Cognition, 23 (1986) 21–41

Representing the existence and the location of hidden objects: Object permanence in 6- and 8-month-old infants*

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Abstract

The present experiment investigated two facets of object permanence in young infants: the ability to represent the existence and the location of a hidden stationary object, and the ability to represent the existence and the trajectory of a hidden moving object. Six- and 8-month-old infants sat in front of a screen; to the left of the screen was an inclined ramp. The infants watched the following event: the screen was raised and lowered, and a toy car rolled down the ramp, passed behind the screen, and exited the apparatus to the right. After the infants habituated to this event, they saw two test events. These were identical to the habituation event, except that a box was placed behind the screen. In one event (possible event), the box stood in back *of the car's tracks; in the other (impossible event), it stood on* top *of the tracks, blocking the car's path. Infants looked longer at the impossible than at the possible event, indicating that they were surprised to see the car reappear from behind the screen when the box stood in its path. A control experiment in which the box was placed in* front *(possible event) or on* top *(impossible event) of the car's tracks yielded similar results. Together, the results of these experiments suggest that infants understood that (1) the box continued to exist, in its same location, after it was occluded by the screen; (2) the car continued to exist, and pursued its trajectory, after it disappeared behind the screen; and (3) the car could not roll through the space occupied by the box. These results have implications for theory and research on the development of infants' knowledge about objects and infants' reasoning abilities.*

*The research reported in this manuscript was supported by a grant from the University Research Institute of the University of Texas at Austin. I thank Judy Deloache and Gwen Gustafson, for their careful reading of the paper; Marty Banks, Kathy Cain, Carol Dweck, Marcia Graber, and Liz Spelke, for helpful comments on different versions of the paper; and Stanley Wasserman and Dawn Iaccobucci for their help with the statistical analyses. I also thank the undergraduates who served as observers and experimenters, and the parents who kindly allowed their infants to participate in the studies.

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1. Introduction

Adults believe an object cannot exist at two separate points in time without having existed during the interval between them. Do infants share this belief about objects? Piaget (1954) was the first to investigate this question. He concluded that it is not until infants reach 9 months of age that they begin to conceive of objects as existing continuously in time. The main evidence for this conclusion came from observations of infants' reactions to hidden objects. Piaget noted that prior to 9 months, infants do not search for objects they have observed being hidden. If an attractive toy is covered with a cloth, for example, they make no attempt to lift the cloth and grasp the toy, even though they are capable of performing each of these actions. Piaget took these observations to suggest that young infants conceive of objects not as permanent entities that continue to exist when concealed by other objects, but as transient entities that cease to exist when they cease to be visible and begin existing anew when they reappear into view.

Although Piaget's observations have been confirmed by numerous investigators (see Harris, 1985, and Schuberth, 1983, for reviews), his interpretation of these observations has been questioned. A number of authors (e.g., Baillargeon, Spelke, & Wasserman, 1985; Bower, 1974) have suggested that young infants fail Piaget's search task because it requires the coordination of two separate actions (one upon the occluder and one upon the object). Studies of the development of action (e.g., Piaget, 1952; Uzgiris & Hunt, 1970) indicate that it is not until 9 months of age that infants begin to coordinate individual actions into means–end sequences.

Baillargeon et al. (1985) devised a test of object permanence that did *not* require infants to perform coordinated actions. This test was rather indirect: it focused on infants' understanding of the principle that a solid object cannot move through the space occupied by another solid object. Baillargeon et al. reasoned that if infants were surprised when a visible object appeared to move through the space occupied by an occluded object, it would indicate that they took account of the existence of the occluded object. Five-month-old infants were habituated to a screen that rotated back and forth through a 180-degree arc, in the manner of a drawbridge. After the infants habituated to this event, a box was placed behind the screen. 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-degree 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. Baillargeon et al. took this finding to indicate that the infants (1) believed the box continued to exist after it was occluded by the screen, and (2) expected the screen to stop against the box and were surprised when it failed to do so. A control experiment in which the box was placed next to the screen provided support for this interpretation of the results.

The present experiment extended the results of Baillargeon et al. in two directions. The results obtained by these authors suggest that by 5 months of age, infants represent the continued *existence* of an object hidden behind an occluder. But how precise is infants' representation of the object? In particular, how accurate is their representation of the *location* of the object behind the occluder? Do infants conceive of the object as occupying a specific spatial location, or, more vaguely, as residing somewhere behind the occluder? This is the first issue the present experiment was designed to address.

The results of Baillargeon et al. suggest that infants as young as 5 months of age believe that objects exist continuously in *time*. The present experiment examined whether they believe that objects exist continuously in *space* as well as in time. Consider the following occlusion event: a moving object disappears at one end of a screen and reappears, a moment later, at the other end. Upon seeing this event, adults would assume that the object continued to exist while out of sight (continuity in time), and traveled from one end of the screen to the other (continuity in space). Would young infants make the same assumptions? Do young infants believe, as adults do, that an object cannot appear at two separate points in space (e.g., the two ends of a screen) without having traveled from one point to the other? This is the second issue the present experiment attempted to address.

In the next sections, I briefly review studies of infants' ability to represent the location of hidden objects, and of infants' beliefs about the permanence of moving objects. Next, I describe the method devised to explore these two issues.

2. Representing the location of a hidden stationary object

Studies of infants' ability to represent the location of a hidden object have typically focused on their ability to search for an object hidden successively in different locations. Piaget (1954) noted that when infants begin to search for hidden objects, at about 9 months of age, they often search in the wrong location. If an object is hidden in a location A and then in a location B, they tend to search for it in A, where they first found it. Piaget took these AB errors to indicate that although infants endow objects with some permanence, as evidenced by their willingness to search for hidden objects, this permanence is still incomplete. Infants conceive of objects not as separate entities whose displacements are regulated by physical laws but as entities "at the disposal" of their actions. According to Piaget, when the infant "searches in A for what he has seen disappear in B, the explanation should be sought in the fact that the object is not yet sufficiently individualized to be dissociated from the global behavior related to position A" (p. 63). It is not until infants reach 9.5 or 10 months of age, Piaget claimed, that they come to view objects as entities whose spatial locations are independent of their perceptions and actions.

In recent years, several alternative interpretations have been offered for infants' AB errors (see Harris, 1985, and Schuberth, 1983, for reviews). One interpretation (e.g., Bjork & Cummings, 1984) is that infants return to A on B trials not because they cannot dissociate the object from the action of discovering it at A but because they cannot remember the precise location of the object. Another interpretation (e.g., Diamond, 1985) is that infants make AB errors not because their object concept or their memory is limited but because they cannot inhibit the conditioned response of reaching to A, possibly due to poor neurological control. In an AB task involving wells, Diamond (1985) observed that on B trials infants would often uncover the A well and then proceed directly to the B well, without even glancing inside the A well, as though they knew such an action would be pointless. Further, infants would sometimes reach for the A well while staring fixedly at the B well, as though they knew where the object was hidden but could not use this information to override their tendency to reach toward A. Other researchers have made similar observations (Deloache, personal communication; Gratch & Schatz, 1984; Wellman, personal communication).

Because of the difficulties associated with the interpretation of infants' search behavior, I sought a new means of testing infants' ability to represent the location of a hidden object. I chose a method that did *not* require infants to manually retrieve a hidden object. This method involved showing infants a moving object whose path was partly occluded by a screen; an obstacle was hidden behind the screen *in* or *out* of the path of the moving object. Before describing the method in detail, I briefly review studies of infants' beliefs about the permanence of moving objects.

3. Representing the existence of a hidden moving object

Studies of infants' beliefs about the permanence of moving objects have typically used an anticipatory tracking paradigm (e.g., Bower, 1974; Bower, Broughton, & Moore, 1971; Meicler & Gratch, 1980; Moore, Borton, & Darby, 1978; Nelson, 1971, 1974). In this paradigm, infants are presented with an object that moves along a track, part of which is occluded. The rationale is that if infants believe the object continues to exist and pursues its trajectory behind the occluder, then they should expect it to reappear on the other side of the occluder.

Unfortunately, studies of infants' anticipatory tracking have yielded divergent results. To illustrate, consider the results of Nelson (1971) and Moore et al. (1978). Nelson (1971) showed infants aged 3 to 9 months a train that traveled around a track, part of which was covered by a tunnel. He found that the first time the train exited the tunnel, the infants were typically still staring at the entrance. Over trials, the infants looked successively farther away from the tunnel entrance; but even after several trials, less than a third anticipated the train's reappearance at the tunnel exit. Further, the older infants were no more likely than the younger infants to produce anticipations. In contrast, Moore et al. (1978) showed 5- and 9-month-olds an object that moved along a linear track occluded by two narrow screens placed a short distance apart. They found that all of the infants anticipated the object's reappearance in between the screens on the first or second trial.

How can one account for these discrepant results? One explanation is suggested by Piaget's (1952) observations on infants' tracking abilities. Piaget noted that even very young infants possess a tracking scheme and are able, through trial and error, to accommodate their scheme to the speed and direction of a moving object so as to keep it in sight. To explain the results summarized above, a Piagetian would need make only one assumption: that the ease with which infants adjust their tracking to the visible and occluded portions of an object's trajectory depends on various stimulus factors, such as the width of the occluder (the wider the occluder, the larger the head movements infants must make to look from one end of the occluder to the other) and the occlusion duration (the longer the occlusion, the longer infants must wait at the exit end of the occluder for the object to reappear). Thus, Moore et al. (1978), who used narrow (17 cm) screens and an occlusion time of about 1 s, observed a high incidence of anticipations. In contrast, Nelson (1971), who used a very long (69 cm) tunnel and a variable occlusion time of about 2 to 4 s, found that neither older nor younger infants reliably produced anticipations.

The preceding account assumes that young infants' anticipations reflect not a belief in the permanence of moving objects but a capacity to develop expectations for events that take place in a regular spatiotemporal sequence (Haith, Hazan, & Goodman, 1984). There is, however, an alternative account for the results cited above. This account holds that infants' anticipations reflect *both* their beliefs about objects and their capacity to learn regular sequences. Infants may believe that a moving object continues to exist behind an occluder, without assuming that it will continue to travel until it reemerges into view. In daily life, infants are often confronted with disappearances that are not promptly followed by reappearances: mother leaves the room and does not return for minutes at a time; toys roll behind chairs or beneath tables and do not reemerge. It is not surprising that infants should need to learn whether an object that has disappeared is likely to reappear and where and when it will reappear. This learning process could be affected by the same type of stimulus factors that were invoked in the preceding account: the larger the occluder, the more likely the infant to become distracted by it and forget the presence of the object behind it; similarly, the longer the occlusion, the more likely the infant to look away and thus fail to see the object reappear.[1]

The present experiment used a new method to test whether young infants understand that an object continues to exist and pursues its trajectory when passing behind an occluder. Infants were shown a moving object whose path was partly occluded by a screen; the experiment tested whether they were surprised to see the object reappear when an obstacle was hidden in its path behind the screen. This method avoided the problems associated with the interpretation of infants' anticipatory tracking. It is described in the next section.

4. The present experiment

The present experiment investigated two facets of object permanence in young infants: the ability to represent the existence and the location of a hidden stationary object, and the ability to represent the existence and the trajectory of a hidden moving object. As in the experiment of Baillargeon et al. (1985), infants were presented with an impossible event in which an object appeared to move through the space occupied by a stationary object. However, in the present experiment, *both* the moving and the stationary objects were occluded.

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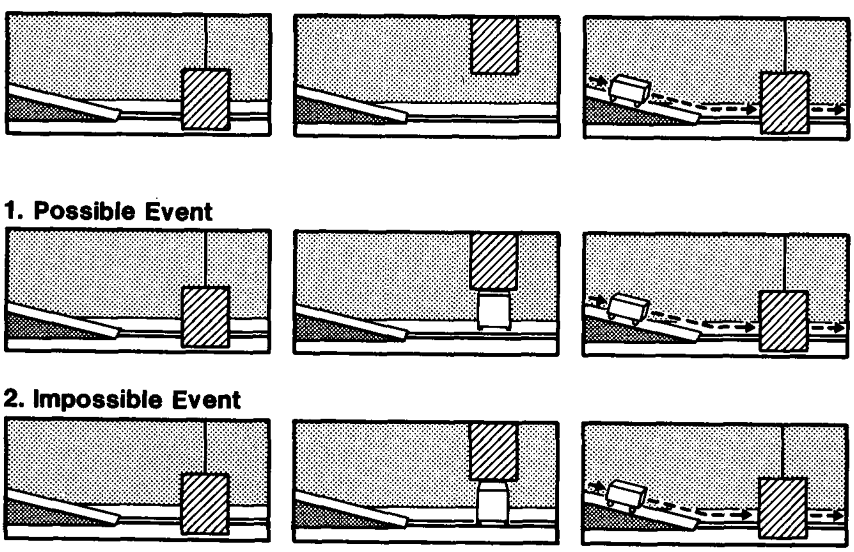
[1]Moore et al. (1978) obtained additional results which, at first sight, seem to contradict this account of infants' anticipations. Recall that they showed 5- and 9-month-old infants an object that moved along a track partly occluded by two narrow screens. On trick trials, the object did not appear between the screens. The authors found that on these trials, only the 9-month-olds showed disrupted tracking. They concluded that "whatever competence the 5-month-olds' anticipatory tracking reflects, it is not permanence" (p. 196). However, examination of the data suggests an alternative conclusion. Whereas the 9-month-olds showed reliably *more* disruptions in their tracking on the trick than on the regular trials, the 5-month-olds showed reliably *less*. It is possible that the 9-month-olds realized, on the trick trials, that two objects were used, and that the disruptions in their tracking were prompted by their search for the first object. The 5-mont-olds, in contrast, could have sensed that something was amiss without being able to infer what it was; their longer fixations could have reflected their puzzlement at the object's impossible trajectory.

The infants sat in front of a large display box. Directly before them was a small screen; to the left of the screen was a long inclined ramp. The infants watched the following event: the screen was raised (so the infants could see there was nothing behind it) and then lowered, and a toy car was pushed onto the inclined ramp; the car rolled down the ramp and across the display box, disappearing at one end of the screen, reappearing at the other end, and finally exiting the display box to the right (see Figure 1A). After the infants habituated to this event, they saw two test events. These events were identical to the habituation event, except that a box was placed behind the screen: the screen was raised (revealing the box) and lowered, and the car rolled down the ramp and across the display box. The only difference between the test events was in the location of the box behind the screen. In one event (possible event), the box was placed at the *back* of the display box, behind the tracks of the car; in the other (impossible event), it was placed on *top* of the tracks so that it blocked the car's path (Figure 1B). To adults, the first event is consistent with the solidity principle: the car rolls freely through empty space. The second event, in contrast, violates the principle: the car appears to roll through the space occupied by the box.

Figure 1. *Schematic representation of the habituation and test events used in Experiment 1: (A: top panel) Habituation event; (B: middle and bottom panels) Test events.*



My reasoning was as follows. If the infants understood that (1) the box continued to exist, in its same location, after it was hidden by the screen; (2) the car continued to exist, and pursued its trajectory, after it rolled behind the screen; and (3) the car could not roll through the space occupied by the box, then they should be surprised to see the car reappear when the box stood in its path. Since infants typically react to surprising events with prolonged attention, they should look longer at the impossible than at the possible test event. On the other hand, if the infants did not realize that the box and the car continued to exist when occluded, or if they forgot the location of the box behind the screen, then they should look equally at the two test events, since these were identical except for the box's location.

5. Experiment 1

5.1. Subjects

Subjects were 40 healthy, full-term infants. There were 20 6-month-olds (5,25–6,29; M = 6,12) and 20 8-month-olds (7,22–8,19; M = 8,2). An additional 4 infants were eliminated from the experiment, 3 because of fussiness and 1 because of equipment failure. Parents were contacted by letters and follow-up phone calls; they were not compensated for their participation.

5.2. Apparatus

The apparatus consisted of an unpainted display box 59 cm high, 152 cm wide, and 53 cm deep. The back wall of the display box was covered with navy corduroy and the side walls and ceiling were covered with white muslin.

A wooden ramp 63 cm long and 14 cm wide was centered against the left-hand wall of the display box below an opening 15 cm high and 15 cm wide. The ramp was 15 cm high at its highest point and sloped downward at a 14-degree angle. There was a rail 1 cm high and 0.5 cm wide on either side of the ramp. Two wooden tracks, each 91 cm long, 1 cm high, and 1 cm thick lay 6 cm apart between the lower end of the ramp and an opening 13 cm high and 20 cm wide in the right-hand wall of the display box. A yellow toy car 7 cm high, 17 cm long, and 12.5 cm wide could roll into the display box through the opening in the left-hand wall. The car rolled down the ramp, between the rails, and then rolled along the tracks until it disappeared through the opening in the right-hand wall. Black felt covered the ramp and the tracks to minimize the noise of the car.[2] White muslin curtains hid the openings in the walls of the display box; they opened as the car went through and closed behind it.

A red cardboard screen 30 cm high and 23 cm wide stood 13 cm in front of the tracks at a distance of 94.5 cm from the left-hand wall and 34.5 cm from the right-hand wall. A wooden handle 80 cm long, 1 cm wide and 1 cm thick was affixed to the back of the screen and protruded through the ceiling of the display box. By means of this handle, the screen could be raised and lowered within two vertical slits, each 30 cm high, 2 cm wide, and 2 cm thick.

A wooden box 15 cm high, 15 cm wide, and 15 cm thick, mounted on four posts each 2.5 cm high and 1.5 cm in diameter, could be introduced into the display box through a hidden opening in the back wall, behind the screen. The box was painted green and was decorated with dots, stars, and push-pins.

A wooden frame 200 cm high and 250 cm wide, covered with white muslin, surrounded the display box. White muslin curtains hung on either side of, and perpendicular to, this frame. Together, the frame and the curtains formed a three-sided chamber that isolated the infant from the experimental room. A white muslin curtain 60 cm high and 160 cm wide was lowered in front of the display box between trials.

5.3. Events

Habituation event

Two experimenters worked in concert to produce the habituation event. The first operated the screen while the second operated the car. To start, the first experimenter lifted the screen 25 cm and then lowered it, taking 1 s to complete each movement. Two seconds after the screen was lowered, the second experimenter pushed the car onto the inclined ramp. The car then rolled down the ramp across the display box, passing behind the screen, and finally exiting the display box to the right. The car took approximately 2 s to traverse the apparatus and was occluded (in part or in total) for approximately 0.75 s. Two seconds after the car emerged from the display box, the first experimenter again lifted the screen, beginning a new cycle. Each cycle thus lasted approximately 8 s. Cycles were repeated without stop until the recorder signaled the trial had ended (see below). When this occurred, the second experimenter lowered the curtain in front of the display box.

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[2]The reader may be concerned that the infants could have used the noise of the car to follow its progress behind the screen. Although this is certainly a possibility, researchers have typically found that infants do not make use of sound cues to track or locate occluded objects (e.g., Meicler & Gratch, 1980; Nelson, 1971; Piaget, 1954). For instance, Meicler and Gratch (1980) and Nelson (1971) found that the younger infants in their studies did not produce anticipatory responses. Yet in both studies, the target object was associated with a distinct sound cue. In the study of Meicler and Gratch, a bell was attached to the flatcar carrying the object; the infants alerted to the sound but did not track it. In Nelson's study, the target object was an electric train.

Impossible test event

The impossible event was identical to the habituation event, with three exceptions. First, the green box was placed on top of the car's tracks, behind the screen. Second, at the start of a trial, the first experimenter kept the screen raised until the recorder signaled that the infant had looked at the box for 1 s. This ensured that the infant had noted the presence and the location of the box. Third, after the screen was lowered, a third experimenter reached through the hidden opening in the back wall of the display box and removed the box from the path of the car; after the car had rolled by, she replaced the box on top of the tracks. When the screen was raised, at the start of the next cycle, the green box thus stood intact in the same location as before. Each cycle (after the first one) lasted about 8 s, and the box remained totally occluded for the last 6 of these 8 s. As with the habituation event, cycles were repeated without stop until the recorder signaled the trial had ended (see below).[3]

Possible test event

The possible event was identical to the impossible event, except that the box was placed 6 cm behind the car's tracks. When the screen was lowered, the third experimenter reached into the apparatus and lifted the box. This ensured that any faint sounds that accompanied the surreptitious movement of the box during the impossible event were also present during the possible event.

5.4. Procedure

Prior to the beginning of the experiment, each infant was allowed to manipulate the green box for a few minutes while his or her parent filled out consent forms. During the experiment, the infant sat on the parent's lap in front of the display box. The infant's head was approximately 48 cm from the screen and 90 cm from the back wall. The parent was instructed not to interact with the infant while the experiment was in progress. At the start of the test trials, the parent was also asked to close his or her eyes.

The infant's looking behavior was monitored by two observers who viewed the infant through peepholes in the muslin frame surrounding the display

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[3]Thus, six assistants were needed to test each infant: two observers, who sat at either end of the apparatus; one recorder, who sat at a table nearby, and three experimenters: the first operated the screen, the second, crouched next to the first, moved the box in and out of the path of the car, and the third operated the car. The third experimenter would drop the car at one end of the apparatus and then tiptoe to the other end to pick it up after it rolled out of the apparatus.

box. The observers could hear the movements of the screen and of the car but were blind as to the location of the box. Each observer was given a button box connected to an event recorder and was instructed to depress the button when the infant attended to the movements of the screen and of the car. Inter-observer agreement on each trial 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. Agreement was calculated for 25 of the infants and averaged 92.4%. The looking times of the primary observer were also registered on a pair of clocks that indicated how long the infant looked (clock 1) and looked away (clock 2) during the trial. By monitoring these clocks, another assistant, the recorder, was able to signal the end of trials and to determine when the habituation criterion had been met (see below).

At the start of the experiment, the infant was given two familiarization trials to acquaint him with the two possible locations of the box and with the relation of these locations to the path of the car. The screen remained lifted throughout these trials. In one, the box stood on top of the tracks with the car next to it (top display); in the other, the box stood at the back of the tracks with the car partly in front of it (back display). Each trial ended when the infant looked away from the display for 2 consecutive seconds after looking at it for 4 cumulative seconds, or when the infant looked at the display for 60 s without looking away for 2 consecutive seconds. Eleven 6-month-olds and 10 8-month-olds saw the top display first, and 9 6-month-olds and 10 8-month-olds saw the back display first.

Following the familiarization trials, the infant was presented with the habituation event described above, using an infant-control procedure (after Horowitz, 1975). Each habituation trial ended when the infant looked away from the event for 2 consecutive seconds after looking at it for 6 cumulative seconds, or when the infant looked at the event for 60 s. Habituation trials continued until the infant met a criterion of a 50% or greater decrease in looking time on 3 consecutive trials, relative to the infant's looking time on the first 3 trials. If the habituation criterion was not met within 12 trials, the habituation phase was ended at that point. This occurred for 6 of the 40 infants (4 8-month-olds and 2 6-month-olds); the other infants took an average of 7.94 trials to reach criterion.

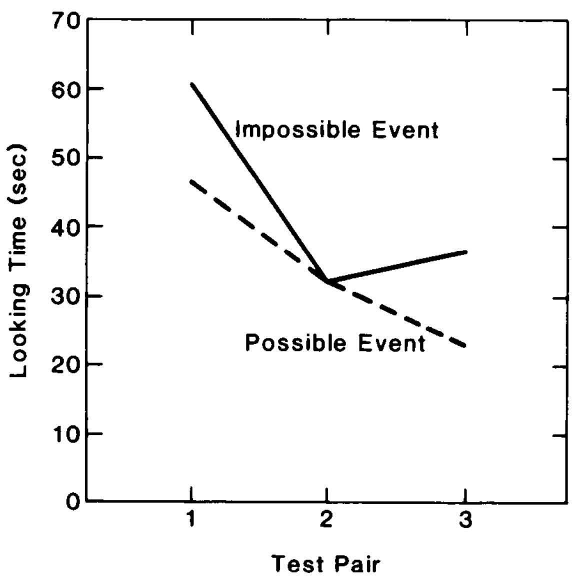
After the habituation phase, the infant again saw the top and back familiarization displays, to remind him of the two possible locations of the box. Following these trials, the infant was given 3 pairs of test trials, with the impossible and possible events being presented on alternative trials. Each test trial ended when the infant looked away from the event for 2 consecutive seconds after looking at least 8 cumulative seconds, or when the infant looked at the event for 120 s.[4] Infants who saw the top display first during the familiarization trials saw the impossible event first; infants who saw the back display first saw the possible event first.

Six of the 40 infants completed fewer than the full complement of 3 pairs of test trials due to fussiness. Of these, 5 (2 8-month-olds and 3 6-month-olds) completed 2 pairs, and 1 (a 6-month-old) completed 1 pair.

5.5. Results

Figure 2 presents the mean looking times to the impossible and possible test events. The infants' looking times were compared by means of a 2 × 2 × 3 × 2 mixed model analysis of variance with Age (6- or 8-month-olds) and Order (impossible or possible event first) as the between-subject factors, and with Trial (first, second, or third pair of test trials) and Event (impossible or possible) as the within-subject factors. Since the design was unbalanced, the SAS GLM procedure (SAS Institute, 1982) was used to compute the analysis of variance. There was a significant effect of Event, $F(1,166) = 5.74$, $p <$

Figure 2. *Looking times of subjects in Experiment 1 to the test events.*



[4]The criteria chosen to determine the beginning of trials corresponded to the time that elapsed before the car exited the apparatus for the first time at the beginning of the trials. In the habituation trials, this time was about 6 s; in the test trials, which included a 2-s pretrial, it was about 8 s.

.05, indicating that the infants looked longer at the impossible than at the possible event. There was also a significant effect of Trial, $F(2,166) = 18.25$, $p < .001$, indicating that the infants looked less as the experiment progressed. There was no effect of Age, $F(1,166) = 0$, and no significant interaction involving Age, all F's < 1.98, $p > .05$.

The effect of Event was qualified by two interactions: that between the Order and Event factors, $F(1,166) = 8.80$, $p < .01$, and that between the Order, Event, and Trial factors, $F(2,166) = 6.33$, $p < .01$. To study this three-way interaction, a 2×2 analysis of variance was conducted for each test pair with Order as the between-subjects factor and with Event as the within-subjects factor. These analyses yielded a significant effect of Event on the first ($F(1,176) = 5.40$, $p < .05$) and third ($F(1,176) = 4.37$, $p < .05$) test pairs, and a significant interaction between the Order and Event factors on the first test pair, $F(1,176) = 22.12$, $p < .001$. To pursuit this two-way interaction, an analysis of the simple effect of Event was conducted for each Order condition on the first test pair (Keppel, 1982, pp. 306–315). These analyses indicated that the infants who saw the impossible event first looked longer at this event than at the possible event, $F(1,176) = 24.26$, $p < .001$, whereas the infants who saw the possible event first did not show a reliable preference for either event, $F(1,176) = 3.26$, $p > .05$.

Thus, the infants' preference for the impossible over the possible event was qualified by both pair and order effects. On the first test pair, the infants who saw the impossible event first looked longer at this event than at the possible event, whereas the infants who saw the possible event first tended to look equally at the two events. One explanation for these results is that two separate tendencies contributed to the infants' looking behavior: a tendency to look longer at the event they saw first, and a tendency to look longer at the impossible event. For the infants who saw the impossible event first, these tendencies acted in the same direction, resulting in a marked preference for the impossible over the possible event. For the infants who saw the possible event first, the two tendencies acted in opposite directions and so tended to cancel each other. On the second test pair, the infants in both order conditions looked equally at the two test events. Finally, on the third test pair, the infants in the two order conditions looked longer at the impossible than at the possible event.

5.6. Discussion

The results of the experiment indicated that the infants preferred the impossible to the possible event and that the extent to which they expressed this preference depended on both the pair and the order in which they saw the events. It is not entirely clear how these pair and order effects should be interpreted; such effects are common in infancy research and are theoretically of little interest. What is clear, however, is that the infants did show a preference for the impossible over the possible event. This preference suggests that the infants were surprised to see the car reappear from behind the screen when the box stood in its path. Such a result implies that the infants understood (1) the box continued to exist, in its same location, after it was occluded by the screen; (2) the car continued to exist, and pursued its trajectory, after it disappeared behind the screen; and (3) the car could not roll through the space occupied by the box.

There is, however, another possible interpretation for the infants' preference for the impossible event. The infants might have looked longer at this event, not because they were surprised to see the car reappear, but because they found the box attractive and so looked longer when it stood closer to them. To test this alternative interpretation of the results, I ran a second experiment that was similar to the first except that the box was placed either on *top* (impossible event) or in *front* (possible event) of the car's tracks during the familiarization and test trials. I reasoned that if the infants in the first experiment looked longer at the impossible event because the box was closer to them, then the infants in the second experiment should look longer when the box was placed in front of the tracks. On the other hand, if the infants in the first experiment looked longer at the impossible event because they were surprised to see the car reappear, then the infants in the second experiment should also look longer when the box stood on top of the tracks.

6. Experiment 2

6.1. Subjects

Subjects were 26 healthy, full-term infants. There were 16 6-month-olds (5,12-6,22; M = 6,7) and 10 8-month-olds (7,28-8,21; M = 8,7). An additional 3 infants were eliminated from the experiment, 1 because of fussiness and 2 because of parental coaching. Parents were contacted by letters and follow-up phone calls; they were not compensated for their participation.

6.2. Apparatus

The apparatus used in this experiment was the same as in Experiment 1, with one exception: the screen was moved forward so that it now stood 22.5 cm in front of the tracks and 53 cm in front of the back wall of the display box. This made it possible to place the box in front of the tracks during the familiarization and test trials.

6.3. Events

The events used in this experiment were identical to those in Experiment 1 except that instead of placing the box behind the tracks of the car, the experimenter placed it 6 cm in front of the tracks.

6.4. Procedure

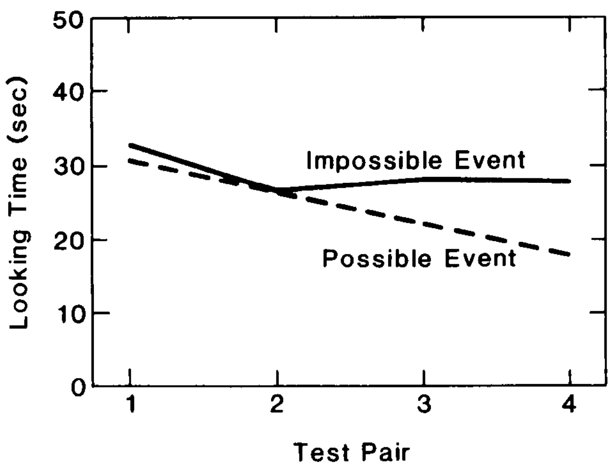
The procedure used in this experiment was similar to that used in Experiment 1, with a few exceptions. An effort was made to abbreviate the experimental procedure. First, infants received familiarization trials at the start of the experiment only; in one trial, the box stood on top of the tracks with the car next to it, and in the other, the box stood in front of the tracks with the car partly behind it. Second, the recorder used shorter criteria to determine the ending of trials. In Experiment 1, the maximal durations of the familiarization, habituation, and test trials were 60, 60, and 120 s, respectively; in Experiment 2, these values were changed to 20, 45, and 45 s. Since the test trials were now much shorter, the infants were given 4 pairs of test trials instead of 3, as in Experiment 1.

Of the 26 infants who participated in the experiment, 5 (3 6-month-olds and 2 8-month-olds) failed to satisfy the habituation criterion within 14 trials; the other infants took an average of 8.38 trials to satisfy the criterion. During the familiarization and test trials, half the infants in each age group saw the box on top of the tracks first, and half saw the box in front of the tracks first. Only 2 infants contributed fewer than 4 pairs of test trials to the analyses, because of fussiness: one 6-month-old contributed 3 pairs, and one 8-month-old contributed 2 pairs. Inter-observer agreement was calculated for 25 of the infants and averaged 96.5% per infant.

6.5. Results

Figure 3 presents the mean looking times to the impossible and possible events. The infants' looking times were analysed as in Experiment 1. There was no effect of Age, $F(1,22) = 0.68$, and no significant interaction involving Age, all F's < 3.14, $p > .05$. There was a significant effect of Event, $F(1,148) = 8.39$, $p < .01$, indicating that the infants looked reliably longer at the impossible than at the possible event. There was also a significant effect of Pair, $F(3,148) = 3.28$, $p < .05$, indicating that the infants looked less as the experiment progressed. No other main effects or interactions were significant.

Figure 3. *Looking times of subjects in Experiment 2 to the test events.*



6.6. *Discussion*

The infants in Experiment 2 looked longer when the box stood on top (impossible event) as opposed to in front (possible event) of the tracks. These results rule out the hypothesis that the infants in Experiment 1 looked longer when the box stood on top (impossible event) as opposed to in back (possible event) of the tracks, simply because the box stood closer to them. Like the results of Experiment 1, the results of Experiment 2 suggest that the infants (1) realized that the car and the box continued to exist behind the screen, and (2) were surprised or puzzled to see the car reappear when the box stood in its path.

Another possible, though unlikely, interpretation for the results of Experiments 1 and 2 is that the infants found the sight of the box on top of the tracks intrinsically more interesting than the sight of the box in back (Experiment 1) or in front (Experiment 2) of the tracks. It is difficult to imagine why the infants would strongly have preferred seeing the box on top rather than in front or in back of the tracks. Further, the results of the two familiarization trials at the start of each experiment did not reveal a preference for the top display: the infants in Experiment 1 looked equally at the top and back displays ($F(1,39) = 0.94$), and the infants in Experiment 2 looked equally at the top and front displays ($F(1,25) = 0.38$). It might be objected that since the familiarization displays involved both the box and the car, these data are inconclusive: the presence of the car could have diverted the infants' attention and thus masked a preference for the top position of the box. However, pilot data collected with the box on top or behind the tracks, without the car, also failed to show a preference for the box in the top position ($F(1,19) = 0.70$).[5]

7. Conclusion

The 6- and 8-month-old infants in Experiments 1 and 2 looked longer at the impossible than at the possible event they were shown. That is, they looked longer when the box stood in the path of the car than when it stood in back (Experiment 1) or in front (Experiment 2) of the car's path. These results indicate that the infants understood that (1) the box continued to exist, in its same location, after it was occluded by the screen; (2) the car continued to exist, and pursued its trajectory, behind the screen; and (3) the car could not roll through the space occupied by the box.

These results suggest three conclusions. The first is that by 6 months of age, infants understand that a stationary object continues to exist when occluded, and that it exists not as a disembodied image residing somewhere behind the occluder but as a substantial entity occupying a specific spatial location. The infants in the experiments clearly knew where the box was located behind the screen; otherwise, they could not have distinguished the two test events since these were identical except for the box's location.

The second conclusion is that by 6 months of age, infants understand that a moving object continues to exist and pursues its trajectory when passing behind an occluder. Past attempts at investigating young infants' beliefs about the permanence of moving objects typically focused on their ability to anticipate the reappearance of an object that disappears behind an occluder. These attempts were inconclusive, since infants' anticipations are open to interpretations that do not implicate a belief in permanence. For instance, infants' anticipations could be explained in terms of their ability to develop expectations for events that take place in a regular spatiotemporal sequence. The present experiments are not open to the same criticism. These experiments did not examine whether the infants expected the car to reappear, after it disappeared behind the screen. Rather, they asked whether the infants, *upon seeing the car reappear*, inferred that it had traveled from one end of the screen to the other, and were surprised that it had done so when the box stood in its path.

[5]These pilot data were collected with 20 infants (5,24–7,20, M = 6,28).

Finally, the third conclusion is that infants aged 6 months and older recognize that a solid object cannot move through the space occupied by another solid object, and are able to apply this principle in a situation involving two occluded objects. The infants in Experiments 1 and 2 were surprised to see the car reappear when the box was on top of the tracks, but not when the box was in front or in back of the tracks. (Note that these results do not tell us exactly *what* the infants expected to happen when the box blocked the path of the car: it is possible that the infants expected the car to stop against the box, or to reappear pushing the box in front of it, or some diffuse combination thereof).

These findings call into question several aspects of Piaget's (1954) description of the development of object permanence. First, they suggest that Piaget was mistaken in claiming that infants less than 9 months of age lack object permanence. The results of the experiments indicate that by 6 months of age, infants understand that stationary as well as moving objects continue to exist when occluded. Second, they call for a reinterpretation of young infants' failure to search for hidden objects. Piaget claimed that before 9 months infants do not search for hidden objects because they do not understand that objects continue to exist when masked by other objects. The results reported here contradict this interpretation. The 6- and 8-month-olds who participated in the experiments clearly recognized that the box and the car continued to exist behind the screen. These results suggest that a belief in object permanence is only one of the factors that contribute to the emergence of search behavior.

Could the development of short-term memory play a role in the emergence of search? Young infants might fail to search for hidden objects simply because they forget their presence. Baillargeon et al. (1985) argued that this explanation is unlikely, and the results of the present experiments support their view. The infants remembered the existence of the occluded box for at least 4 s (the time it took the car to reappear from behind the screen after the box was occluded) and for perhaps 6 s (the time the box remained occluded during each cycle). In the standard Piagetian search task, infants are allowed to search for the object immediately after it is hidden (e.g., Uzgiris & Hunt, 1970).

Baillargeon et al. speculated that the emergence of search might depend on the development of action—more specifically, on the development of infants ability to coordinate separate actions into means–end sequences (Piaget, 1952). They proposed that infants may need "to map out their behavioral repertoire, discovering what actions produce what outcomes, and then learning to combine these actions to achieve increasingly complex goals" (1985, p. 19).

Finally, the results of the experiments may have implications for interpretations of infants' AB errors. As indicated earlier, Piaget found that when infants begin to search for hidden objects, at about 9 months of age, they often search in the wrong location. If an object is hidden in a location A and then in a location B, infants often return to A instead of searching in B. In recent years, investigators have found that AB errors rarely occur when infants are allowed to retrieve the object immediately after it is hidden in B; errors occur only when infants are forced to wait, and the older the infants, the longer the delay that gives rise to errors (e.g., Diamond, 1985; Webb, Massan, & Nadolny, 1972). For example, Diamond (1985) reported that the delay needed to produce AB errors increased at a rate of about 2 s per month, from less than 2 s at 7.5 months to over 10 s at 12 months. These errors are puzzling when one considers that the 6- and 8-month-olds in the present experiments appeared to have no difficulty remembering which location (e.g., top or back of the tracks) the box occupied behind the screen, and furthermore, were able to remember this information for several seconds at a time.

How can we explain the discrepancy between the present results and the results of AB search tasks? One explanation is that the mnemonic demands associated with the present task are less stringent than those associated with the AB task. For instance, it might be easier for infants to remember the location of an object hidden behind a single occluder (e.g., top or back of the tracks), than to remember the location of an object hidden behind one of two occluders (e.g., occluders A and B). Another explanation, which is consistent with Diamond's (1985) conclusions, is that infants can remember the location of a hidden object (within reasonable time limits), but cannot always use this information to guide their search behavior, possibly due to immature neurological control.[6] One prediction which follows from this explanation is that infants should perform better in tasks that do not rely on manual search to assess their ability to remember the location of a hidden object. The results of the present experiments lend support to this prediction.

[6]There is evidence in the animal literature linking the prefrontal cortex to successful performance on spatial delayed tasks (e.g., Diamond & Goldman-Rakic, 1983; Goldman-Rakic, Isseroff, Schwartz, & Bugbee, 1982; Lawicka, 1969; Lawicka & Konorski, 1959, 1961). For example, Lawicka and Konorski (1961) tested prefrontal cats in a room containing three foodtrays. A buzzer was attached to each foodtray. Before each trial, one of the buzzers was sounded for several seconds to signal which foodtray contained food. After a delay, the animal was released and the experimenters recorded whether it went to the proper foodtray. The most common type of error was a perseverative error: the cats approached not the signaled foodtray but the one where they had last obtained food. Interestingly, after making an error, the cats often corrected themselves and went to the proper foodtray, indicating that they did remember which foodtray had been signaled. The parallel between these results and those of Diamond (1985) is striking.

The results of the experiments reported in this paper indicate that infants possess far more competence than Piaget's account of the development of object permanence leads one to suspect. By 6 months of age, infants represent the existence and the location of hidden stationary objects, and they represent the existence and the trajectory of hidden moving objects. Further, they are able to use such representations to reason about simple collision events involving hidden objects. These findings suggest that rather than viewing a belief in object permanence as an isolated conceptual attainment, as it is often viewed, it might be better to think of it as an inseparable facet of the infant's developing knowledge about the physical world. From this perspective, the general problem for research becomes that of examining infants' intuitive "theories" about the rules that underlie the displacement of objects, and of specifying the nature and range of their causal reasoning abilities.

References

Baillargeon, R., Spelke, E.S., & Wasserman, S. (1985). Object permanence in five-month-old infants. *Cognition, 20*, 191–208.

Bjork, E.L., & Cummings, E.M. (1984). Infant search errors: Stage of concept development or stage of memory development? *Memory & Cognition, 12*, 1–19.

Bower, T.G.R. (1974). *Development in infancy.* San Francisco: Freeman.

Bower, T.G.R., Broughton, J.M., & Moore, M.K. (1971). Development of the object concept as manifested in the tracking behavior of infants between 7 and 20 weeks of age. *Journal of Experimental Child Psychology, 11*, 182–193.

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., & Goldman-Rakic, P. (1983, November). Comparison of performance on a Piagetian object permanence task in human infants and rhesus monkeys: Evidence for involvement of prefrontal cortex. Paper presented at the Annual Meeting of the Society of Neuroscience, Boston, MA.

Goldman-Rakic, P.S., Isseroff, A., Schwartz, M.L., & Bugbee, N.M. (1983). The neurobiology of cognitive development. In M.H. Haith and J.J. Campos (Eds.), *Infancy and developmental psychobiology.* In P.H. Mussen (Ed.), *Handbook of child psychology.* New York: Wiley.

Gratch, G., & Schatz, J.A. (1984, April). *Piaget, the object concept and the permanence of objects: A continuing search.* Paper presented at the Biennial International Conference on Infant Studies, New York City, NY.

Haith, M.M., Hazan, C., & Goodman, G. (1984). *Infants' expectation and anticipation of future visual events.* Paper presented at the Biennial International Conference on Infant Studies, New York City, NY.

Harris, P.L. (1985). The development of search. In P. Salapatek and L.B. Cohen (Eds.), *Handbook of infant perception.* New York: Academic Press.

Horowitz, F.D. (Ed.) (1975). Visual attention, auditory stimulation, and language discrimination in young infants. *Monographs of the Society for Research in Child Development, 39*, (5–6).

Keppel, G. (1982). *Design and analysis: A researcher's handbook* (2nd edition). Englewood Cliffs, NJ: Prentice-Hall.

Lawicka, W. (1969). A proposed mechanism for delayed response. *Acta Biologiae Experimentalis, 29*, 401–414.

Lawicka, W., & Konorski, J. (1959). Physiological mechanism of delayed reactions. III. The effects of prefrontal ablations on delayed reactions in dogs. *Acta Biologiae Experimentalis, 19*, 221–231.

Lawicka, W., & Konorski, J. (1961). The effects of prefrontal lobectomies on the delayed responses in cats. *Acta Biologiae Experimentalis, 21*, 141–156.

Meicler, M., & Gratch, G. (1980). Do 5-month-olds show object conception in Piaget's sense? *Infant Behavior and Development, 3*, 265–282.

Moore, M.K., Borton, R., & Darby, B.L. (1978). Visual tracking in young infants: Evidence for object identity or object permanence? *Journal of Experimental Child Psychology, 25*, 183–198.

Nelson, K.E. (1971). Accommodation of visual-tracking patterns in human infants to object movement patterns. *Journal of Experimental Child Psychology, 12*, 182–196.

Nelson, K.E. (1974). Infants' short-term progress toward one component of object permanence. *Merrill-Palmer Quarterly*, 3–8.

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.

SAS User's Guide: *Statistics* (1982 Edition). 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 and C.K. Rovee-Collier (Eds.), *Advances in infancy research* (Vol. 2). Norwood, NJ: Ablex.

Uzgiris, I.C., & Hunt, J. McV. (1970). *Assessment in infancy: Ordinal scales of psychological development.* Urbana, IL: University of Illinois Press.

Webb, R.A., Massan, B., & Nadolny, I. (1972). Information and strategy in the young child's search for hidden objects. *Child Development, 43*, 91–104.

Résumé

Ce travail étudie deux aspects de la permanence des objets chez de jeunes enfants: leur capacité à se représenter l'existence et l'emplacement d'un objet stationnaire occulté, et leur capacité à se représenter l'emplacement et la trajectoire d'un objet en mouvement lorsqu'une partie de sa trajectoire est occultée. Des enfants âgés de 6 et 8 mois étaient placés devant un écran; une rampe inclinée se trouvait sur la gauche de l'écran. Les enfants observaient l'événement d'habituation suivant: on soulevait puis on abaissait l'écran; on faisait ensuite rouler une petite voiture sur la rampe, qui passait derrière l'écran et ressortait par la droite. Une fois que les enfants s'étaient habitués à cet événement, on les testait sur deux événements du même type que l'événement d'habituation, sauf qu'une boite était placée derrière l'écran. Dans un cas (événement possible) la boite se trouvait *derrière* la trajectoire de la voiture; dans l'autre (événement impossible), elle se trouvait *sur* la trajectoire de la voiture, empêchant le passage de celle-ci. Les enfants regardaient plus longuement l'événement impossible que l'événement possible; cela indique qu'ils étaient surpris de voir la voiture passer derrière l'écran lorsque la boite lui bloquait le passage. Une expérience de contrôle lors de laquelle la boite était placée *devant* la rampe (événement possible) ou *sur* la rampe (événement impossible) a fourni des résultats analogues. Pris conjointement, ces résultats suggèrent que les enfants savaient que: 1) la boite continuait d'exister au même endroit lorsqu'elle était cachée par l'écran; 2) la voiture continuait d'exister et de poursuivre sa trajectoire lorsqu'elle était chachée par l'écran, et 3) la voiture ne pouvait pas traverser l'endroit occupé par la boite. Ces résultats ont des conséquences théoriques et expérimentales pour l'étude du développement des connaissances et des capacités de raisonnement des enfants sur les objets.