm high and 10 cm wide, colored white, blue, and orange, and containing a chime, and (2) a rectangular pink cardboard barrier, 17 cm high, 15 cm deep, and 8.5 cm wide, with a handle 6 cm long and 2 cm in diameter in the center of its back panel. During the impossible event, the bird was positioned 3 cm to the left of the barrier, 41.5 cm from the left wall, and 4 cm from the screen. The barrier was positioned 37 cm from the right wall and 2 cm from the screen and stood directly in front of an opening 17 cm high and 9 cm wide in the back wall of the apparatus. This opening was used to surreptitiously remove the barrier from the path of the hand. The opening was hidden by a curtain of the same color as the back wall; a slit in the curtain allowed the barrier's handle to project out of the apparatus. During the possible event, the positions of the bird and the barrier were reversed: The bird stood on the right, 37 cm from the right wall, and the barrier stood on the left, 41.5 cm from the left wall. The barrier's handle protruded through a small hole in the back wall of the apparatus.

In the cover condition, the objects placed behind the screen were: (1) a pink, red, and white plastic squeaky bear, 13 cm tall and 8 cm wide, and (2) a clear plastic cover (an inverted container), 16 cm high and 14 cm wide, which was decorated with a few dots and stars to render it more salient. During the impossible event, the bear was positioned 37 cm from the right wall and 5 cm from the screen; the cover stood over the bear, 34 cm from the right wall and 3 cm from the screen. The cover was positioned directly in front of an opening 22 cm high and 16 cm wide in the back wall of the apparatus. This opening was larger than that in the barrier condition (different back walls with different openings were used in the barrier and the cover conditions) to make possible the surreptitious removal of the cover. The opening was hidden by a curtain of the same color as the back wall. During the possible event, the bear stood in the same position as in the impossible event; the cover was positioned immediately to the bear's left, 41 cm from the left wall and 3 cm from the screen.

During the experiment, a human right hand, wearing a silver spandex glove, entered the apparatus through an opening 15 cm high and 15 cm wide in the right wall (white muslin curtains helped to hide this opening). The silver glove was 70 cm long and thus covered both the hand and arm of the experimenter.

The infant was tested in a brightly lit room. Four lights (each with a 40 W lightbulb) were attached to the back and side walls of the apparatus to provide additional light. The 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 fabric, stood at an angle on either side of the apparatus. These frames isolated the infant from the experimental room. Between trials, a muslin-covered frame 61 cm high and 94 cm wide was lowered in front of the opening in the front wall of the apparatus.

4.1.3. Events

Barrier condition

Three experimenters worked together to produce the events. The first wore the silver glove and manipulated the bird, the second operated the screen, and the third manipulated the barrier. The numbers in parentheses indicate how long it took to perform the actions described.

Impossible test event. At the beginning of the event, the screen stood in front of the bird and the barrier. The first experimenter's hand was held in mid-air, half-way between the screen and the right wall of the apparatus. To start, the second experimenter pulled the screen until it stood 1.5 cm from the left wall (2 s). The bird, on the left, and the barrier, on the right, were then clearly visible to the infant. After a 2-s pause, the second experimenter pushed the screen back in front of the bird and the barrier (2 s). The third experimenter then lifted the curtain that hid the opening in the back wall of the apparatus and pulled the barrier out of the apparatus (1 s). Next, the first experimenter's hand reached behind the screen's right edge and reappeared holding the bird (2 s). After gently shaking the bird (2 s), causing it to chime, the first experimenter's hand replaced the bird behind the screen and returned to its previous position between the screen and the right wall (2 s). During the last of these 2 s, the third experimenter replaced the barrier behind the screen. The second experimenter then pulled the screen back toward the left wall, revealing the bird and the barrier standing intact in the same positions as before, and beginning a new event cycle. Each event cycle thus lasted approximately 13 s. Cycles were repeated until the computer signaled that the trial had ended (see below). When this occurred, the third experimenter lowered the curtain in front of the opening in the front wall of the apparatus.

Possible test event. The possible test event was identical to the impossible test event with two exceptions. First, the positions of the bird and the barrier were reversed: The bird stood on the right and the barrier on the left. Second, the third experimenter, as before, lifted the curtain that hid the opening in the back wall of the apparatus, but instead of sliding the barrier in or out of the apparatus, gently slid a box against the floor of the apparatus behind the back wall. This ensured that neither the infant nor the observers could distinguish between the impossible and the possible events on the basis of the faint sounds associated with the displacement of the barrier.

Left and right familiarization events. The left and right familiarization events were identical to the impossible and the possible test events, respectively, except that the barrier was absent. These events served to familiarize the infant with the movement of the screen and the actions of the hand (retrieving the bird from its left or its right position, shaking the bird, and then replacing it).

Cover condition

Impossible test event. The impossible test event shown to the infants in the cover condition was identical to that shown to the infants in the barrier condition except that the bird was replaced by the bear, and the barrier by the cover.

Possible test event. The possible test event was identical to the impossible test event with two exceptions. First, the cover stood to the left of the bear instead of over the bear. Second, instead of removing and replacing the cover, the third experimenter gently lifted and deposited a box on the floor of the apparatus behind the back wall. This ensured that neither the infant nor the observers could discriminate between the impossible and the possible events on the basis of the faint sounds associated with the displacement of the cover.

Familiarization event. The familiarization event was identical to the impossible and the possible test events except that the cover was absent. This event served to familiarize the infant with the movement of the screen and the actions of the hand (retrieving, squeaking, and replacing the bear). Note that, since the bear occupied the same position in the impossible and the possible events, only one familiarization event was needed.

To help the experimenters adhere to the same 13-s event cycle throughout the familiarization and test events shown to the infants in the barrier and the cover conditions, a metronome beat softly once per second.[1]

4.1.4. Procedure

The infant sat on his or her parent's lap in front of the apparatus, facing the screen. The infant's head was approximately 62 cm from the screen. Prior to the experiment, the infant was allowed to manipulate the bird and the barrier (barrier condition) or the bear and the cover (cover condition); the objects were held one at a time by the first experimenter in her gloved right hand. The parent was asked not to interact with the infant during the experiment. At the beginning of the test trials, the parent was instructed to close his or her eyes.

The infant's looking behavior was monitored by two observers who viewed the infant through small peepholes in the cloth-covered frames on either side of the apparatus. The observers could not see the objects inside the apparatus 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. Inter-observer agreement on each trial was computed on the basis of the number of seconds that the two observers agreed on the direction of the infant's gaze out of the total number of seconds that the trial lasted. Disagreements of less than 0.1 s were ignored. Agreement in this experiment and in the next experiment averaged 92% per trial per infant. The looking times recorded by the primary observer were used to determine the end of the trials (see below).

Each infant was tested according to a three-phase procedure: a pretest

[1]In order to adhere to the same 13-s cycle throughout the events, the first experimenter slowed her motions slightly (a) when retrieving or replacing the bird in the right familiarization event and the possible test event shown to the infants in the barrier condition and (b) when retrieving or replacing the bear in the familiarization and test events shown to the infants in the cover condition. Recall that in these events, the bird or the bear stood 37 cm from the right wall; in the left familiarization event and the impossible test event shown to the infants in the barrier condition, in contrast, the bird stood farther to the left, 48.5 cm from the right wall.

phase, a familiarization phase, and a test phase. During the *pretest* phase, the infants in each condition received two pretest trials to acquaint them with the two possible locations of the bird and the barrier or the bear and the cover. Throughout these trials, the screen stood 1.5 cm from the left wall of the apparatus so that the objects were fully visible. The infants in the barrier condition saw the bird to the left of the barrier in one trial and to the right of the barrier in the other trial. The infants in the cover condition saw the bear under the cover in one trial and to the right of the cover in the other trial. Each trial ended when the infant either (a) looked away from the display for 2 consecutive seconds after having looked at it for at least 5 cumulative seconds or (b) looked at the display for 30 cumulative seconds without looking away for 2 consecutive seconds.

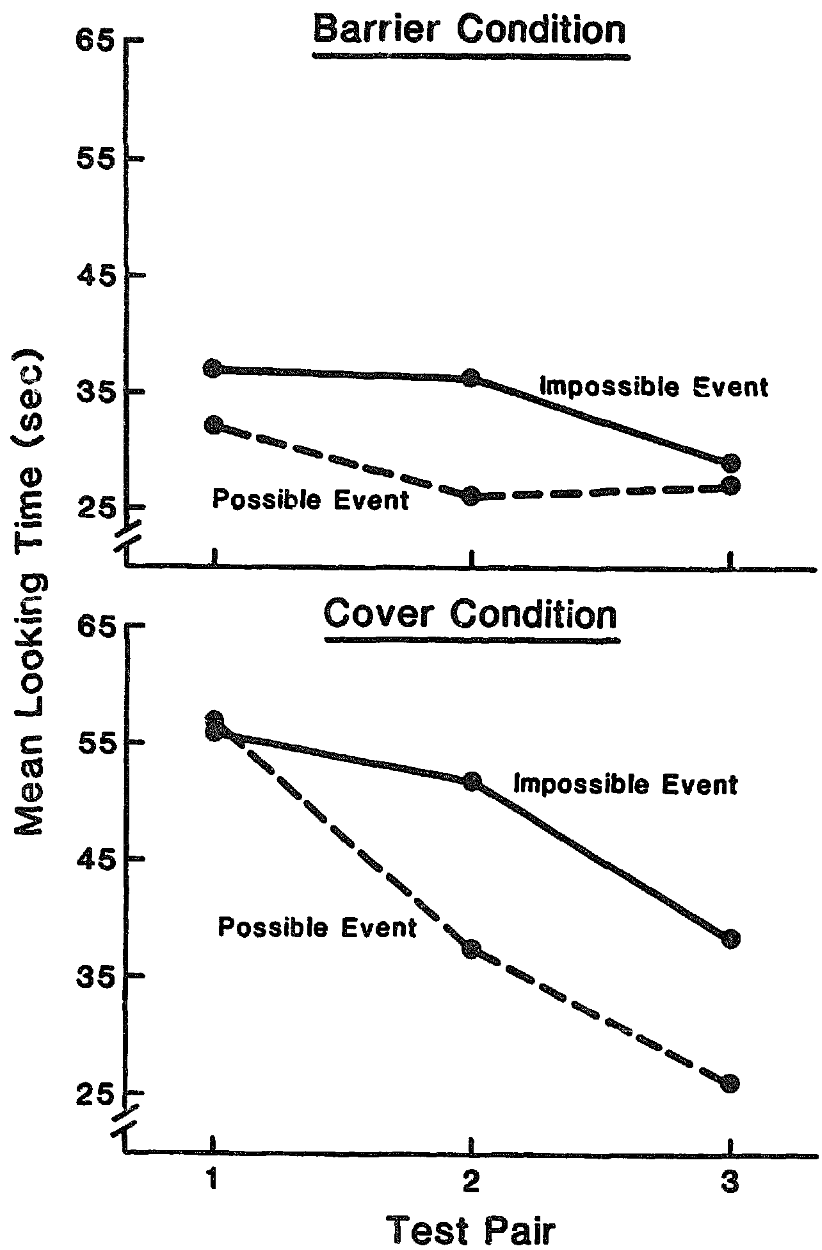
During the *familiarization* phase, the infants in the barrier condition saw the left and the right familiarization events described above on alternate trials until they had completed two pairs of trials. The infants in the cover condition saw the familiarization event described above on two successive trials. Each familiarization trial ended when the infant either (a) looked away from the event for 2 consecutive seconds after having looked at it for at least 13 cumulative seconds (the duration of a cycle) or (b) looked at the event for 65 cumulative seconds without looking away for 2 consecutive seconds.

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. At the beginning of each test trial, the second experimenter waited to push the screen back in front of the objects until the computer signaled that the infant had looked at the display for 2 cumulative seconds. This ensured that the infant had noted the presence and the location of the objects (to help the infant focus on the objects, the hand only entered the apparatus at the end of the 2-s pretrial). The criteria used to determine the end of the test trials were the same as for the familiarization trials.

Half of the infants in the barrier condition saw the bird on the left first in the pretest, familiarization, and test trials; the other half saw the bird on the right first. Similarly, half of the infants in the cover condition saw the cover on the left first in the pretest and test trials; the other half saw the cover over the bear first.

Three of the 28 infants in the experiment completed fewer than three pairs of test trials. These infants completed only two pairs, because of fussiness. All subjects (in this experiment as well as in the next experiment) were included in the data analyses whether or not they had completed the full complement of three pairs of test trials.

Figure 2. *Mean looking times of the infants in the barrier and the cover conditions in Experiment 1 at the impossil 'e and the possible events.*



4.2. *Results*

Figure 2 shows the mean looking times of the infants in the barrier and the cover conditions at the impossible and the possible test events. It can be seen that the infants in the two conditions looked longer at the impossible event.

The infants' looking times were analyzed by means of a 2 × 3 × 2 mixed model analysis of variance, with condition (barrier or cover condition) as the between-subjects factor and with test pair (first, second, or third pair of test trials) and event (impossible or possible event) as the within-subjects factors.[2] 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, $F(1, 124) = 9.07$, $p < .005$, indicating that the infants looked reliably longer at the impossible ($M = 40.8$) than at the possible ($M = 33.6$) event. This effect was found for both the infants in the barrier (impossible event: $M = 34.4$, possible event: $M = 28.4$) and in the cover (impossible event: $M = 48.7$, possible event: $M = 40.1$) conditions.

The analysis of variance also yielded significant main effects of condition, $F(1, 26) = 13.36$, $p < .002$, and test pair, $F(2, 124) = 10.85$, $p < .0001$, as well as a significant Condition × Test Pair interaction, $F(2, 124) = 6.08$, $p < .005$. Follow-up comparisons indicated that the infants in the cover condition looked reliably longer than the infants in the barrier condition on the first ($F(1, 124) = 29.89$, $p < .0001$) and the second ($F(1, 124) = 11.18$, $p < .002$) test pairs, though not on the third ($F(1, 124) = 0.98$). At least two explanations can be offered for these results. One is that because the infants in the barrier condition received four familiarization trials and the infants in the cover condition received only two, the infants in the latter condition were less fatigued and looked longer overall on the initial test pairs. The other explanation is that the cover condition test events were more interesting to the infants than the barrier condition test events (e.g., the squeaky bear may have been more attractive than the chiming bird). Since these effects do not interact with the infants' preference for the impossible event, they do not bear on the theoretical issues investigated here and will not be discussed further.

Pretest trials

Analysis of the infants' looking times during the pretest trials revealed that (a) the infants in the barrier condition tended to look equally when the bird

[2]In this experiment and in the next experiment, the two-way interaction terms involving the random factor infant (Infant × Test Pair, Infant × Event) were first tested against the error term Infant × Test Pair × Event and, when found to be statistically nonsignificant, were pooled into the error term (cf. Green & Tukey, 1960; Kirk, 1982).

was to the right (M = 10.5) and to the left (M = 11.5) of the barrier, $F(1, 14)$ = 0.18, and (b) the infants in the cover condition looked reliably less when the bear stood under (M = 11.6), rather than to the right of (M = 16.1), the cover, $F(1, 10)$ = 5.09, $p < .05$, perhaps because they could then see the bear less clearly. These results provide evidence against the hypothesis that the infants in the two conditions looked longer at the impossible event because they preferred the arrangement of the toy and the obstacle in the impossible event (bird to the barrier's left, bear under the cover) to that in the possible event (bird to the barrier's right, bear to the cover's right).

4.3. Discussion

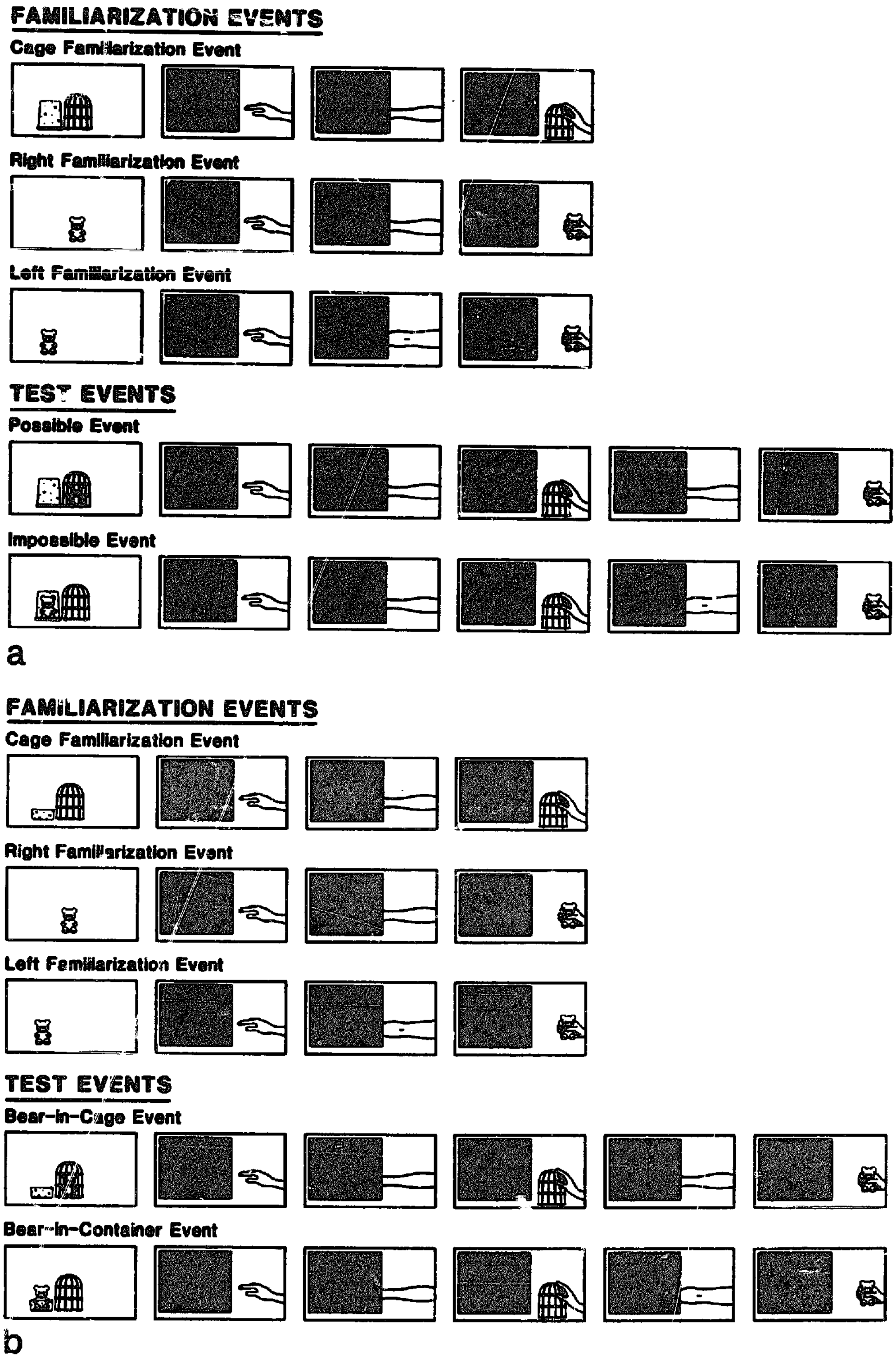
The infants in the barrier and the cover conditions in Experiment 1 looked reliably longer at the impossible than at the possible event, suggesting that they (a) represented the existence and the location of the toy (bird, bear) and the obstacle (barrier, cover) behind the screen; (b) realized that the direct reaching action of the hand could result in the retrieval of the toy when it stood in front of, but not behind (barrier condition) or under (cover condition), the obstacle; and therefore (c) were surprised in the impossible event to see the hand reappear from behind the screen holding the toy.

These results suggest that, by 5.5 months of age, infants are aware that a direct reaching action is insufficient to retrieve a toy placed behind or under an obstacle. Do infants this age know what actions *could* result in the toy's retrieval? Experiment 2 was designed to address this question.

5. Experiment 2

Experiment 2 tested whether 5.5-month-old infants understand that a toy placed under an obstacle can be retrieved only after the obstacle has been removed. As in Experiment 1, the infants saw a possible and an impossible test event. At the start of each event, the infants saw two covers placed side by side: On the left was the clear cover used in Experiment 1 and on the right was a small cage. The toy bear used in Experiment 1 stood under one of the two covers. After a few seconds, a screen was pushed in front of the objects, hiding them from view. Next, a hand reached behind the screen's right edge and reappeared holding the cage. After depositing the cage on the floor of the apparatus, the hand again reached behind the screen and reappeared holding the bear. The only difference between the two test events was in the location of the bear at the start of the events. In the possible event, the bear was under the cage and hence could be retrieved after the cage was removed.

Figure 3. *Schematic representation of the familiarization and test events shown to the infants in the experimental (3a) and the control (3b) conditions in Experiment 2.*



In the impossible event, the bear was under the clear cover and hence should still have been inaccessible after the cage was removed (see Figure 3a).

Our reasoning was as follows. If the infants (a) represented the existence and the location of the bear and the two covers behind the screen and (b) understood that the hand's sequence of actions could result in the retrieval of the bear when it stood under the cage but not when it stood under the clear cover, then they should be surprised in the impossible event when the hand reappeared holding the bear. Therefore, they should look longer at the impossible than at the possible event. On the other hand, if the infants (a) did not represent the bear and covers behind the screen or (b) believed that the hand's actions were sufficient to retrieve the bear from under the cage or from under the clear cover, 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 our experiment. The infants might look reliably longer at the impossible event because they focused exclusively on the cage, ignoring the clear cover, and hence were surprised, after observing that the cage was empty, to see the hand reappear from behind the screen holding the bear. To test this alternative interpretation, we included a control condition that was identical to the experimental condition except that the clear cover was replaced by a shallow, clear container. The bear's head and upper body protruded above the rim of the container (see Figure 3b).

We reasoned that if the infants in the experimental condition looked longer at the impossible event because they were surprised to see the hand reappear with the bear when the cage was empty, then the infants in the control condition should look longer at the bear-in-container than at the bear-in-cage event. On the other hand, if the infants in the experimental condition looked longer at the impossible event because they understood that the hand's actions were insufficient to retrieve the bear from under the clear cover, then the infants in the control condition should look equally at the bear-in-container and the bear-in-cage events because the bear could be retrieved in either event after the cage was removed.

5.1. Method

5.1.1. Subjects

Subjects were 32 healthy, full-term infants ranging in age from 4 months 26 days to 5 months 24 days (*M* = 5 months 10 days). One additional infant was eliminated from the experiment, because of fussiness. Half of the infants were assigned to the experimental condition (*M* = 5 months 11 days), and half to the control condition (*M* = 5 months 7 days).

5.1.2. Apparatus

The apparatus used in this experiment was identical to that used in the cover condition in Experiment 1 with a few exceptions. First, a larger screen was used. This screen was 33 cm high and 40 cm wide and was positioned 37 cm from the left wall, 23 cm from the right wall, and 23 cm from the front edge of the apparatus. Second, in addition to the bear and the clear cover used in Experiment 1, two additional stimuli were used: a brown plastic cage, 19 cm high and 15 cm in diameter, and a clear plastic container, 6 cm high, 12 cm wide, and 11 cm deep. Like the clear cover, this container was decorated with a few dots and stars. At the start of the test events, the cage was positioned 23 cm from the right wall and 2 cm behind the screen. The clear cover used in the experimental condition events stood immediately next to the cage, 48 cm from the left wall and 3 cm behind the screen. The clear cover was positioned directly in front of a hole 23 cm high and 16 cm wide in the back wall of the apparatus. This hole was used to surreptitiously remove the clear cover and was hidden by a curtain of the same color as the back wall. The container used in the control condition events was positioned 1 cm to the left of the cage, 49 cm from the left wall, and 4.5 cm behind the screen. When moved to the side of the screen, the cage was deposited 4 cm from the screen, 4 cm from the right wall, and 5 cm from the front edge of the apparatus.

5.1.3. Events

Experimental condition events

As in Experiment 1, three experimenters worked in concert to produce the events. The first wore the silver glove and manipulated the cage and the bear, the second operated the screen, and the third manipulated the clear cover.

Impossible test event. At the beginning of the event, the screen stood in front of the clear cover and the cage; the bear stood under the clear cover. The first experimenter's hand was held in mid-air, half-way between the screen and the right wall of the apparatus. To start, the second experimenter pulled the screen until it stood 1.5 cm from the left wall of the apparatus (2 s). The clear cover, the bear, and the cage were then clearly visible to the infant. After a 2-s pause, the second experimenter pushed the screen back to its original position (2 s). The first experimenter's hand then reached behind the screen's right edge, reappeared holding the cage, and deposited it on the floor of the apparatus (2 s). During these 2 s, the third experimenter lifted the curtain that hid the hole in the back wall of the apparatus and removed the clear cover. Next, the first experimenter's hand again reached behind the screen and reappeared holding the bear (2 s). After squeaking the bear for about 2 s, the first experimenter's hand replaced the bear behind the screen and then took hold of the cage (2 s). Next, the hand replaced the cage behind the screen and then returned to its initial position between the screen and the right wall (2 s). During these last 2 s, the third experimenter replaced the clear cover over the bear. After a 1-s pause, the second experimenter pulled the screen toward the left wall of the apparatus, revealing the clear cover, bear, and cage standing intact in the same positions as before, and beginning a new event cycle. Each event cycle thus lasted approximately 17 s. Cycles were repeated until the computer signaled that the trial had ended (see below). When this occurred, the third experimenter lowered the curtain in front of the opening in the front wall of the apparatus.

Possible test event. The possible test event was identical to the impossible test event except that the bear stood under the cage, instead of under the clear cover. (The third experimenter removed the clear cover to ensure that neither the infant nor the observers could distinguish between the impossible and the possible test events on the basis of any faint sounds associated with the displacement of the clear cover.)

Cage familiarization event. The cage familiarization event served to familiarize the infant with the removal and replacement of the cage. At the beginning of the event, the screen stood in front of the clear cover and the cage, both of which were empty, and the first experimenter's hand stood midway between the screen and the right wall. To start, as before, the second experimenter pulled the screen aside (2 s), paused (2 s), and then pushed the screen back in place (2 s). Next, as before, the first experimenter's hand reached behind the screen, reappeared holding the cage, and deposited it on the floor of the apparatus (2 s). After a 2-s pause, the hand replaced the cage behind the screen and returned to its initial position (1 s). The second experimenter waited 1 s and then pulled the screen aside once more, beginning a new event cycle. Each event cycle thus lasted about 12 s.

Left and right familiarization events. The left and right familiarization events served to familiarize the infant with the retrieval and replacement of the bear. No covers were present in these events. In the left familiarization event, the bear stood on the left, as in the impossible test event; in the right familiarization event, the bear stood on the right, as in the possible test event. As before, the second experimenter first pulled the screen to the side (2 s), paused (2 s), and then pushed the screen back in place (2 s). Next, the first experimenter's hand reached behind the screen and reappeared holding the bear (2 s). After squeaking the bear for about 2 s, the hand replaced the bear behind the screen and then returned to its starting position (1 s). Following a 1-s pause, the second experimenter again pulled the screen aside, beginning a new event cycle. Each event cycle thus lasted approximately 12 s, as with the cage familiarization event.

Control condition events

Bear-in-container and bear-in-cage test events. The bear-in-container and the bear-in-cage test events shown to the infants in the control condition were identical to the impossible and the possible test events shown to the infants in the experimental condition, respectively, with two exceptions. First, the clear cover was replaced by the container. Second, the third experimenter was not involved in the production of these events because no obstacle obstructed the hand's access to the bear.

Cage familiarization event. The cage familiarization event shown to the infants in the control condition was identical to that shown to the infants in the experimental condition except that the clear cover was replaced by the container.

Left and right familiarization events. The left and right familiarization events shown to the infants in the control condition were identical to those shown to the infants in the experimental condition.[3]

5.1.4. Procedure

The procedure used in Experiment 2 was similar to that in Experiment 1. Each infant participated in a three-phase procedure. In the *pretest* phase, the infants received two pretest trials designed to acquaint them with the clear cover or container, the cage, and the bear. Throughout these trials, the screen stood 1.5 cm from the left wall of the apparatus so that the objects were fully visible. The infants in the experimental condition saw the bear under the clear cover in one trial and under the cage in the other trial. The infants in the control condition saw the bear inside the container in one trial and under the cage in the other trial. Each trial ended when the infant (a) looked away from the display for 2 consecutive seconds after having looked at it for 5 cumulative seconds or (b) looked at the display for 30 cumulative seconds without looking away for 2 consecutive seconds.

During the *familiarization* phase, the infants saw the three familiarization events described above on three successive trials. All infants saw the cage familiarization event on the first trial and the left and right familiarization events on the following trials. Each trial ended when the infant (a) looked away from the event for 2 consecutive seconds after having looked at it for

[3]In order to adhere to the same 12-s cycle during the left and right familiarization events shown to the infants in the experimental and the control conditions, the first experimenter slowed her motions slightly when retrieving and replacing the bear during the right familiarization event. Similarly, in order to adhere to the same 17-s cycle during the test events shown to the infants in the two conditions, the hand slowed its motions slightly when retrieving and replacing the bear during the possible test event and the bear-in-cage test event. Recall that in these events the bear stood on the right and hence was closer to the hand.

at least 12 seconds (the duration of one cycle) or (b) looked at the display for 70 cumulative seconds without looking away for 2 consecutive seconds.

During the *test* phase, the infants in the two conditions saw the test events described above on alternate trials until they had completed three pairs of test trials. At the start of each test event, the second experimenter waited to push the screen back in front of the objects until the computer signaled that the infant had looked at the display for 3 cumulative seconds. This helped ensure that the infant had noted the presence and the location of the objects (to help the infant focus on these objects, the hand only entered the apparatus at the end of the pretrial). Each trial ended when the infant (a) looked away from the event for 2 consecutive seconds after having looked at it for at least 17 cumulative seconds (the duration of one cycle) or (b) looked at the event for 70 cumulative seconds without looking away for 2 consecutive seconds.

Half of the infants in each condition saw the bear on the left first in the pretest, familiarization, and test trials; the other infants saw the bear on the right first.

Only one of the 32 infants in the experiment failed to contribute the full complement of three pairs of test trials to the data analysis. This infant completed only two test pairs, because of fussiness.

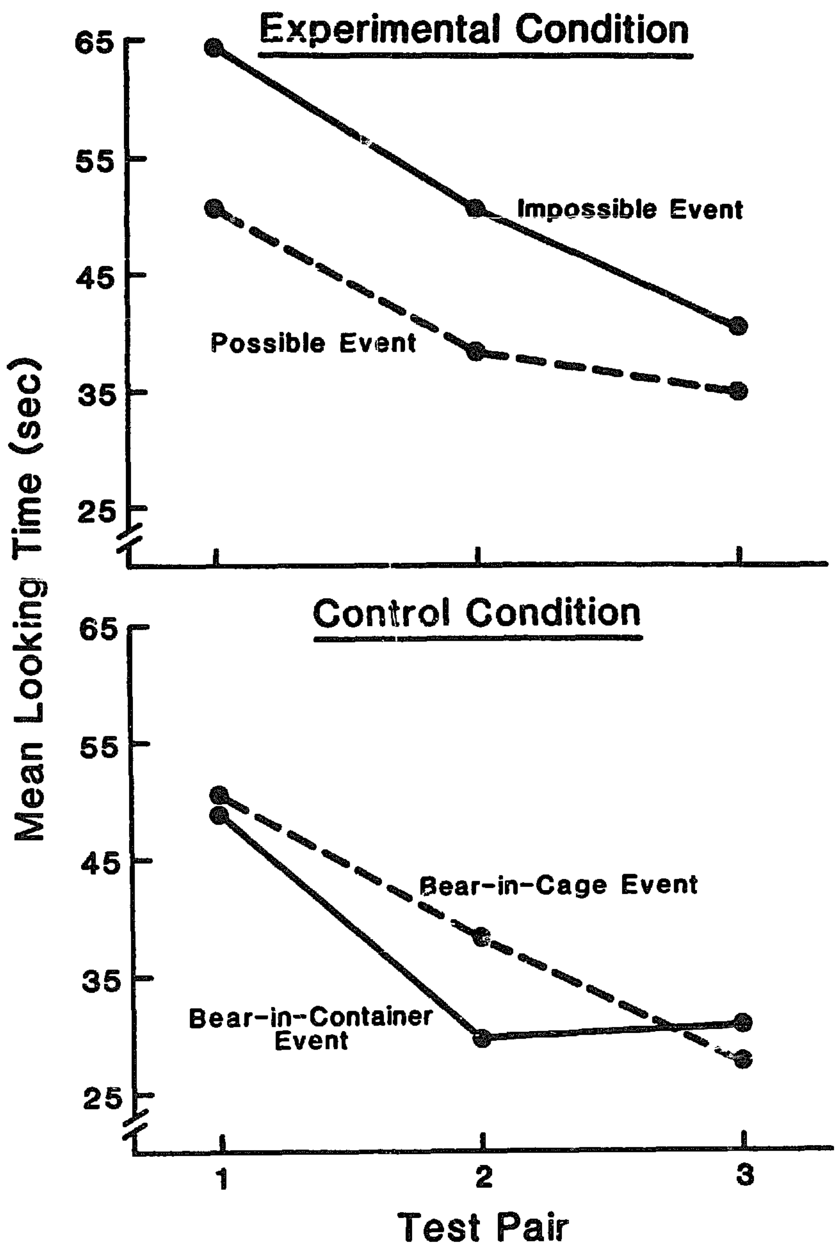
5.4. Results

Figure 4 shows the looking times of the infants in the experimental and the control conditions at the test events. It can be seen that the infants in the experimental condition tended to look longer at the impossible than at the possible event, whereas the infants in the control condition tended to look about equally at the bear-in-cage and the bear-in-container events.

The infants' looking times were analyzed by means of a 2 × 3 × 2 mixed model analysis of variance with condition (experimental or control condition) as the between-subjects factor and with test pair (first, second, or third test pair) and event (impossible/bear-in-container or possible/bear-in-cage event) as the within-subjects factors. There was a significant main effect of condition, $F(1, 22) = 6.28$, $p < .05$, and a significant Condition × Event interaction, $F(1, 148) = 5.95$, $p < .05$. Planned comparisons indicated that the infants in the experimental condition looked realiably longer at the impossible (M = 52.2) than at the possible (M = 41.5) event, $F(1, 148) = 8.05$, $p < .01$, whereas the infants in the control condition looked about equally at the bear-in-container (M = 36.4) and the bear-in-cage (M = 38.8) events, $F(1, 148) = 0.40$.

The analysis of variance also yielded a significant main effect of test pair, $F(2, 148) = 21.42$, $p < .0001$, indicating that the infants looked reliably less as the experiment progressed.

Figure 4. *Mean looking times of the infants in the experimental and the control conditions in Experiment 2 at the impossible and the possible events.*



Pretest trials

Analysis of the data obtained during the pretest trials revealed that the infants in the experimental condition looked less when the bear stood under the clear cover (M = 8.7) than when it stood under the cage (M = 12.3), though this preference was not significant at the .05 level, $F(1, 15) = 3.49$, $p < .09$. This result is consistent with the pretest results of the cover condition in Experiment 1, where the infants looked reliably less when the bear was placed under, as opposed to next to, the cover. The infants in the control condition looked equally when the bear stood in the container (M = 13.9) and under the cage (M = 13.6), $F(1, 15) = 0.01$.

5.5. Discussion

The infants in the experimental condition in Experiment 2 looked reliably longer at the impossible than at the possible event, whereas the infants in the control condition tended to look equally at the bear-in-container and the bear-in-cage events. These results suggest that the infants (a) represented the existence and the location of the bear, the cage, and the clear cover or container behind the screen; (b) understood that the hand's sequence of actions was sufficient to retrieve the bear when it stood under the cage or inside the container, but not when it stood under the clear cover; and hence (c) were surprised in the impossible event when the hand reappeared holding the bear.

6. Conclusion

In the introduction, we argued that young infants are unable to search for hidden objects because they are unable to produce means–end sequences, that they are unable to produce means–end sequences because they are unable to plan these sequences, and that they are unable to plan these sequences because of difficulties in reasoning about operators. We next hypothesized that young infants' difficulties with operators could take one of two forms. On the one hand, infants' knowledge about operators could be inaccurate or incomplete. On the other hand, infants could be unable to select and chain operators adequately, even when these are operators well-known to them.

The results of Experiment 1 and 2 provide evidence against the first of these two hypotheses. The 5.5-month-old infants in the experiments were clearly aware of the preconditions under which the hand's actions could and could not be applied, and of the effects these actions could and could not have. Thus, the infants in the barrier condition in Experiment 1 understood that the hand's direct reaching and grasping action could result in the retrieval of the bird when it stood in front of, but not behind, the barrier. Similarly, the infants in the cover condition realized that the hand's action could result in the retrieval of the bear when it stood in front of, but not under, the clear cover. Furthermore, the infants in Experiment 2 recognized that (a) the hand's initial reaching and grasping action could result in the retrieval of the cage and (b) the hand's subsequent reaching and grasping action could result in the retrieval of the bear when it stood under the cage or in the shallow container, but not when it stood under the clear cover. In each case, when shown a possible action (e.g., the hand reaching for and grasping the cage), the infants seemed aware that the action's preconditions were satisfied (e.g., no obstacle blocked the hand's access to the cage), and that the action's effect (e.g., the retrieval of the cage) was consistent with the nature of the action. In contrast, when shown an impossible action (e.g., the hand reaching for and grasping the bear despite the fact that it stood under the clear cover), the infants appeared to realize that the action's preconditions were not satisfied (e.g., the clear cover blocked the hand's access to the bear), and hence that the action should not have been carried out and that its effect (e.g., the bear's retrieval) should not have been observed.[4]

The second hypothesis we listed above was that young infants are unable to plan means–end sequences because they are unable to select or chain appropriate operators, even when these are well-known to them. At least two explanations could be advanced for this inability. One is that young infants lack a subgoaling ability – an ability to form sequences of operators such that each operator satisfies a subgoal that brings infants one step closer to their goal. This explanation seems unlikely given that young infants routinely perform what appear to be intentional series of actions directed at single objects. An example of such a goal-directed action sequence might be infants' reaching for and grasping a bottle, bringing it to their mouths, and sucking its nipple. Piaget (1952) described many sequences of this type. Several of his

[4]It should be noted that there are several ways in which the infants in Experiments 1 and 2 could have responded to the impossible events they were shown. They could have been surprised at the inconsistency between the location of the toy, the nature of the hand's action, and the result of this action, but made no attempt to generate an explanation for this inconsistency. Alternatively, they could have attempted to make sense of the inconsistency in some way. For example, they could have assumed that the toy's location was modified behind the screen in some inexplicable way, or that once behind the screen the hand performed some unknown, lightning-quick maneuver that enabled it to retrieve the toy despite the obstacle in its path, or that the obstacle in the path of the hand had a secret entrance that allowed the hand to gain access to the toy, or that the toy retrieved by the hand was in fact a second, identical toy hidden behind the screen. The data collected in the present experiments are insufficient to determine which, if any, of these construals the infants imposed on the impossible events. All that the data indicate is that the infants detected that the toy's location, the hand's action(s), and the toy's retrieval were inconsistent.

observations involve his children's responses to chains suspended from rattles attached to their bassinet hood. For example, Piaget noted the following: "At 0;3(14) Laurent looks at the rattle at the moment I hang up the chain. He remains immobile for a second. Then he tries to grasp the chain (without looking at it), brushes it with the back of his hand, grasps it but continues to look at the rattle without moving his arms. Then he shakes the chain gently while studying the effect. Afterwards he shakes it more and more vigorously. A smile and expression of delight" (p. 163). It is very difficult to imagine how an infant might be capable of such clearly intentional actions and yet lack a subgoaling ability. Laurent's reaching for, grasping, and shaking the chain are all actions performed in the service of his goal, experienced from the start, of shaking the rattle.

A second explanation for young infants' inability to chain operators in means–end sequences is that young infants possess a subgoaling ability but have difficulty with situations in which the performance of the means would put them in apparent conflict with the achievement of their goal. That is, if infants want to grasp a toy placed under a cover, then grasping the cover puts them in apparent conflict with their goal of grasping the toy. Similarly, reaching around a screen to retrieve an object placed behind the screen may be difficult for infants because it puts them in the position of having to reach away from where they know the object to be.

Exactly why infants have difficulty with these conflict situations is unclear. However, it should be noted that adults often show exactly the same difficulty. Khlar (personal communication, April 16, 1990) has found that naïve adults who are given the Tower of Hanoi problem will avoid performing moves that are in apparent conflict with their goal, even though these counter-intuitive moves are in fact the correct ones. According to this second explanation, then, young infants would be in the same position as adults who, when faced with physical problems whose solutions require counter-intuitive actions, find themselves able to *identify* but not to *generate* correct solutions to the problems.

We have been arguing that young infants' failure to search for hidden objects, and more generally, to produce means–end sequences, stems from their limited problem solving ability. Apart from its intrinsic merit, this explanation has the added value of dovetailing with a recent account of 7- to 12-month-old infants' perseverative search errors that also focuses on the limitations of infants' problem solving ability (Baillargeon, DeVos, & Graber, 1989). Researchers have noted that if an object is hidden in a location A and then in a location B, infants search perseveratively in A if forced to wait a few seconds before they search, but search correctly in B if allowed to search immediately after the object disappears in B (e.g., Diamond, 1985;

Fox, Kagan, & Weiskopf, 1979; Gratch, Appel, Evans, LeCompte, & Wright, 1974; Harris, 1973; Miller, Cohen, & Hill, 1970; Wellman, Cross, & Bartsch, 1987).

The explanation proposed by Baillargeon et al. (1989) for infants' perseverative search errors rests on a distinction between two types of problem solving. One, *reactive* type corresponds to situations in which solutions are produced immediately, without conscious reasoning. Operators that are stored in memory and whose conditions of application are satisfied are simply "run off" or executed. An example of such problem solving is reaching for an object whose location is known or driving home along a familiar route. The second, *planful* type of problem solving corresponds to situations in which solutions are generated through an active reasoning or computation process. An example of this second type of problem solving is finding an object whose location can be deduced from available cues or planning a trip to a novel location. It is assumed that because the second type of problem solving is effortful, individuals use it only when no other avenues are available. Whenever possible, individuals prefer relying on previously computed solutions rather than generating new ones. Hence, when a problem situation is perceived to be similar to a previously experienced situation, individuals attempt to apply the solution computed in the initial situation, thus engaging in reactive as opposed to planful problem solving (see Logan, 1988, and Suchman, 1987, for interesting discussions of similar concepts and relevant data in adult problem solving).

According to Baillargeon et al. (1989), which type of problem solving infants undertake in the AB search task depends on the length of the enforced delay between the object's hiding and retrieval. When no delays or short delays are used, infants engage in reactive problem solving. When longer delays are used, however, infants shift to planful problem solving. On the initial A trial, infants compute a solution (i.e., determine where to find the object) and store this solution in memory. On the subsequent B trial, instead of recomputing a solution, infants simply "run off" their previous solution, leading to perseverative errors. Baillargeon et al. suggest that the overall similarity of the task context on the A and B trials may lure infants into thinking "Ah, ah, I know what to do here!" and into blindly applying what is no longer an appropriate solution (see Baillargeon et al., 1989, for a review of the evidence supporting this explanation of infants' performance in the AB search task and for a discussion of how this explanation can be extended to other means–end tasks).

Researchers have identified two distinct stages in the early development of infants' search behavior: (a) Prior to about 7 months of age, infants do not search for objects they have observed being hidden and (b) prior to about

12 months of age, infants do search for hidden objects but their performance is fragile and easily disrupted by task factors such as the introduction of a delay between hiding and retrieval. According to the arguments put forth in the present paper and those advanced by Baillargeon (in press), both of these stages reflect limitations of infants' problem solving. During the first stage, infants are unable to plan means–end sequences such as search sequences, perhaps because of a limited subgoaling ability. During the second stage, infants become able to plan search sequences but are overly inclined, under certain conditions, to repeat previously planned sequences rather than to compute new and context-appropriate sequences. Furthermore, at each stage infants show themselves better able to evaluate than to generate correct action sequences. The results of the present experiments indicate that infants can identify correct sequences for the retrieval of a hidden object long before they spontaneously produce these sequences. Similarly, the results of experiments conducted by Baillargeon and her colleagues (Baillargeon, in press; Baillargeon & Graber, 1988; Baillargeon et al., 1989) demonstrate that infants can identify context-appropriate searches after delays of 15, 30, and even 70 s long before they produce correct searches at comparable delays.

Much additional research will have to be carried out before one can admit the hypothesis that the emergence and early development of infants' search behavior reflects progress in their problem solving ability. One of the main incentives for undertaking systematic tests of this hypothesis, we believe, is the intriguing possibility that it will bring together behaviors in infants and older individuals previously assumed to be entirely disparate.

References

Anderson, J.R. (1985). *Cognitive psychology and its implications* (2nd ed.). New York: Freeman.

Baillargeon, R. (1986). Representing the existence and the location of hidden objects: Object permanence in 6- and 8-month-old infants. *Cognition, 23*, 21–41.

Baillargeon, R. (1987a). Object permanence in 3.5- and 4.5-month-old infants. *Developmental Psychology, 23*, 655–664.

Baillargeon, R. (1987b). Young infants' reasoning about the physical and spatial properties of a hidden object. *Cognitive Development, 2*, 179–200.

Baillargeon, R. (in press-a). Reasoning about the height and location of a hidden object in 4.5- and 6.5-month-old infants. *Cognition*.

Baillargeon, R. (in press-b). The object concept revisited: New directions in the investigation of infants' physical knowledge. In C.E. Granrud (Ed.), *Visual perception and cognition in infancy: Carnegie-Mellon symposia on cognition* (Vol. 23). Hillsdale, NJ: Erlbaum.

Baillargeon, R., & DeVos, J. (1990). *Object permanence in 3.5- and 4.5-month-old infants: Further evidence.* Manuscript submitted for publication.

Baillargeon, R., DeVos, J., & Graber, M. (1989). Location memory in 8-month-old infants in a non-search AB task: Further evidence. *Cognitive Development, 4*, 345–367.

Baillargeon, R., & Graber, M. (1987). Where is the rabbit? 5.5-month-old infants' representation of the height of a hidden object. *Cognitive Development, 2*, 375–392.
Baillargeon, R., & Graber, M. (1988). Evidence of location memory in 8-month-old infants in a non-search AB task. *Developmental Psychology, 24*, 502–511.
Baillargeon, R., Spelke, E.S., & Wasserman, S. (1985). Object permanence in 5-month-old infants. *Cognition, 20*, 191–208.
Bushnell, E.W. (1985). The decline of visually guided reaching during infancy. *Infant Behavior and Development, 8*, 139–155.
Diamond, A. (1981, April). *Retrieval of an object from an open box: The development of visual-tactile control of reaching in the first year of life.* Paper presented at the biennial meeting of the Society for Research in Child Development, Boston, MA.
Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Development, 56*, 868–883.
Diamond, A. (1987). *Frontal lobe involvement in cognitive changes during the first year of life.* Manuscript submitted for publication.
Diamond, A. (in press). Differences between adult and infant cognition: Is the crucial variable presence or absence of language? In L. Weskrantz (Ed.), *Thought without language.* Oxford: Oxford University Press.
Fox, N., Kagan, J., & Weiskopf, S. (1979). The growth of memory during infancy. *Genetic Psychology Monographs, 99*, 91–130.
Granrud, C.E. (1986). Binocular vision and spatial perception in 4- and 5-month-old infants. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 36–49.
Gratch, G., Appel, K.J., Evans, W.F., LeCompte, G.K. & Wright, N.A. (1974). Piaget's stage IV object concept error: Evidence of forgetting or object conception. *Child Development, 45*, 71–77.
Green, B.F., & Tukey, J.W. (1960). Complex analyses of variance: General problems: *Psychometrika, 25*, 127–152.
Harris, P.L. (1973). Perseverative errors in search by young children. *Child Development, 44*, 28–33.
Harris, P.L. (1987). The development of search. In P. Salapatek & L.B. Cohen (Eds.), *Handbook of infant perception* (Vol. 2, pp. 155–207). New York: Academic Press.
Harris, P.L. (in press). Object permanence in infants. In A. Slater & J.G. Bremner (Eds.), *The psychology of infancy.* Hillsdale, N.J.: Erlbaum.
Hofsten, C. von (1980). Predictive reaching for moving objects by human infants. *Journal of Experimental Child Psychology, 30*, 369–382.
Hood, B., & Willatts, P. (1986). Reaching in the dark to an object's remembered position: Evidence of object permanence in 5-month-old infants. *British Journal of Developmental Psychology, 4*, 57–65.
Kirk, R.E. (1982). *Experimental design.* (2nd ed.). Belmont, CA: Brooks/Cole.
Logan, G.D. (1988). Toward an instance theory of automatization. *Psychological Review, 95*, 492–527.
Mayer, R.E. (1983). *Thinking, problem-solving, cognition.* New York: Freeman.
Miller, D., Cohen, L., & Hill, K. (1970). A methodological investigation of Piaget's theory of object concept development in the sensory-motor period. *Journal of Experimental Child Psychology, 9*, 59–85.
Newell, A., & Simon, H.A. (1972). *Human problem solving.* Englewood Cliffs, NJ: Prentice-Hall.
Newell, K.M., Scully, D.M., McDonald, P.V., & Baillargeon, R. (in press). Task constraints and infant grip configurations. *Developmental Psychology.*
Piaget, J. (1952). *The origins of intelligence in children.* New York: International University Press.
Piaget, J. (1954). *The construction of reality in the child.* New York: Basic Books.
Rochat, P., Clifton, R.K., Litovsky, R., & Perris, E. (1989, April). *Preparatory reaching for various sized objects in the light and the dark by 5-month-olds.* Paper presented at the biennial meeting of the Society for Research in Child Development, Kansas City, MO.
SAS user guide: Statistics (1985). Gary, NC: SAS Institute Inc.

Schuberth, R.E. (1983). The infant's search for objects: Alternatives to Piaget's theory of concept development. In L.P. Lipsitt & C.K. Rovee-Collier (Eds.), *Advances in infancy research* (Vol. 2, pp. 137–182). Norwood, NJ: Ablex.

Sophian, C. (1984). Developing search skills in infancy and early childhood. In C. Sophian (Ed.), *Origin of cognitive skills* (pp. 27–56). Hillsdale, NJ: Erlbaum.

Spelke, E.S. (in press). Where perceiving ends and thinking begins: The apprehension of objects in infancy. In A. Yonas (Ed.), *Perceptual development in infancy: Minnesota Symposia on Child Psychology* (Vol. 20). Hillsdale, NJ: Erlbaum.

Suchman, L.A. (1987). *Plans and situated actions: The problem of human–machine interaction.* Cambridge: Cambridge University Press.

Wellman, H.M., Cross, D., & Bartsch, K. (1987). A meta-analysis of research on Stage 4 object permanence: The A-not-B error. *Monographs of the Society for Research in Child Development, 51* (No. 3).

Willatts, P. (1984). Stages in the development of intentional search by young infants. *Developmental Psychology, 20*, 389–396.

Willatts, P. (in press). Development of problem-solving. In A. Slater & J.G. Bremner (Eds.), *The psychology of infancy.* Hillsdale, NJ: Erlbaum.