Cognition, 20 (1985) 191–208

Object permanence in five-month-old infants*

RENÉE BAILLARGEON**
University of Illinois

ELIZABETH S. SPELKE
University of Pennsylvania

STANLEY WASSERMAN
University of Illinois

Abstract

A new method was devised to test object permanence in young infants. Five-month-old infants were habituated to a screen that moved back and forth through a 180-degree arc, in the manner of a drawbridge. After infants reached habituation, a box was centered behind the screen. Infants were shown two test events: a possible event and an impossible event. In the possible event, the screen stopped when it reached the occluded box; in the impossible event, the screen moved through the space occupied by the box. The results indicated that infants looked reliably longer at the impossible than at the possible event. This finding suggested that infants (1) understood that the box continued to exist, in its same location, after it was occluded by the screen, and (2) expected the screen to stop against the occluded box and were surprised, or puzzled, 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. Together, the results of these experiments indicate that, contrary to Piaget's (1954) claims, infants as young as 5 months of age understand that objects continue to exist when occluded. The results also indicate that 5-month-old infants realize that solid objects do not move through the space occupied by other solid objects.

*This research was supported by a grant from the National Institute of Health (HD-13248) to ESS. The data analysis was supported by a grant from the National Science Foundation (SES84-08626) to SW. While working on this research, RB was supported by fellowships from the Natural Sciences and Engineering Research Council of Canada and the Québec Department of Education. We thank Judy Deloache and Bob Reeve, for their careful reading of the manuscript; Marty Banks, Susan Carey, and Paul Harris, for helpful comments on earlier versions of the manuscript; Wendy Smith Born, Sarah Mangelsdorf, and the members of the Infant Lab at the University of Pennsylvania, for their help with the data collection; and Dawn Iacobucci, for her help with the data analysis.

**Reprint requests should be sent to Renée Baillargeon, Psychology Department, University of Illinois at Urbana-Champaign, 603 East Daniel Street, Champaign, IL 61820, U.S.A.

0010-0277/85/$5.90 © Elsevier Sequoia/Printed in The Netherlands

1. Background: Piaget's theory

For adults, an object is an entity that exists continuously in time and space: it cannot exist at two separate points in time without having existed during the interval between them, and it cannot appear at two separate points in space without having traveled from one point to the other. Do infants share this conception of objects as temporally and spatially continuous? On the basis of detailed observations of infants' reactions to object disappearances, Piaget (1954) concluded that they do not. For the young infant, Piaget maintained, each disappearance amounts to an annihilation and each reappearance to a resurrection. An object is not a permanent entity that continuous to exist while out of sight, but an ephemeral entity that is continually made and unmade: "a mere image which reenters the void as soon as it vanishes, and emerges from it for no objective reason" (p. 11).

Piaget discerned six stages in the development of the infant's object concept. He claimed that it is not until infants reach the fourth stage, at about 9 months of age, that they begin to endow objects with permanence, as evidenced by their willingness to search for hidden objects. Piaget observed that prior to stage 4, infants do not search for fully hidden objects. 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. Beginning in stage 4, however, infants do remove obstacles to retrieve hidden objects. In subsequent stages, infants come to take into account visible (stage 5) and invisible (stage 6) displacements of objects to find objects hidden in successive locations.

Why did Piaget select infants' search for hidden objects as marking the beginning of object permanence? This question is important, because Piaget observed several behaviors prior to stage 4 that are suggestive of object permanence. For example, he noted that as early as stage 1 (0–1 month), infants may look at an object, look away from it, and then return to it several seconds later, without any external cue having signaled its continued presence. In addition, Piaget observed that beginning in stage 3 (4–9 months), infants anticipate the future positions of moving objects: if they are tracking an object and temporarily lose sight of it, they look for in further along its trajectory; similarly, if they are holding an object out of sight and accidentally let go it, they stretch their arm to recapture it.

Piaget claimed that although these and other behaviors *seem* to revea[1] a notion of object permanence, closer analysis indicates "how superficial this interpretation would be and how phenomenalistic the primitive universe remains" (p. 11). Prior to stage 4, Piaget maintained, the infant lacks a concept of physical causality and regards all of reality as being dependent on his

activity. When he acts upon an object, the infant views the object not as an independent entity but as the extension, or the product, of his action. If the object disappears from view, the infant reproduces or extends his action, because he expects that his action will again produce the object. Proof for Piaget that the infant regards the object as being "at the disposal" of his action is that if his action fails to bring back the object, he does not perform alternative actions to recover it. Beginning in stage 4, however, the infant acts very differently. For example, if a ball rolls behind a cushion and he cannot recapture it by extending his reach, he tries alternative means for recovering it: he lifts the cushion, or pulls it aside, or gropes behind it. According to Piaget, such activities indicate that the infant conceives of the ball, not as a thing at the disposal of a specific action, but as a substantial entity that is located out of sight behind the cushion and that any of several actions may serve to reveal.

2. Tests of Piaget's theory

In recent years, Piaget's (1954) description of the sequences of changes in infants' search behavior has been tested by numerous investigators and has been accepted with few modifications (see Gratch, 1975, 1976; Harris, 1985; Schuberth, 1983, for reviews). Nevertheless, Piaget's interpretation of this sequence has been questioned. A number of authors (e.g., Bower, 1974; Diamond and Goldman-Rakic, 1983) have suggested that young infants' failure to search for hidden objects stems not from a lack of object permanence but from an inability to perform coordinated actions. Perhaps ironically, support for this hypothesis comes from Piaget's (1952) own work on the development of action. Piaget found that the capacity to act in a coordinated manner develops very slowly over the course of infancy. He noted that a major milestone is achieved at about 9 months of age, when infants begin to coordinate separate actions into means–ends sequences. In these sequences, infants perform one action in order to create the conditions under which they will be able to perform a second, independent action. Since Piaget's (1954) search task requires infants to coordinate two separate actions (one upon the occluder and one upon the object), young infants could fail this task because they are generally unable to perform such an action sequence.

A number of studies, notably by Bower (1967, 1972, 1974; Bower, Broughton and Moore, 1971; Bower and Wishart, 1972), have attempted to investigate young infants' conception of an object using methods that do not require coordinated sequences of actions. Bower's studies have yielded four findings that seem to provide evidence for object permanence in infants well

below 9 months. First, 7-week-old infants were found to discriminate between disappearances that signaled the continued existence of an object (e.g., gradual occlusion), and disappearances that did not (e.g., gradual dissolution or sudden implosion) (Bower, 1967). Second, 2-month-old infants were found to anticipate the reappearance of an object that stopped behind a screen, "looking to that half of the movement path the object would have reached had it not stopped" (Bower *et al.*, 1971, p. 183). Third, 5-month-old infants were found to show disruptions in their tracking when an object was altered while passing behind a screen: they tended to look back at the screen, as though in search of the original object (Bower, 1974; Bower *et al.*, 1971). Finally, 5-month-old infants were found to reach for an object that had been "hidden" by darkening the room (Bower and Wishart, 1972).

Although suggestive, Bower's findings do not provide conclusive evidence for object permanence in young infants. First, methodological problems cast doubts upon the validity of the results (Gratch, 1976; Harris, 1985). Second, the results are open to alternative interpretations that do not implicate object permanence. In particular, most of the results could be explained by Piagetian theory in terms of the extension of an ongoing action or the reproduction of a previous action. When infants reach for an object in the dark, they could simply be extending an action initiated before the lights were extinguished. Similarly, when infants anticipate the reappearance of an object, they could be extending a tracking motion begun prior to the object's disappearance. Finally, when infants look back at a screen, after a novel object has emerged from behind it, they could be repeating a prior action of looking in that direction, with the expectation that this action will again produce the original object.

The first finding cited above cannot be explained in terms of the extension or the reproduction of an action, but it, too, is open to other interpretations. One interpretation, mentioned by Bower *et al.* (1971), apparently has its source in Piaget: "Piaget (personal communication) has rightly objected that the methods used were insufficient to demonstrate that the infants were responding to objects as such, rather than to perceptual configurations which contained the object as an undifferentiated element" (p. 182). Another interpretation is that infants discriminate between permanence and impermanence sequences on the basis of superficial expectations about the way objects typically disappear, rather than on the basis of a belief in object permanence. In their daily environment, infants often see objects occlude one another but they rarely, if ever, see objects implode from view or dissolve into the air. Hence, infants could respond differently to occlusions than to implosions or dissolutions because occlusions are the only type of disappearance that is familiar to them.

3. The present experiment

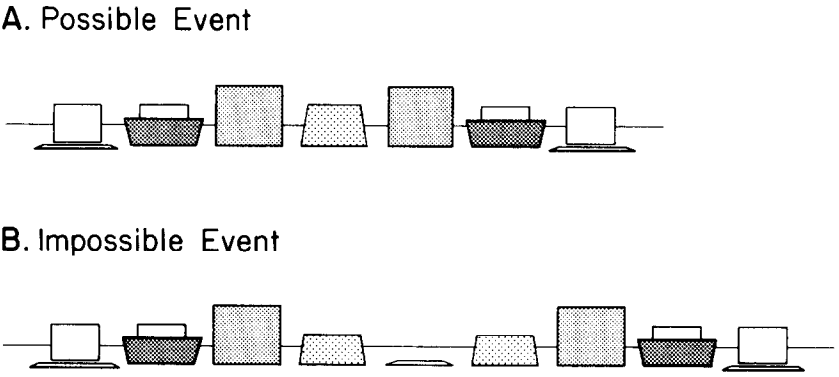
Because of the difficulties associated with Piaget's and Bower's tasks, we sought a new means of testing object permanence in young infants. Like Bower, we chose not to rely on manual search as our index of object permanence. However, we tried to find an index that could not depend on (1) the extension or reproduction of an action, or (2) knowledge about superficial properties of object disappearances.

The method we devised 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 ("solidity principle"). Infants' understanding of this principle was tested in a situation involving a visible object and an occluded object. If infants were surprised when the visible object appeared to move through the space occupied by the occluded object, it would suggest that they took account of the existence and the location of the occluded object. In other words, evidence that infants applied the solidity principle would also provide evidence that they possessed object permanence.

In the experiment, a box was placed on a surface behind a wooden screen. The screen initially lay flat, so that the box was clearly visible. The screen was then raised, in the manner of a drawbridge, thus hiding the box from view. Infants were shown two test events: a possible event and an impossible event. In the possible event, the screen moved until it reached the occluded box, stopped, and then returned to its initial position (see Figure 1A). In the impossible event, the screen moved until it reached the occluded box—and then kept on going as though the box were no longer there! The screen completed a full 180-degree arc before it reversed direction and returned to its initial position, revealing the box standing intact in the same location as before (see Figure 1B). To adults, the possible event is consistent with the solidity principle: the screen stops when it encounters the box. The impossible event, in contrast, violates the principle: the screen appears to move freely through the space occupied by the box. Note that adults would not perceive the event as impossible if they did not believe that the box continued to exist, in its same location, after it was occluded by the screen.

To test infants' perception of these events, we used a habituation paradigm. Infants were habituated to the screen moving back and forth through a 180-degree arc, with no box present. After infants reached habituation, the box was placed behind the screen, and infants were shown the possible and impossible events. Our reasoning was as follows. If infants understood that (1) the box continued to exist, in its same location, after it was occluded by the screen, and (2) the screen could not move through the space occupied by the box, then they should perceive the impossible event to be

Figure 1. *Schematic representation of the possible and impossible test events used in the principal experiment.*



novel, surprising, or both. On the basis of the commonly-held assumption that infants react to novel or surprising events with prolonged attention, we predicted that infants would look longer at the impossible than at the possible event. On the other hand, if infants did not understand that the box continued to exist after it was occluded by the screen, then they should attend to the movement of the screen without concerning themselves with the presence of the box in its path. Since the screen movement was the same in the impossible and the habituation events (in both events the screen moved through a 180-degree arc), we predicted that infants would look longer at the possible event, which depicted a novel, shorter screen movement.

There was one foreseeable difficulty with the design of our experiment. Infants might look longer at the impossible than at the possible event, not because they understood the underlying structure of the events, but because they found the 180-degree movement intrinsically more interesting than the 120-degree movement. To check this possibility, we ran a control experiment that was similar to the first experiment except that the box was placed behind and to the side of the screen, out of its path of motion. Therefore, neither the 180- nor the 120-degree screen movement violated the solidity principle. We reasoned that if infants in the first experiment looked longer at the impossible event because they found the 180-degree movement intrinsically more interesting than the 120-degree movement, then infants in the control experiment should look longer at the 180-degree event. On the other hand, if infants in the first experiment looked longer at the impossible event because they viewed it as impossible, then infants in the control experiment should look equally at the 180- and the 120-degree events, since neither was impos-

sible, or they should look longer at the 120-degree event, since it involved a novel screen movement.

4. Method

4.1. Principal experiment

4.1.1. Subjects

Subjects were 21 full-term infants ranging in age from 4 months, 24 days to 5 months, 26 days (mean age: 5 months, 12 days). An additional 7 infants were eliminated from the experiment, 3 because of experimenter error and 4 because of fussiness. All infants were from the Philadelphia area. Parents were contacted by phone and were compensated for their participation.

4.1.2. Apparatus

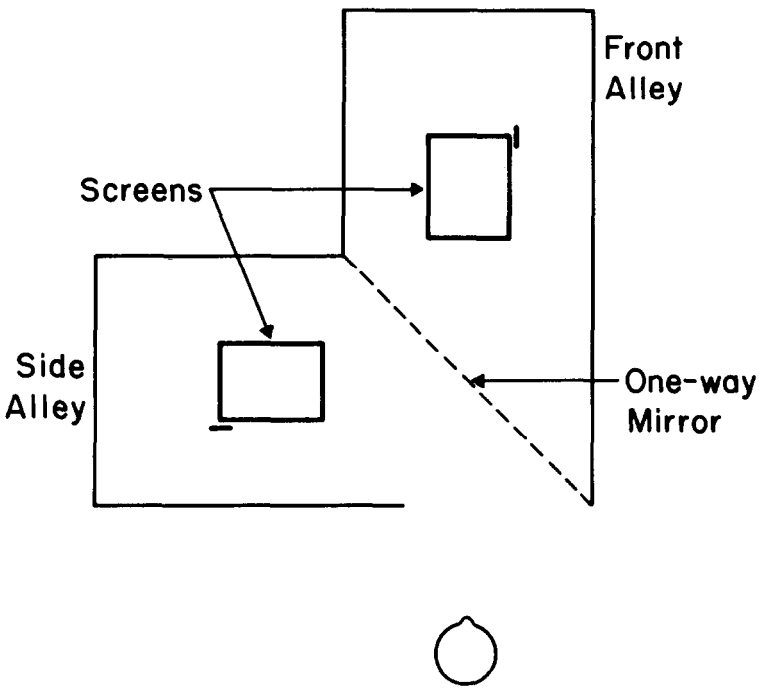
The apparatus resembled that used by Bower (1967). It involved two identical alleys containing identical screens and separated by a one-way mirror. Only one alley was visible at any one time. Shifts between the alleys were accomplished instantaneously by extinguishing the lights in one alley and illuminating those in the other alley. During those shifts, naive adult observers were not aware that they were shown two different alleys. It appeared merely as though one alley underwent a brief flickering of illumination.

Alleys. The apparatus consisted of a large wooden box in the shape of an inverted "L". A one-way mirror 38 cm high and 81 cm wide divided this box to form a front and a side alley (see Figure 2). Infants faced the mirror through an opening 38 cm high and 43 cm wide at one end of the front alley.

The two alleys were of the same color and dimensions: both were painted black, and both were 38 cm high, 61 cm wide, 122 cm deep on one side and 61 cm deep on the other. In addition, both alleys contained an unpainted wooden screen 28 cm high, 20 cm wide, and 1 cm thick. Each screen was attached by hinges to the floor of its respective alley and was positioned 20 cm from the side walls and 30 cm from the back wall. To one side of each screen (right in the front alley, left in the side alley) was attached a thin metal pulley, 11 cm in diameter. One half of each pulley stood above the floor of the alley, and the other half hung beneath it. The two pulleys were operated by identical manual cranks located underneath the alleys. By means of these cranks, the two screens could be moved back and forth through a 180-degree arc.

A wooden box 15 cm high, 10 cm wide, and 10 cm thick could be intro-

Figure 2. *Top view of the apparatus.*



duced into the front alley through a hidden door in its back wall. This box was painted bright yellow and was decorated with small red stars. During the test, the box was centered 8 cm behind the far edge of the screen when the screen lay in its initial position on the floor of the alley, toward the infant.

Lighting. Miniature bayonet light bulbs were affixed to the ceiling of each alley. Bands of black cardboard hid these light bulbs from the infant's view. More lightbulbs were used in the front alley to equalize the luminance of the two alleys, because the one-way mirror considerably reduced the amount of light that reached the infant's eye from the front alley.

The lights in the two alleys were wired in such a way that one could reverse their illumination condition by depressing a single switch. When the front alley was lit and the side alley was dark, the one-way mirror functioned as a window: infants looked through it into the front alley. When the side alley was lit and the front alley was dark, it functioned as a mirror: infants saw the side alley reflected in it. In each case, the alley that was not lit was not visible.

Experimental chamber. A wooden frame 229 cm high and 213 cm wide hung in front of the apparatus. This frame was covered with white muslin except for an opening that coincided with the opening into the front alley. Floorlength curtains hung on either side of, and perpendicular to, the muslin-covered frame. Together, the curtains and the frame formed a three-sided chamber that isolated the infant from the experimental room.

4.1.3. Events

Impossible test event. Two experimenters worked in concert to produce this event. The first experimenter operated the front alley screen and controlled the illumination condition of the alleys; the second experimenter operated the side alley screen. To start, the first experimenter lit the front alley; infants could see the screen, laid flat against the floor of the alley, with the box clearly visible behind it. The first experimenter raised her screen at the approximate rate of 30 degrees per second until it had completed a 120-degree arc, at which point it made contact with the box. She then reversed the illumination condition of the alleys, so that the side alley became lit. The second experimenter, who held his screen in readiness in the 120-degree position, then lowered it to the floor of the alley, away from the infant, at the same approximate rate of 30 degrees per second. The entire process was then repeated in reverse. The second experimenter raised his screen back to the 120-degree position, at which point the primary experimenter again reversed the illumination of the alleys and then lowered her screen down to its original position against the floor of the alley.

Each full cycle of movement lasted approximately 12 seconds. The box remained occluded for about 10 of these 12 seconds: it was in view only during the first and last seconds, when the screen was raised less than 30 degrees. Cycles were repeated without stop until the recorder signaled that the trial had ended (see below). At that point, the first experimenter extinguished the lights in the alleys and brought her screen back to its starting position.

Possible test event. This display was produced by the first experimenter alone. After lighting the front alley, she raised her screen at the same rate of 30 degrees per second until it had moved 120 degrees and contacted the occluded box; she then lowered her screen back to its initial position against the floor of the alley. Each cycle of movement—one 120-degree movement away from the infant and one 120-degree movement back toward the infant—lasted approximately 8 seconds. The box was totally occluded for about 6 of these 8 seconds. Cycles were repeated without stop until the recorder signaled that the trial had ended (see below). At that point, the first experimenter extinguished the lights in the alley and returned her screen to its starting position.

Habituation event. The habituation event was exactly the same as the impossible event, except that the yellow box was absent. Both alleys were used to produce this event. We sought to habituate infants to the slight changes in noise and illumination that accompanied the shifts between the alleys, to minimize the possibility that such factors would lead infants to look longer at the impossible event.

4.1.4. Procedure

Each infant was seated on a parent's lap in front of the opening into the front alley. The infant's head was approximately 30 cm from the opening, 61 cm from the one-way mirror, and 152 cm from the back wall of the front alley. The parent wore occluding glasses and was instructed not to interact with the infant while the experiment was in progress.

The infant's looking behavior was monitored by two observers who viewed the infant through peepholes in the muslin frame that hung in front of the apparatus. The observers could not see the experimental events and they were not told the order in which the test events were presented. Each observer was given a button box connected to an event recorder and was instructed to depress the button when the infant looked into the opening of the display box. Inter-observer agreement for each infant 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 habituation and test trials lasted. Agreement was calculated for 18 of the infants and averaged 93% per infant. The looking times of the primary observer were also registered on a clock. By monitoring this clock, another assistant, the recorder, was able to signal the ending of each trial and to determine when the habituation criterion was met (see below).

Infants were presented repeatedly with the habituation event following 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 at least 4 consecutive seconds, or when the infant looked at the event for 120 seconds. The inter-trial interval was 3 seconds. Habituation trials continued until the infant reached a criterion of habituation: 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 criterion was not met within 14 trials, the habituation phase was ended at that point. This occurred for only 1 of the 21 infants. The other infants took an average of 7.35 trials to reach criterion.

After the habituation phase, the yellow box was introduced into the front alley. Infants were given two 3-second pretest trials to call their attention to the presence of the box. During these trials, the screen lay flat against the

floor of the alley, with the box standing clearly visible behind it. Following these trials, testing began. Infants were given 3 pairs of test trials, with the impossible and possible events being presented on alternate trials. Eleven infants saw the impossible event first, and 10 infants saw the possible event first. The criteria used to determine the ending of the test trials were the same as for the habituation trials.

Of the 21 infants in the experiment, 5 contributed fewer than 3 pairs of test trials to the analyses. Four infants contributed only 2 pairs, 3 because of fussiness and 1 because the primary observer could not follow the direction of his gaze. Another infant contributed a single pair: one pair was eliminated because of fussiness and one pair because of equipment failure.

4.2. Control experiment

4.2.1. Subjects

Subjects were 22 full-term infants ranging in age from 4 months, 26 days to 5 months, 29 days (mean age: 5 months, 10 days). An additional 8 infants were eliminated from the experiment. 3 because of experimenter error, 1 because of equipment failure, and 4 because of fussiness. All infants were from the Philadelphia area. Parents were contacted by phone and were compensated for their participation.

4.2.2. Apparatus and events

The apparatus and events were the same as in the principal experiment, except for the placement of the box during the familiarization and test trials. The yellow box in the front alley was positioned 8 cm behind and to the left of the screen so that the screen's path of movement was not obstructed. Since both the front and the side alleys were used in producing the 180-degree test event, an identical yellow box was placed 8 cm behind and to the right of the screen in the side alley.

4.2.3. Procedure

As in the principal experiment, infants were given habituation trials until they met the habituation criterion. All infants met the criterion before completing 14 habituation trials; the mean number of trials to criterion was 7.32. Following habituation, infants were given two pretest trials during which the screen lay flat against the floor of the alley, with the yellow box to one side. To minimize the possibility that infants would attend only to the box on the test trials, the pretest trials were presented using an infant-control procedure. Specifically, each pretest trial ended when the infant looked away from the display for 2 consecutive seconds after looking at it for at least 4 cumulative

seconds. Each pretest trial lasted 9.18 seconds on average. Following these trials, infants were given 3 pairs of test trials, with the 180- and the 120-degree events being presented on alternate trials. Twelve infants saw the 180-degree event first and 10 saw the 120-degree event first. The criteria used to determine the beginning and end of the habituation and test trials were the same as in the principal experiment. Inter-observer agreement was calculated for 21 of the infants and averaged 92% per infant.

Of the 22 infants who participated in the experiment, 5 contributed fewer than 3 pairs of test trials to the analyses, due to fussiness: 4 contributed 2 pairs and 1 contributed 1 pair.

5. Result

5.1. Principal experiment

The results of the principal experiment were clear-cut: infants showed a strong, consistent preference for the impossible over the possible test event.

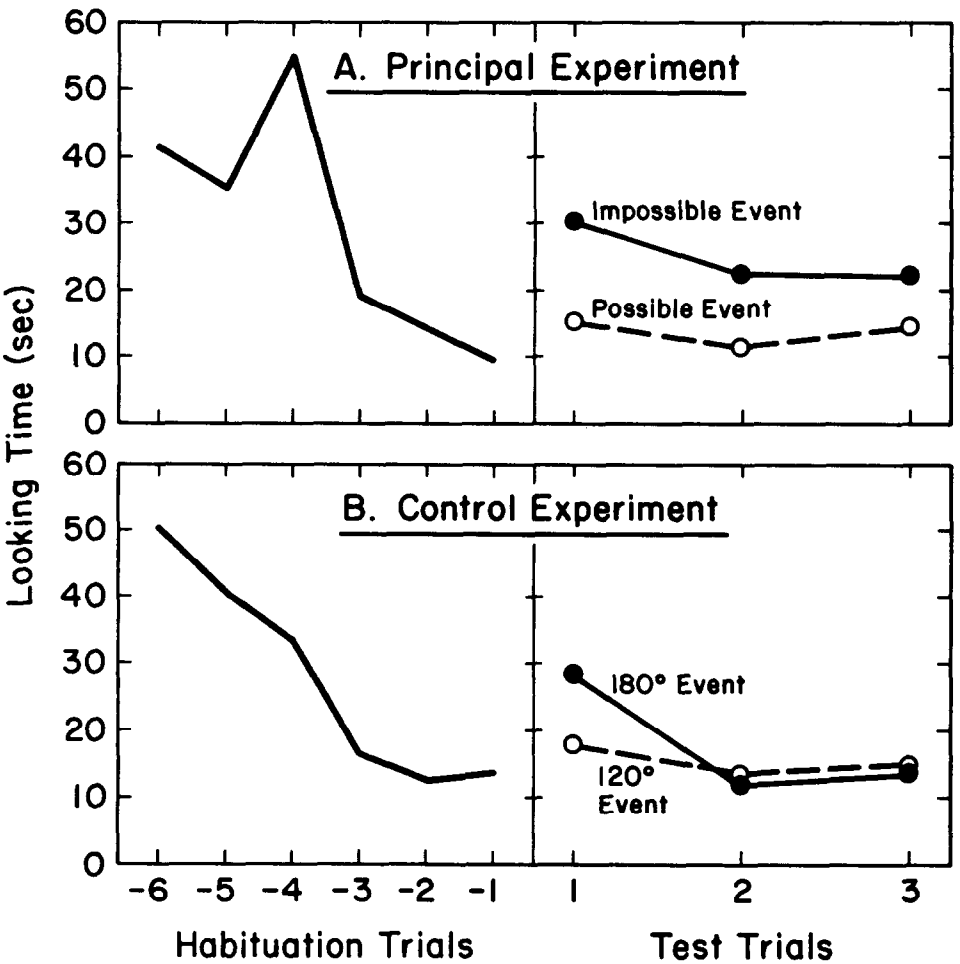
Figure 3a presents the mean looking times during the habituation and test phases of the experiment. Infants' looking times during the test trials were compared by means of a 2 × 3 × 2 mixed model analysis of variance with Order (impossible or possible event first) as the between-subjects factor and with Trial (first, second, or third pair of test trials) and Event (impossible or possible) as the within-subjects factors. Since the design was unbalanced, the SAS GLM procedure (SAS Institute, 1982) was used to calculate the analysis of variance. The only significant effect was that of Event, $F(1,83) = 13.66$, $p = 0.0004$.

5.2. Control experiment

The results of the control experiment were quite different: infants showed no overall preference between the 180- and the 120-degree test events.

Figure 3b presents the mean looking times to the habituation and test events. Infant's looking times during the test trials were analysed as in the principal experiment. There was no effect of Event, $F(1,88) = 0.67$, $p = 0.4157$. However, there was a significant effect of Trial, $F(2,88) = 6.68$, $p = 0.0020$, and two significant interactions: that between the Order and Event factors, $F(1,88) = 6.76$, $p = 0.0104$, and that between the Order, Event, and Trial factors, $F(2,88) = 3.96$, $p = 0.0226$. Analysis of the simple interaction of Order and Event, for each test pair (Keppel, 1982, pp. 306–309), yielded a significant interaction for the first ($F(1,88) = 12.95$, $p = 0.0005$) but not

Figure 3. *Looking times of subjects in the principal and control experiments to the habituation and test trials.**



*The habituation trials are numbered backwards from the trial in which criterion was reached.

for the second ($F(1,88) = 0.17$) or the third ($F(1,88) = 1.99$, $p = 0.1621$) test pair (note 1). To study the interaction obtained on the first test pair, an analysis of the simple main effect of Event was conducted for each Order condition (Keppel, 1982, pp. 309–311). These analyses revealed that infants who saw the 180-degree event first looked longer at this event than at the 120-degree event, $F(1,88) = 17.23$, $p = 0.00008$, whereas infants who saw the 120-degree event first looked equally at the two test events, $F(1,88) = 1.17$, $p = 0.2815$.

6. Discussion

The results of the principal experiment are easily summarized: infants showed a marked preference for the impossible over the possible event. Further, infants showed this preference on all three pairs of test trials, regardless of the order in which they saw the two events. The results of the control experiment were very different: only infants who saw the 180-degree event first showed a preference for that event, and that only on the first test pair; infants who saw the 120-degree event first looked equally at the two events on all three test pairs. These results provide evidence that infants in the principal experiment looked longer at the impossible event not because they preferred the 180-degree screen movement, but because they expected the screen to stop against the occluded box and were surprised, or puzzled, when it failed to do so.

The results of these experiments indicate that 5-month-old infants understand that an object continues to exist when occluded. These results suggest that infants who, according to Piaget's (1954) scale, have just entered stage 3 already endow objects with some permanence. Such results call into question several aspects of Piaget's description of the development of object permanence. First, they call for a reinterpretation of the behaviors—visual anticipations, interrupted prehensions, deferred actions, and so on—Piaget observed in stage 3 infants. Piaget maintained that these behaviors reflect a primitive phenomenalism, rather than a belief in object permanence: "In the present behavior patterns ... the search only continues the earlier act of accommodation ... the expected object is still related to the action itself" (p. 11). Since our results cannot be interpreted in terms of the extension or the

[1]Because the design was unbalanced, we also analysed the simple effect of Order × Event for each test pair using the method od unweighted means recommended by Myers (1979, pp. 109–119). The results of these analyses were very similar to those reported in the text: Pair 1: $F(1,88) = 11.67$, $p = 0.00096$; Pair 2: $F(1,88) = 0.15$; and Pair 3: $F(1,88) = 2.31$, $p = 0.132$.

reproduction of an earlier action, they provide unambiguous evidence of object permanence in stage 3 infants. As such, they suggest that Piaget was mistaken in his interpretation of stage 3 behaviors and that these behaviors are guided by a belief in object permanence, rather than by an egocentric phenomenalism.

Second, our findings call for a reinterpretation of stage 3 infants' failure to search for hidden objects. Piaget (1954) believed that these infants do not search because they do not yet view objects as permanent entities that continue to exist when concealed by other objects. Since our results indicate that infants of 5 months do confer permanence to objects, they imply that factors other than or in addition to infants' beliefs about objects contribute to the emergence of search behavior. What might these factors be? One relevant factor might be the development of short-term memory (e.g., Bower, 1967). Young infants might fail to search for hidden objects simply becayse they forget their presence; as their memory improves, infants would become more likely to remember, and to search for, hidden objects. However, there are reasons to question this explanation. Piaget's observations on deferred actions suggest that stage 3 infants can remember the location of objects for several seconds at a time. In addition, the results of our first experiment suggest that infants could remember the presence of the box behind the screen for at least 3 seconds (the time it took the screen to reach the box after it was occluded) and perhaps for as long as 6 to 10 seconds (the occlusion times for the possible and the impossible events). Few search studies require retention times longer than those.

A more likely explanation for young infants' failure to search for hidden objects, one already alluded to in the introduction, is that young infants may be generally unable to coordinate separate actions into means–end sequences. This explanation appears especially plausible in light of Uzgiris's (1973) observation that infants begin to search for hidden objects at about the same age they begin to engage in reversible actions, pushing and pulling objects, crumpling and straightening them, putting them in and taking them out of containers, and so on. It is as though infants began, at 8 or 9 months, to map out their behavioral repertoire, discovering what actions produce what outcomes, and then learning to combine these actions to achieve increasingly complex goals.

We are not alone in proposing that search behavior reflects the interaction of different factors. In recent years, investigators have identified several factors that appear to play a role in the development of search behavior in stage 4, stage 5, and beyond (DeLoache, 1984; Sophian, 1984). For example, three factors that have been implicated in stage 4 infants' search errors are a deficit in memory for spatial locations (e.g., Bremner, 1978; Cornell, 1981; Cum-

mings and Bjork, 1977; Lucas and Uzgiris, 1977), a sensitivity to proactive interference (e.g., Schacter and Moscovitch, 1983), and an inability to inhibit repetitive actions due to poor neurological control (e.g., Diamond and Goldman-Rakic, 1983).

We have questioned Piaget's claims about the time at which object permanence is attained, and the behaviors by which it is manifested. Despite these differences, however, one aspect of Piaget's (1954) theory seems exactly right to us. According to Piaget, the development of the object is intimately tied to the development of the concepts of time, space, and causality: "A world composed of permanent objects constitutes not only a spatial universe but also a world obeying the principle of causality in the form of relationships between things, and regulated in time, without continuous annihilations or resurrections" (p. 3). Like Piaget, we believe that a notion of object permanence is not an isolated conceptual attainment but an inseparable aspect of the infant's knowledge of how objects behave in time and space. Our experiments provide evidence that by 5 months of age, infants already appreciate two aspects of the behavior of objects. First, they understand that an object continues to exist when occluded, and that it exists not as a disembodied image residing somewhere behind the occluder but as a solid, three-dimensional entity occupying a specific spatial location. Second, they understand that an object can move only through space not occupied by other objects. Recently, researchers have begun to investigate infants' knowledge of other aspects of the behavior of objects. Their experiments suggest that young infants understand that objects tend to move on undeviating paths (Baillargeon, 1984), to move continuously through space and over time (Spelke and Kestenbaum, 1984), and to begin moving only when contacted by other objects (Leslie, 1984).

From this perspective, occlusion transformations are simply a subclass of all the transformations that occur in the physical world, and the notion that objects continue to exist when occluded is only one aspect of the infant's object concept. The general problem for research is not to establish whether young infants believe objects are permanent. Rather, it is to determine what infants know about the displacements and transformations of objects, and how they attain and represent this knowledge.

References

Baillargeon, R. (1984) Reasoning about hidden obstacles: Object permanence in 6- to 8-month-old infants. Paper presented at the Biennial Meeting of the International Conference on Infant Studies, New York, April.

Bower, T.G.R. (1967) The development of object permanence: Some studies of existence constancy. *Percep. Psychophys.*, *2*, 411–418.

Bower, T.G.R. (1972) Object perception in infants. *Perception*, *1*, (1).

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

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

Bower, T.G.R., and Wishart, J.G. (1972) The effects of motor skill on object permanence. *Cog.*, *1*, 165–172.

Bremner, J.G. (1978) Spatial errors made by infants: Inadequate spatial cues or evidence of egocentrism? *Brit. J. Psychol.*, *69*, 77–84.

Cornell, E.H. (1981) The effects of cue distinctiveness on infants' manual search. *J. exp. Child Psychol.*, *32*, 330–342.

Cummings, E.M., and Bjork, E.L. (1977) Piaget's stage IV object concept error: Evidence of perceptual confusion, state change, or failure to assimilate? Paper presented at the Meeting of the Western Psychological Association, Seattle, April.

DeLoache, J.S. (1984) Oh where, oh where: Memory-based searching by very young children. In C. Sophian (ed.), *Origins of Cognitive Skills*. Hillsdale, NJ: Lawrence Erlbaum.

Diamond, A., and Goldman-Rakic, P. (1983) 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 for Neuroscience, Boston, November.

Gratch, G. (1975) Recent studies based on Piaget's view of object concept development. In L.B. Cohen and P. Salapatek (eds.), *Infant Perception: From Sensation to Cognition*. Vol. II. New York: Academic Press, 51–99.

Gratch, G. (1976) A review of Piagetian infancy research: Object concept development. In W.F. Overton and J.M. Gallagher (eds.), *Knowledge and Development: Advances in Research and Theory (I)*. New York: Plenum.

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. *Mono. Soc. Res. Child Dev.*, *39*, (5–6).

Keppel, G. (1982) *Design and Analysis: A Researcher's Handbook* (2nd edition). Englewood Cliffs, NJ: Prentice-Hall.

Leslie, A.M. (1984) Spatiotemporal continuity and the perception of causality in infants. *Perception*, in press.

Lucas, T.C., and Uzgiris, I.C. (1977) Spatial factors in the development of the object concept. *Dev. Psychol.*, *13*, 492–500.

Myers, J.L. (1979) *Fundamentals of Experimental Design*. 3rd edition. Boston: Allyn and Bacon.

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.

SAS User's Guide: Statistics, 1982 Edition. Gary, NC: SAS Institute Inc., 1982.

Schacter, D.L., and Moscovitch, M. (1983) Infants, amnesics, and dissociable memory systems. In M. Moscovitch (ed.), *Infant Memory: Its Relation to Normal and Pathological Memory in Humans and Other Animals*. Volume 9 in *Advances in the Study of Communication and Affect*. New York: Plenum Press.

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.

Sophian, C. (1984) Developing search skills. In C. Sophian (ed.), *Origins of Cognitive Skills*. Hillsdale, NJ: Lawrence Erlbaum.

Spelke, E.S., and Kestelbaum, R. (1984) *Spatiotemporal Continuity and Object Persistence in Infancy*. Unpublished manuscript, University of Pennsylvania, Philadelphia.

Uzgiris, I.C. (1973) Patterns of cognitive development in infancy. *Merrill-Palmer Quart.*, *19*, 181–204.

Résumé

Une nouvelle méthode a servi à étudier la permanence de l'objet chez les nourrissons. Des enfants de 5 mois ont été habitués avec un écran bougeant d'avant en arrière à la façon d'un pont-levis. Après atteinte du critère d'habituation, une boîte est placée derrière l'écran. Les enfants sont confrontés à deux situations: une situation possible et une situation impossible. Dans la première situation, l'écran s'arrête quand il atteint la boîte cachée, dans l'autre l'écran continue sa rotation à travers l'espace occupé par la boîte. Les résultats montrent que les enfants regardent plus l'événement impossible que l'événement possible. Ce résultat indique que (1) les enfants comprennent que la boîte continue d'exister, à la même place, après qu'elle ait été cachée par l'écran et (2) qu'ils s'attendent à ce que l'écran s'arrête contre la boîte cachée. Ils sont surpris ou intrigués quand elle ne le fait pas. Une expérience contrôle dans laquelle la boîte était placée à côté de l'écran conforte l'interprétation des résultats. Pris dans leur ensemble, les résultats de ces expériences montrent que, contrairement à ce que pensait Piaget (1954) les enfants de 5 mois réalisent que les objets solides ne se déplacent pas à travers un espace occupé par d'autres objets solides.