Object Permanence in 3 ½- and 4 ½-Month-Old Infants

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These experiments tested object permanence in 3 ½- and 4 ½-month-old infants. The method used in the experiments was similar to that used by Baillargeon, Spelke, and Wasserman (1985). The infants were habituated to a solid screen that rotated back and forth through a 180° arc, in the manner of a drawbridge. Following habituation, a box was placed behind the screen and the infants were shown two test events. In one (possible event), the screen rotated until it reached the occluded box; in the other (impossible event), the screen rotated through a full 180° arc, as though the box were no longer behind it. The 4 ½-month-olds, and the 3 ½-month-olds who were fast habituators, looked reliably longer at the impossible than at the possible event, suggesting that they understood that (a) the box continued to exist after it was occluded by the screen and (b) the screen could not rotate through the space occupied by the occluded box. Control experiments conducted without the box supported this interpretation. The results of these experiments call into serious question Piaget's (1954) claims about the age at which object permanence emerges and about the processes responsible for its emergence.

Adults believe that an object cannot exist at two separate points in time without having existed during the interval between them. Piaget (1954) held that infants do not begin to share this belief until they reach about 9 months of age. The main evidence for this conclusion came from observations of young infants' reactions to hidden objects. Piaget noticed that prior to 9 months, infants do not search for objects they have observed being hidden. If a 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 speculated that for young infants objects are not permanent entities that exist continuously in time but transient entities that cease to exist when they are no longer visible and begin to exist anew when they come back into view.

Although Piaget's (1954) observations have been confirmed by numerous researchers (see Gratch, 1975, 1977, Harris, in press, and Schuberth, 1983, for reviews), his interpretation of these observations has been questioned. A number of researchers (e.g., Baillargeon, Spelke, & Wasserman, 1985; Bower, 1974) have suggested that young infants might fail Piaget's search task, not because they lack object permanence, but because

they are generally unable to perform coordinated actions. Studies of the development of action (e.g., Piaget, 1952; Uzgiris & Hunt, 1970) have shown that it is not until infants reach about 9 months of age that they begin to coordinate actions directed at separate objects into means–end sequences. In these sequences, infants apply one action to one object so as to create conditions under which they can apply another action to another object (e.g., pulling a cushion to get a toy placed on it or deliberately releasing a toy so as to grasp another toy). Thus, young infants could fail Piaget's task simply because it requires them to coordinate separate actions on separate objects.

This interpretation suggests that young infants might show evidence of object permanence if given tests that did *not* require coordinated actions. Bower (1967, 1974; Bower, Broughton, & Moore, 1971; Bower & Wishart, 1972) devised several such tests and obtained results that he took to indicate that by 2 months of age, if not sooner, infants already possess a notion of object permanence. Bower's tests, however, have been faulted on methodological and theoretical grounds (e.g., Baillargeon, 1986, in press; Baillargeon et al., 1985; Gratch, 1975, 1977; Harris, in press; Muller & Aslin, 1978).

Because of the problems associated with Bower's tests, Baillargeon et al. (1985) sought a new means of testing object permanence in young infants. The test they devised was indirect: It focused on infants' understanding of the principle that a solid object cannot move through the space occupied by another solid object. The authors reasoned that if infants were surprised when a visible object appeared to move through the space occupied by a hidden object, it would suggest that they took account of the existence of the hidden object. In their study, 5 ½-month-old infants were habituated to a screen that rotated back and forth through a 180° arc, in the manner of a drawbridge. Following habituation, a box was placed behind the screen and the infants were shown two test events. In one (possible event), the screen rotated until it reached the occluded box and then returned to its initial position. In the other (impossible event),

Experimental Condition
(with box)

Control Condition
(without box)

Habituation Event

Test Events

Impossible Event   180° Event

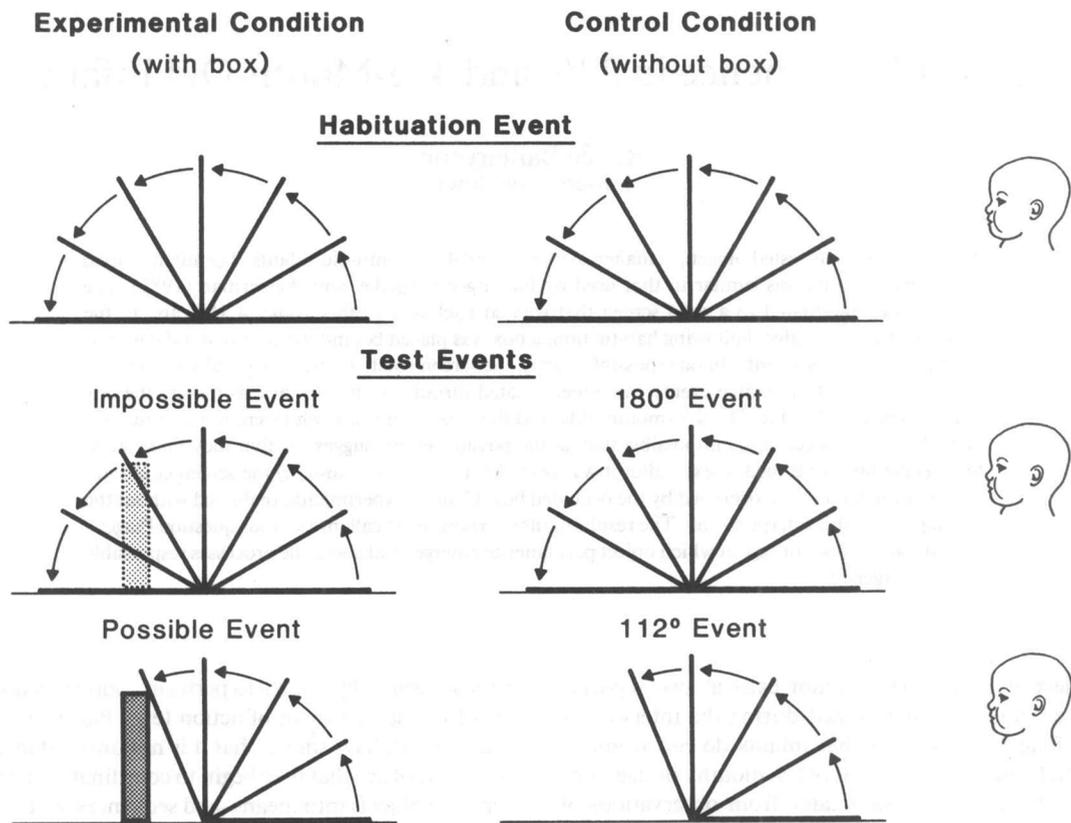Possible Event   112° Event

Figure 1. Schematic representation of the habituation and test events shown to the infants in the experimental and control conditions in Experiment 1.

the screen rotated until it reached the occluded box and then continued as though the box were no longer behind it! The screen rotated through a full 180° arc before it reversed direction and returned to its initial position, revealing the box standing intact in the same location as before. The infants looked reliably longer at the impossible than at the possible event, suggesting that they understood that (a) the box continued to exist after it was occluded by the screen and (b) the screen could not rotate through the space occupied by the occluded box.

The results of Baillargeon et al. indicate that, contrary to Piaget's claims, 5 ½-month-old infants understand that an object continues to exist when occluded. The first experiment reported here attempted to extend these results by examining whether younger infants, 4 ½-month-olds, expect the continued existence of occluded objects.

There are two reasons to ask whether younger infants have object permanence. The first is purely descriptive: Before we can propose a theory of the development of infants' beliefs about objects, we must establish *what* beliefs they hold at different ages. The second is more theoretical: The age at which infants are granted a notion of object permanence will undoubtedly constrain the nature of the mechanism we invoke to explain the attainment of this notion. Piaget (1952, 1954) attributed the emergence of object permanence to the coordination of sensorimotor schemes, which, as was mentioned earlier, begins at about 9 months of age. The discovery by Baillargeon

et al. that 5 ½-month-olds already possess a notion of object permanence is clearly inconsistent with Piaget's account. What mechanism could explain the presence of this notion in infants aged 5 ½ months or less? This question will be addressed in the General Discussion section.

Experiment 1

The method used in Experiment 1 was similar to that used by Baillargeon et al. (1985); it is depicted in Figure 1.

There was one foreseeable difficulty with the design of Experiment 1. The infants might look longer at the impossible than at the possible event, not because they were surprised to see the screen rotate through the space occupied by the occluded box, but because they found the 180° screen rotation more interesting than the shorter, 112° rotation shown in the possible event. In order to check this possibility, a second group of 4 ½-month-olds was tested in a control condition identical to the experimental condition except that there was *no box* behind the screen during the test events (see Figure 1). If the infants in the experimental condition looked longer at the impossible event because they preferred the 180° to the 112° rotation, then the infants in the control condition should also look longer at the 180° event. On the other hand, if the infants in the experimental condition looked longer at the impossible event because they were surprised when the screen failed to stop against the occluded box,

then the infants in the control condition should look equally at the 180° and the 112° events because no box was present behind the screen.[1]

Method

Subjects

Subjects were 24 full-term infants ranging in age from 4 months, 2 days to 5 months, 2 days (M = 4 months, 14 days). Half of the infants were assigned to the experimental condition and half to the control condition. Another 5 infants were excluded from the experiment, 3 because of fussiness, 1 because of drowsiness, and 1 because of equipment failure. The infants' names in this experiment and in the succeeding experiments were obtained from birth announcements in a local newspaper. Parents were contacted by letters and follow-up phone calls; they were offered reimbursement for their travel expenses but were not compensated for their participation.

Apparatus

The apparatus consisted of a large wooden box that was 120 cm high, 95 cm wide, and 74 cm deep. The infant faced an opening, 49 cm high and 95 cm wide, in the front wall of the apparatus. The interior of the apparatus was painted black and was decorated with narrow pink and green stripes.

At the center of the apparatus was a silver cardboard screen that was 31 cm high, 28 cm wide, and 0.5 cm thick. The lower edge of the screen, which was set 0.5 cm above the floor of the apparatus, was affixed to a thick metal rod that was 28.5 cm long and 1 cm in diameter. This rod was connected to a right-angle gear box that was 2 cm high, 3.5 cm wide, and 4 cm deep. A drive rod, which was 0.5 cm in diameter, was also connected to the gear box. This rod was 54 cm long and protruded through the back wall of the apparatus. By rotating this rod, an experimenter could rotate the screen back and forth through a 180° arc.[2]

A wooden box, 25 cm high, 15 cm wide, and 5 cm thick, could be introduced into the apparatus through a hidden door in its back wall. This box was painted yellow and was decorated with a two-dimensional clown face. The box was placed on a platform, which was 21 cm wide and 28 cm long, in the floor of the apparatus, behind the screen. This platform was mounted on a vertical slide located underneath the apparatus. By lowering the platform, after the screen occluded the box from the infant's view, an experimenter could surreptitiously remove the box from the path of the screen.

The infant was tested in a brightly lit room. Four clip-on lights (each with a 40-W lightbulb) were attached to the back and side walls of the apparatus to provide additional light. Two frames, each 183 cm high and 71 cm wide and covered with black cloth, stood at an angle on either side of the apparatus. These frames isolated the infant from the experimental room. At the end of each trial, a muslin-covered curtain, 65 cm high and 95 cm wide, was lowered in front of the opening in the front wall of the apparatus.

Experimental-Condition Events

Two experimenters worked in concert to produce the events in the experimental condition. The first operated the screen, and the second operated the platform.

Impossible test event. To start, the screen lay flat against the floor of the apparatus, toward the infant. The yellow box stood clearly visible, centered 12.5 cm behind the screen. The first experimenter rotated the screen at the approximate rate of 45°/s until it had completed a 90° arc, at which point she paused for 1 s. This pause allowed the second experimenter to lower the platform supporting the box. The first experi-

menter then continued to rotate the screen toward the back wall at the same rate of about 45°/s until it lay flat against the floor of the apparatus, covering the space previously occupied by the box. The entire process was then repeated in reverse: The first experimenter rotated the screen 90° and paused for 1 s, allowing the second experimenter to raise the platform; the first experimenter then lowered the screen to its original position against the floor of the apparatus, revealing the box standing intact in the same position as before.

Each full cycle of movement thus lasted approximately 10 s. The box remained occluded for about 8 of these 10 s: It was in view only during the first and last seconds, when the screen was raised less than 45°. There was a 1-s pause between successive cycles. Cycles were repeated until the computer signaled that the trial had ended (see below). At that point, the second experimenter lowered the curtain in front of the apparatus.

Possible test event. As before, the first experimenter rotated the screen 90° at the rate of about 45°/s and then paused for 1 s, allowing the second experimenter to lower the platform. The first experimenter then continued to rotate the screen 22.5° toward the back wall (where the screen would have contacted the box had the latter not been lowered), taking about 0.5 s to complete this movement. The first experimenter held the screen in this position for 2 s, and then the entire process was repeated in reverse: The first experimenter returned the screen to the 90° position, paused for 1 s (to allow the second experimenter to raise the platform), and then lowered the screen to its initial position against the floor of the apparatus. Each full cycle of movement thus lasted about 9 s, with the box remaining totally occluded for about 7 of these 9 s.[3]

Habituation event. The habituation event was exactly the same as the impossible test event, except that the box was absent.

Control-Condition Events

180° and 112° test events. The 180° and the 112° test events shown to the infants in the control condition were identical to the impossible and possible test events (respectively) shown to the infants in the experimental condition, except that the box was absent.

Habituation event. The habituation event shown to the infants in

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[1] The control condition was conducted without the box, rather than with the box to the side of the screen as in Baillargeon et al. (1985), to avoid a possible ambiguity. If the infants looked equally at the 180° and the 112° events, with the box to the side, one could not be sure whether (a) they had an equal preference for the two rotations or (b) they fixated the box and ignored the screen. Baillargeon et al. found, in their control experiment, that the order in which the infants saw the two screen events had a reliable effect on their looking behavior; such a finding rules out the possibility that the infants were merely staring at the box. Nevertheless, because of this potential confound, it seemed best to conduct the control experiment without the box.

[2] In order to help the experimenter move the screen at a constant, steady pace, a protractor was attached to the drive rod. In addition, the experimenter listened through headphones to a metronome clicking once per second.

[3] The 2-s pause in the possible event was introduced to make the rate of disappearance and reappearance of the box more similar in the two events. With the pause, the occlusion time of the box was 8 out of 10 s in the impossible event and 7 out of 9 s in the possible event. Making these two figures highly similar helped ensure that (a) the infants could not discriminate between the two events on the basis of rate differences and (b) the observers could not identify the events by the rate at which the platform was lowered and raised. Pilot data collected with the two observers indicated that they were unable to guess which event was being shown on the basis of the sounds associated with the movement of the platform.

the control condition was identical to that shown to the infants in the experimental condition.

The platform was moved in the same manner in all of the events to ensure that the sounds that accompanied the lowering and raising of the platform could not contribute to differences in the infants' looking times between and within conditions.

Procedure

Prior to the beginning of the experiment, each infant was allowed to manipulate the yellow box for a few seconds while the parent filled out consent forms. During the experiment, the infant sat on the parent's lap in front of the apparatus. The infant's head was approximately 65 cm from the screen and 100 cm from the back wall. The parent was asked not to interact with the infant while the experiment was in progress. At the start of the test trials, the parent was instructed to close his or her eyes.

The infant's looking behavior was monitored by two observers who viewed the infant through peepholes in the cloth-covered frames on either side of the apparatus. The observers could not see the experimental events and did not know the order in which the test events were presented. Each observer held a button box linked to a MICRO/PDP-11 computer and depressed the button when the infant attended to the experimental events. Interobserver agreement was calculated for each trial on the basis of the number of seconds for which the observers agreed on the direction of the infant's gaze out of the total number of seconds the trial lasted. Disagreements of less than 0.1 s were ignored. Agreement in this experiment as well as in the subsequent experiments averaged 88% (or more) per trial per infant. The looking times recorded by the primary observer were used to determine when a trial had ended and when the habituation criterion had been met (see below).
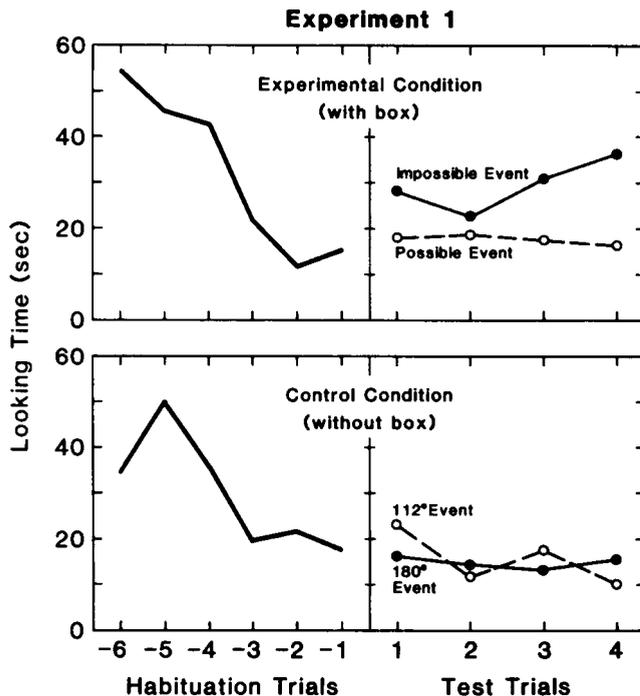

Experiment 1

Figure 2. Looking times of the infants in the experimental and control conditions in Experiment 1 during the habituation and test trials. (Note that the habituation trials are numbered backward from the trial in which habituation was reached.)

At the start of the experiment, each infant received a familiarization trial to acquaint him or her with the position of the box behind the screen. During this trial, the screen lay flat against the floor of the apparatus, with the box standing clearly visible behind it. The trial ended when the infant (a) looked away from the display for 2 consecutive seconds after having looked at it for at least 10 cumulative seconds, or (b) looked at the display for 30 cumulative seconds without looking away for 2 consecutive seconds.

Following the familiarization trial, each infant was habituated to the habituation event described above, using an infant-control procedure (after Horowitz, 1975). The main purpose of this habituation phase was to familiarize the infant with the (relatively unusual) motion of the screen.[4] Each habituation trial ended when the infant (a) looked away from the event for 2 consecutive seconds after having looked at it for at least 5 cumulative seconds (the duration of a half-cycle), or (b) looked at the event for 60 cumulative seconds without looking away for 2 consecutive seconds. The intertrial interval was 2–3 s. Habituation trials continued until the infant reached a criterion of habituation of a 50% or greater decrease in looking time on three consecutive trials, relative to the infant's looking time on the first three trials. If the criterion was not met within nine trials, the habituation phase was ended at that point. Therefore, the minimum number of habituation trials an infant could receive was six, and the maximum number was nine. Only 3 of the infants failed to reach the habituation criterion within nine trials; the other 21 infants took an average of 6.62 trials to satisfy the criterion. It should be noted that, in this experiment as in the subsequent experiments, infants who failed to reach the habituation criterion within nine trials were not terminated: At the completion of the ninth habituation trial, the experimenters simply proceeded to the test phase.

After the habituation phase, the infants in the experimental condition saw the impossible and the possible test events on alternate trials until they had completed four pairs of test trials. Similarly, the infants in the control condition saw the 180° and the 112° test events on alternate trials until they had completed four pairs of test trials. Within each condition, half of the infants saw one test event first and the other half saw the other test event first. At the beginning of each test trial, the first experimenter waited to move the screen until the computer signaled that the infant had looked inside the apparatus for 2 cumulative seconds. This ensured that the infants in the experimental condition had noted the presence of the box behind the screen. The criteria used to determine the end of each test trial were the same as for the habituation trials.

Six of the 24 infants in the experiment completed fewer than four pairs of test trials. Five infants completed only three pairs, 3 because of fussiness, 1 because of procedural error, and 1 because the primary observer could not follow the direction of the infant's gaze. The other infant completed only two pairs, because of fussiness. All subjects (in this experiment as well as in the subsequent experiments) were included in the data analyses, whether or not they had completed the full complement of four pairs of test trials.

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[4] It is interesting to speculate about the role of the habituation trials in the experiment. As stated in the text, the main rationale for including these trials was to familiarize the infants with the (presumably unfamiliar) movement of the screen. However, it could be that such familiarization was not necessary and that the infants would have responded in the same way had they received no habituation trials. Another possibility is that the habituation trials served to acquaint the infants with the fact that the screen rotated freely through empty space but stopped rotating when it encountered a hard surface. This hypothesis predicts that the infants would look less at the possible event (in which the screen rotated freely until it reached the occluded box) than at the impossible event (in which the screen continued to rotate after encountering the box). Further research is needed to evaluate these and related alternatives.

Results

Figure 2 presents the mean looking times of the infants in the experimental and control conditions during the habituation and test phases of the experiment. It can be seen that the infants in the experimental condition looked longer at the impossible than at the possible event, whereas the infants in the control condition looked equally at the 180° and the 112° events.

The infants' looking times to the test events were analyzed by means of a $2 \times 2 \times 4 \times 2$ mixed-model analysis of variance (ANOVA), with Condition (experimental or control) and Order (impossible/180° or possible/112° event first) as the between-subjects factors, and with Event (impossible/180° or possible/112°) and Test Pair (first, second, third, or fourth pair of test trials) as the within-subjects factors. Because the design was unbalanced, the SAS GLM procedure was used to calculate the ANOVA (SAS Institute, 1985). There was a significant main effect of condition, $F(1, 20) = 8.53, p < .01$, and of event, $F(1, 126) = 6.16, p < .05$, and a significant Condition $\times$ Event interaction, $F(1, 126) = 8.50, p < .005$. Planned comparisons indicated that the infants in the experimental condition looked reliably longer at the impossible ($M = 29.2, SD = 20.6$) than at the possible ($M = 17.7, SD = 13.1$) event, $F(1, 126) = 14.48, p < .0005$, whereas the infants in the control condition looked equally at the 180° ($M = 15.1, SD = 9.3$) and the 112° ($M = 16.2, SD = 12.3$) events, $F(1, 126) = 0.12$.

The analysis also revealed a significant Order $\times$ Event interaction, $F(1, 126) = 4.64, p < .05$. Post hoc comparisons indicated that the infants who saw the impossible/180° event first looked reliably longer at this event ($M = 24.17, SD = 16.88$) than at the possible/112° event ($M = 14.45, SD = 9.51$), $F(1, 126) = 10.56, p < .005$, whereas the infants who saw the possible/112° event first tended to look equally at the impossible/180° ($M = 20.24, SD = 18.01$) and the possible/112° ($M = 19.67, SD = 14.99$) events, $F(1, 126) = 0.03$. Such order effects are not uncommon in infancy research and are of little theoretical interest.

Discussion

The infants in the experimental condition looked reliably longer at the impossible than at the possible event, suggesting that they understood that (a) the box continued to exist after it was occluded by the screen, and (b) the screen could not move through the space occupied by the occluded box. In contrast to the infants in the experimental condition, the infants in the control condition tended to look equally at the 180° and the 112° events. This finding provides evidence that the infants in the experimental condition looked longer at the impossible event, not because they found the 180° screen rotation intrinsically more interesting than the 112° rotation, but because they expected the screen to stop when it reached the occluded box and were surprised that it failed to do so.

The results of Experiment 1 suggest that, contrary to Piaget's (1954) claims, infants as young as 4½ months of age understand that an object continues to exist when occluded. Experiment 2 investigated whether infants aged 3 ½–4 months also possess a notion of object permanence. The design of this experiment was identical to that of Experiment 1.
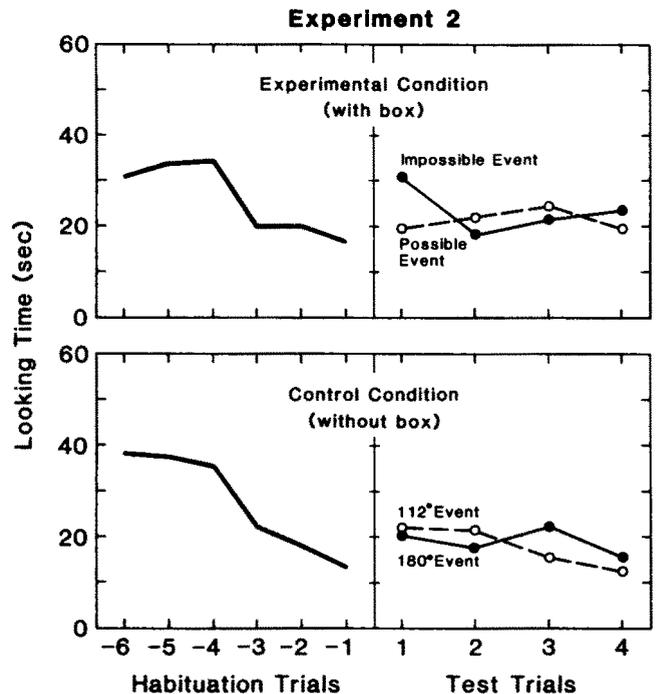

Figure 3. Looking times of the infants in the experimental and control conditions in Experiment 2 during the habituation and test trials.

Experiment 2

Method

Subjects

Subjects were 40 full-term infants ranging in age from 3 months, 15 days to 4 months, 3 days ($M = 3$ months, 24 days). More infants were tested in Experiment 2 than in Experiment 1 because pilot data indicated that the responses of these younger infants tended to be more variable; some infants produced consistently short looks, and other infants produced consistently long looks. Half of the infants were assigned to the experimental condition and half to the control condition. Six other infants were excluded from the experiment, 5 because of fussiness and 1 because of drowsiness.

Apparatus, Events, and Procedure

The apparatus, events, and procedure used in this experiment were the same as in Experiment 1. Of the 40 infants in the experiment, 12 failed to reach the habituation criterion within 9 trials; the others took an average of 7.14 trials to reach the criterion. Ten infants contributed only three pairs of test trials to the data analyses, 7 because of fussiness, 1 because he would not look at the events, 1 because of procedural error, and 1 because of equipment failure.

Results

Figure 3 presents the mean looking times of the infants in the experimental and control conditions during the habituation and test phases of the experiment. The infants' looking times during the test phase were analyzed as in the preceding experi-

ment. The analysis revealed no significant main effects or interactions, all $Fs < 2.69$, $ps > .05$.

Fast and Slow Habituators

Examination of the infants' looking times during the habituation and test phases of the experiment suggested that the pattern revealed by the initial analysis (statistically equal looking times to the impossible/180° and the possible/112° events) represented the average of two distinct looking patterns. Specifically, it appeared that, in the experimental condition, the infants who reached the habituation criterion within six or seven trials tended to look longer at the impossible than at the possible event, whereas the infants who required eight or nine trials to reach the criterion or who did not reach the criterion tended to look equally at the two test events. In the control condition, in contrast, both groups of infants tended to look equally at the 180° and the 112° events. These patterns were not unexpected, because rate of habituation is known to relate to posthabituation performance (Bornstein & Benasich, 1986; DeLoache, 1976; McCall, 1979).

The infants were therefore classified as *fast* habituators (the infants who took six or seven trials to reach the habituation criterion) and *slow* habituators (the infants who required eight or nine trials to reach the criterion or who failed to reach the criterion within nine trials). In the experimental condition, 9 infants were classified as fast habituators and 11 as slow habituators. In the control condition, 7 infants were classified as fast habituators and 12 as slow habituators (the remaining infant could not satisfy the habituation criterion because he produced very short looks on each trial[5]; because it was unclear how this infant should be classified, he was excluded from the next analyses).

The looking times of the fast and slow habituators in the experimental and control conditions to the test events were analyzed by means of a $2 \times 2 \times 2 \times 4 \times 2$ mixed-model ANOVA with Habituation (fast or slow habituators), Condition (experimental or control), and Order (impossible/180° or possible/112°) as the between-subjects factors, and with Test Pair (first, second, third, and fourth pair of test trials) and Event (impossible/180° or possible/112°) as the within-subject factors. As anticipated, this analysis yielded a significant Habituation × Condition × Event interaction, $F(1, 189) = 6.54$, $p < .05$. In order to study this interaction, four comparisons were carried out. These indicated that in the experimental condition, the fast habituators looked reliably longer at the impossible ($M = 23.78$, $SD = 18.28$) than at the possible ($M = 14.68$, $SD = 11.79$) event, $F(1, 189) = 7.38$, $p < .01$, whereas the slow habituators looked about equally at the two events (impossible, $M = 23.45$, $SD = 19.05$; possible, $M = 27.68$, $SD = 20.97$), $F(1, 189) = 1.75$, $p > .05$ (see Figure 4).[6] In the control condition, the fast habituators looked about equally at the 180° ($M = 17.06$, $SD = 15.45$) and 112° ($M = 19.80$, $SD = 18.09$) events, $F(1, 189) = 0.48$, as did the slow habituators (180° event, $M = 20.34$, $SD = 16.87$; 112° event, $M = 18.30$, $SD = 15.10$), $F(1, 189) = 0.41$. There were no other significant main effects or interactions (all $Fs < 3.53$, $ps > .05$).

At the end of each habituation and test trial, the observers rated the state of the infant. Examination of these ratings re-
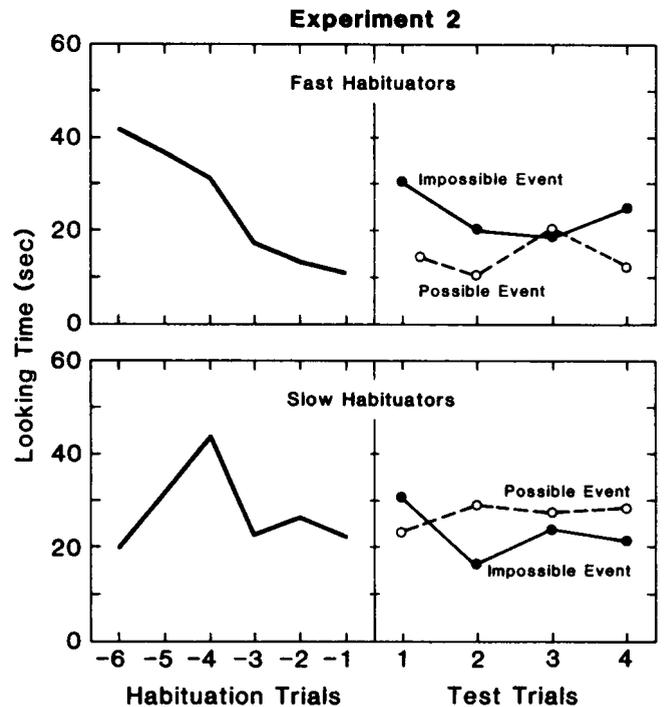

Experiment 2

Figure 4. Looking times of the fast and slow habituators in Experiment 2 (experimental condition) during the habituation and test trials.

vealed that during the habituation trials, the slow and fast habituators did not differ in amount of fussiness: Only four (17%) slow and three (19%) fast habituators were judged by the observers to have been slightly or moderately fussy on two or more trials. During the test trials, however, the slow habituators tended to be slightly fussier than the fast habituators. Seven (30%) slow habituators, but only one (6%) fast habituator, completed fewer than four pairs of test trials because of fussiness. Furthermore, nine (39%) slow habituators, but only four (25%)

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[5] Because the minimal looking time for any test trial was 5 s, an infant had to cumulate at least 30 s of looking across three consecutive trials in order to show a 50% decline in looking time.

[6] It may seem puzzling that, although the fast and slow habituators differed in how long they looked at the possible event (fast, $M = 14.68$; slow, $M = 27.68$), both groups of infants looked about equally at the impossible event (fast, $M = 23.78$; slow, $M = 23.45$). One might want to suggest, on the basis of these data, that although both groups of infants dishabituated to the impossible event (because it was impossible), only the slow habituators dishabituated to the possible event (perhaps because of the novel screen rotation). However, examination of the habituation data in Figure 4 argues against this interpretation. The fast habituators' mean looking time on their last three habituation trials ($M = 14.13$) was similar to their mean looking time to the possible ($M = 14.68$) but not to the impossible ($M = 23.78$) event. In contrast, the slow habituators' mean looking time on their last three habituation trials ($M = 22.46$) was similar to their mean looking time to the impossible ($M = 23.45$) and, to a lesser extent, to the possible ($M = 27.68$) event. The fast and slow habituators' equal looking times to the impossible event would thus reflect differences in their absolute levels of looking at the events, rather than similarities in their processing of the events.

fast habituators, were rated as slightly or moderately fussy on two or more test trials.

Why were the slow habituators fussier than the fast habituators during the test trials? One reason might be that, having looked longer during the habituation phase, the slow habituators were more likely to become tired or bored during the test phase. A one-way ANOVA indicated that the slow habituators ($M = 254.59$, $SD = 99.90$) looked reliably longer overall during the habituation trials than did the fast habituators ($M = 180.94$, $SD = 62.87$), $F(1, 35) = 6.39, p < .05$. Hence, the slow habituators might have been somewhat fussier during the test trials because they were more tired, bored, or restless.

Discussion

The fast habituators in the experimental condition showed a pronounced preference for the impossible over the possible event, a preference akin to that observed in the 4 ½-month-olds in Experiment 1. In contrast, the fast habituators in the control condition tended to look equally at the 180° and the 112° events. Together, these results indicate that the fast habituators in the experimental condition looked longer at the impossible event, not because they found the 180° rotation of the screen more interesting than the 112° rotation, but because they were surprised or puzzled to see the screen rotate through the space occupied by the occluded box. Such results suggest that at least some infants between the ages of 3 ½ and 4 months realize that an object continues to exist when occluded.

The slow habituators in the experimental condition, in contrast to the fast habituators, tended to look equally at the impossible and the possible events. The marked discrepancy in the responses of these two groups of infants will be discussed in the General Discussion.

Experiment 3: Replication

Given the unexpected nature and potential significance of the results obtained in the experimental condition of Experiment 2, it seemed important that they be confirmed. Experiment 3 attempted to do so with 3 ½-month-old infants.

Method

Subjects

Subjects were 24 full-term infants ranging in age from 3 months, 6 days to 3 months, 25 days ($M = 3$ months, 15 days). Five additional infants were eliminated from the experiment, 4 because of fussiness, and 1 because the primary observer could not follow the direction of the infant's gaze.

Apparatus and Events

The apparatus was the same as that used in the preceding experiments, with one exception. Instead of the yellow box, a brightly colored, three-dimensional Mr. Potato Head was used. Casual observations indicated that most infants found this toy more attractive than the box.

Because Mr. Potato Head was shorter than the box (15.5 cm as opposed to 25 cm), the screen was rotated 135°, instead of 112°, in the possible event. That is, after rotating the screen 90° at the usual rate of 45°/s and then pausing for 1 s, as before, the primary experimenter ro-

tated the screen 45° toward the back wall of the apparatus, taking 1 s to complete the movement. The first experimenter paused for 2 s and then repeated the same actions in reverse. Each full cycle of movement thus lasted approximately 10 s, as in the impossible event. Mr. Potato Head was totally occluded for about 8 of the 10 s.

Procedure

The procedure was the same as that of the experimental condition in Experiment 2, with one exception. In an attempt to abbreviate the test phase of the experiment, no pretrials were given at the beginning of the test trials.

Of the 24 infants in the experiment, 8 failed to reach the habituation criterion within 9 trials; the other infants took an average of 6.94 trials to reach the criterion. Five infants completed only three pairs of test trials, 4 because of fussiness, and 1 because the primary observer could not follow the direction of the infant's gaze. Another 2 infants completed only two test pairs because of fussiness.

Results

The looking times of the infants to the impossible and possible test events were first analyzed by means of a 2 × 4 × 2 mixed-model ANOVA, with Order (impossible or possible event first) as the between-subjects factor, and with Test Pair (first, second, third, or fourth pair of test trials) and Event (impossible or possible event) as the within-subjects factors. The analysis yielded no significant main effects or interactions, all Fs < 2.05, ps > .11.

Fast and Slow Habituators

Of the 24 infants who participated in the experiment, 12 were classified as fast habituators, and 12 were classified as slow habituators, using the same criteria as in Experiment 2.

Figure 5 shows the mean looking times of each group of infants during the habituation and test trials. The looking times of the two groups to the test events were analyzed by means of a 2 × 2 × 4 × 2 mixed-model ANOVA, with Habituation (fast or slow habituators) and Order (impossible or possible event first) as the between-subjects factors, and with Test Pair (first, second, third, or fourth test pair) and Event (impossible or possible event) as the within-subjects factors. As expected, the analysis yielded a significant Habituation × Event interaction, $F(1, 122) = 5.13, p < .05$. Planned comparisons showed that the fast habituators looked reliably longer at the impossible ($M = 21.97$, $SD = 16.33$) than at the possible ($M = 14.24$, $SD = 10.56$) event, $F(1, 122) = 6.35, p < .02$, whereas the slow habituators looked at the impossible ($M = 23.24$, $SD = 20.00$) and the possible ($M = 26.42$, $SD = 21.15$) events about equally, $F(1, 122) = .91$.

Comparison of the fast and slow habituators indicated that they did not differ in fussiness during the habituation trials: Only one infant, a slow habituator, was judged to have been fussy on two or more habituation trials. However, as in Experiment 2, the slow habituators tended to be fussier than the fast habituators during the test trials. Five of the slow habituators, but only one of the fast habituators, completed fewer than four test pairs due to fussiness. In addition, seven slow habituators, but only three fast habituators, were fussy on two or more trials. A one-way ANOVA showed that, as in Experiment 2, the slow
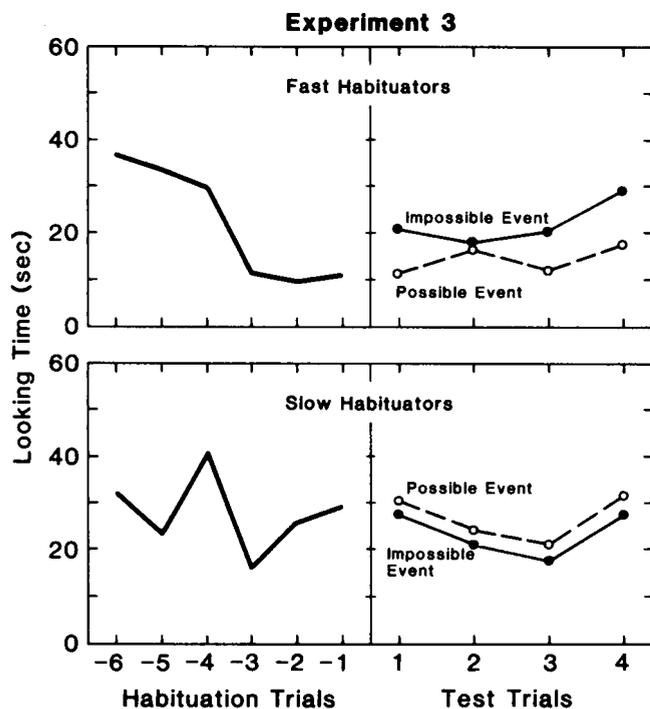
Experiment 3

Figure 5. Looking times of the fast and slow habituators in Experiment 3 during the habituation and test trials.

habituators (M = 218.59, SD = 139.75) tended to look longer overall during the habituation trials than did the fast habituators (M = 140.25, SD = 37.80), $F(1, 21)$ = 3.50, p = .075.

Discussion

The results of Experiment 3 replicated those of the experimental condition in Experiment 2. The fast habituators looked reliably longer at the impossible than at the possible event, suggesting that they were surprised or puzzled to see the screen move through the space occupied by Mr. Potato Head.

Could the fast habituators' preference for the impossible event be due to their having found the 180° screen rotation intrinsically more interesting than the shorter rotation shown in the possible event? This interpretation seems highly unlikely for two reasons. First, the fast habituators in the control conditions of Experiments 1 and 2 did not show an overall preference for the 180° rotation. Second, the slow habituators in Experiment 3 looked about equally at the impossible and the possible events. It is difficult to imagine why the fast, but not the slow, habituators would have found the 180° rotation intrinsically more interesting than the shorter, 135° rotation shown in the possible event.

General Discussion

The 4 ½-month-olds in Experiment 1 and the 3 ½-month-olds in Experiments 2 and 3 who were fast habituators all looked reliably longer at the impossible than at the possible event, suggesting that they understood that (a) the object behind

the screen (i.e., box or Mr. Potato Head) continued to exist after the screen rotated upward and occluded it and (b) the screen could not move through the space occupied by the object. The results of the control conditions in Experiments 1 and 2 provide support for this interpretation. These results indicated that when no object was present behind the screen, the infants did not look longer at the 180° screen rotation.

These results call into question Piaget's (1954) claims about the *age* at which object permanence is attained, about the *processes* responsible for its emergence, and about the *behaviors* by which it is manifested. These are discussed in turn.

Piaget maintained that it is not until infants reach about 9 months of age that they begin to view objects as permanent. However, the results of the experiments reported here indicate that infants as young as 3 ½ months of age already realize that objects continue to exist when occluded. This finding does not mean that by 3 ½ months, infants' conception of occluded objects is as sophisticated as that of older infants. Further research is necessary to determine whether young infants are able to represent not only the existence but also the physical and spatial characteristics of occluded objects (e.g., Baillargeon, 1986, in press; Baillargeon & Graber, in press).

Piaget also held that the emergence of object permanence depends on the coordination of sensorimotor schemes, which begins at about 9 months of age. The present findings, like those of Baillargeon et al. (1985), are inconsistent with this explanation, because they suggest that infants possess a notion of object permanence long before they begin to perform coordinated actions.

How can we account for the presence of a notion of object permanence in 3 ½-month-old infants? One possibility is that this notion is innate (e.g., Bower, 1971; Spelke, 1985). Spelke (1985), for example, hypothesized that infants are born with a conception of objects as spatially bounded entities that exist continuously in time and move continuously in space, maintaining their internal unity and external boundaries. This conception, according to Spelke, provides infants with a basis for recognizing that objects continue to exist when occluded. A second possibility is that infants are born, not with a substantive belief in the permanence of objects, but with a learning mechanism that is capable of arriving at this notion given a limited set of pertinent observations.[7] These observations could arise from infants' examination of the displacements and interactions of objects (Mandler, 1986) as well as from infants' actions upon objects. Although infants do not show mature reaching for objects until about 4 months of age (e.g., Granrud, 1986; von Hofsten, 1980), infants less than 4 months often perform arm extensions in the presence of objects (e.g., Bruner & Koslowski, 1972; Field, 1976; Provine & Westerman, 1979). Infants might notice, when performing these arm extensions, that their hands sometimes occlude and sometimes are occluded by objects (Harris, 1983). The same point can be made about infants' manipulations of objects. White (1969) reported that beginning at about 3 months of age, objects that are placed in one hand are often brought to the midline to be simultaneously viewed and explored tactually by the other hand. Infants might notice

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[7] I have left open the question of whether the learning mechanism is constrained in terms of the types of observations it can detect or the nature of the generalizations it can derive.

in the course of these manipulations that their hands occlude (parts of) the objects.

The results of the present experiments are not sufficient to determine which (if either) of the two hypotheses mentioned above better explains the presence of object permanence in 3½-month-old infants. What these results do indicate, however, is that whatever explanation is proposed cannot depend on perceptual or motor abilities more sophisticated than those available after the third month of life.

Piaget viewed the search for hidden objects as the hallmark of object permanence. Yet the present results indicate that infants possess object permanence long before they begin to engage in search activities. How can we explain this discrepancy? Why do infants' actions lag so far behind their understanding? One possibility, alluded to in the introduction, is that young infants may fail to search because they are generally unable to perform sequences of actions in which one action is applied to one object in order to create conditions under which another action can be applied to another object (e.g., pulling a cushion to get an object placed on it). Why infants should have difficulty with these types of action sequences remains somewhat of a mystery. Piaget's (1952) remarkable observations of the development of action in infancy make it clear that 3- and 4-month-old infants can perform means–end sequences in which one action is applied to one object (e.g., pulling a chain) in order to produce a result involving another object (e.g., shaking a toy attached to the other end of the chain). Further research is needed to compare the cognitive and motor requirements of the means–end sequences observed at 3–4 and at 7–8 months to identify the source of the latter's difficulty.

A final issue raised by the results of the present experiments concerns the differences between the performances of the fast and slow habituators in Experiments 2 (experimental condition) and 3. Recall that the fast habituators looked longer at the impossible than at the possible event, whereas the slow habituators looked about equally at the two events. At least two explanations could be offered for the discrepancy between these two groups, one appealing to transient and the other to more stable differences between the fast and slow habituators.

The first possibility is that the slow habituators were less engaged by the experimental events than the fast habituators. Perhaps the slow habituators were less alert, or more distressed by their novel surroundings. In any case, they were less involved with the events: (a) they required more trials to reach the habituation criterion, if they reached it at all, and (b) they were more likely to become fussy during the test trials. In other words, because the task of interpreting the impossible and possible events was a difficult one for the young infants in Experiments 2 and 3, only the infants whose attention was fully engaged were able to grasp the underlying structure of the events (i.e., realized that the screen rotated through the space occupied by the occluded box). The infants whose attention wandered—because they were fussy, bored, hungry, or ill at ease in their unfamiliar surroundings—were apparently unable to do so.

Two predictions follow from this first interpretation. One is that whether a given 3½-month-old looks longer at the impossible event in any one test session should depend on his or her attentional state at the time of the session. The other is that, as infants grow older and the task of understanding the impossible

and possible events becomes less difficult, attentional states should have less impact on their performances. Partial support for this prediction comes from the experimental condition of Experiment 1. Of the 12 infants in this condition, 8 were fast habituators (6–7 trials to criterion), and 4 were slow habituators (8–9 trials to criterion). Six of the 8 fast habituators (75%) and 3 of the 4 slow habituators (75%) looked at the impossible event for at least 9 s longer than at the possible event. For the younger infants in Experiments 2 (experimental condition) and 3 combined, the comparable figures were 17 of 21 (81%) fast habituators and 7 of 23 (31%) slow habituators.

The second interpretation for the discrepancy in the responses of the fast and slow habituators is that it reflects, not transient fluctuations in alertness and mental involvement, but stable, meaningful differences between the two groups of infants. Suppose that the fast habituators were generally more efficient than the slow habituators at processing information about the physical world—at detecting, discriminating, representing, and categorizing regularities about objects and events. One consequence might be that at the time of testing, the fast habituators had already formed strong expectations about the permanence and the solidity of objects, whereas the slow habituators had just begun developing these expectations. This would explain why the fast habituators showed marked and consistent attention to the impossible event and why the slow habituators did not.

Note that the hypothesized difference between fast and slow habituators need not be cognitive in origin: It could also be motivational (e.g., fast habituators might be more motivated or more persistent in their examination of the physical world), social (e.g., fast habituators might have caretakers who consistently direct their attention toward objects), or physiological (e.g., fast habituators might have better state control) (cf. Bornstein & Benasich, 1986; Bornstein & Sigman, 1986).

Longitudinal data will be needed to decide which (if either) of the two interpretations put forth is accurate. If one finds that the same infants show a preference for the impossible event when they habituate quickly and fail to show this preference when they habituate more slowly, one might be warranted to conclude that the infants possess a notion of object permanence but only manifest this notion when they are sufficiently alert and calm to attend to the events. A simpler test of object permanence, one necessitating less sustained attention, might be less subject to the vagaries of infants' attentional states.

The results of the experiments reported in this article indicate that by 3½ months of age, infants already possess expectations about the behavior of objects in time and space. Specifically, infants assume that objects continue to exist when occluded and that objects cannot move through the space occupied by other objects. It is likely that further investigations of young infants' physical knowledge will bring to light further competence. As the picture of infants' physical world becomes more complex, the task of describing how they attain, represent, and use their physical knowledge will undoubtedly open new avenues into the central issue of the origins of human cognition.

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