Cognitive Psychology **39,** 116–157 (1999)
Article ID cogp.1999.0717, available online at http://www.idealibrary.com on IDEAL®

# 2.5-Month-Old Infants' Reasoning about When Objects Should and Should Not Be Occluded

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The present research examined 2.5-month-old infants' reasoning about occlusion events. Three experiments investigated infants' ability to predict whether an object should remain continuously hidden or become temporarily visible when passing behind an occluder with an opening in its midsection. In Experiment 1, the infants were habituated to a short toy mouse that moved back and forth behind a screen. Next, the infants saw two test events that were identical to the habituation event except that a portion of the screen's midsection was removed to create a large window. In one event (high-window event), the window extended from the screen's upper edge; the mouse was shorter than the bottom of the window and thus did not become visible when passing behind the screen. In the other event (low-window event), the window extended from the screen's lower edge; although the mouse was shorter than the top of the window and hence should have become fully visible when passing behind the screen, it never appeared in the window. The infants tended to look equally at the high- and low-window events, suggesting that they were not surprised when the mouse failed to appear in the low window. However, positive results were obtained in Experiment 2 when the low-window event was modified: a portion of the screen above the window was removed so that the left and right sections of the screen were no longer connected (two-screens event). The infants looked reliably longer at the two-screens than at the high-window event. Together, the results of Experiments 1 and 2 suggested that, at 2.5 months of age, infants possess only very limited expectations about when objects should and should not be occluded. Specifically, infants expect objects (1) to become visible when passing *between* occluders and (2) to remain hidden when passing *behind* occluders, irre-

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This research was supported by Grant BEX-2688 from CAPES-Brasilia/Brasil to the first author and by a grant from the National Institute of Child Health and Human Development (HD-21104) to the second author. We thank Noam Chomsky, Dov Cohen, Cindy Fisher, Rochel Gelman, Valerie Makin, Jean Mandler, and Brian Ross for helpful comments and Rebecca Bloch, Laura Brueckner, Beth Cullum, Susan Hespos, Lisa Kaufman, Marsha Keeler, Laura Kotovsky, Melsie Minna, Helen Raschke, Teresa Wilcox, and the undergraduate assistants at the Infant Cognition Laboratory at the University of Illinois for their help with the data collection. We also thank the parents who kindly agreed to have their infants participate in the research.

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0010-0285/99 $30.00

spective of whether these have openings extending from their upper or lower edges. Experiment 3 provided support for this interpretation. The implications of these findings for models of the origins and development of infants' knowledge about occlusion events are discussed.

As they look about them, infants often see events in which objects become occluded by nearer objects: for example, infants may see a parent step behind a door, a sibling crouch behind a bed, or a toy roll behind a nearer toy. Piaget (1954) was the first researcher to examine how well infants understand occlusion events. He concluded that it is not until infants are about 8 months of age that they realize that objects continue to exist when occluded. This conclusion was based primarily on analyses of infants' responses in search tasks. Piaget found that after watching an experimenter hide a toy behind a cover, infants aged less than 8 months typically do not search for the toy: they make no attempt to remove the cover and grasp the toy, even though they are usually capable (beginning at 4 to 5 months) of performing each of these actions. For the next 3 decades, developmental researchers generally accepted Piaget's conclusion that young infants' physical world includes only those objects that they can directly perceive (see Bremner, 1985; Gratch, 1975, 1976; Harris, 1987, 1989; and Schubert, 1983, for reviews of this early work). This state of affairs began to change in the mid 1980s, however, when experiments conducted with novel, more sensitive tasks yielded findings that contradicted Piaget's long-standing conclusion (e.g., Baillargeon, 1986, 1987a,b; Baillargeon & Graber, 1987; Baillargeon, Spelke, & Wasserman, 1985; Hood & Willatts, 1986; Spelke & Kestenbaum, 1986). Today, there is consistent evidence from several different laboratories that infants aged 2.5 months and older believe that (1) a stationary object continues to exist and retains its location when occluded and (2) a moving object continues to exist and pursues a continuous path when occluded (e.g., Aguiar & Baillargeon, 1999, in press; Baillargeon, 1991; Baillargeon & DeVos, 1991; Baillargeon, Graber, DeVos, & Black, 1990; Clifton, 1998; Hespos & Baillargeon, 1999; Hespos & Rochat, 1997; Hofstadter & Reznick, 1996; Koechlin, Dehaene, & Mehler, in press; Lécuyer & Durand, 1998; Leslie & Das Gupta, submitted for publication, cited in Leslie, 1995; Simon, Hespos, & Rochat, 1995; Spelke & Kestenbaum, 1986; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wilcox & Baillargeon, 1998b; Wilcox, Nadel, & Rosser, 1996; Wynn, 1992).

Such evidence does not necessarily mean, of course, that infants as young as 2.5 months of age understand all facets of occlusion events. In particular, young infants could realize that an object continues to exist *after* it becomes occluded and still have difficulty predicting *when* the object should be occluded. For example, upon seeing an object move behind an occluder with an opening in its midsection, infants could be unable to predict, until they learn what information to use in making such predictions, whether the object should remain hidden or become temporarily visible when passing behind the occluder. Similarly, upon seeing a wide object approach a narrow occluder, or a tall object approach a short occluder, infants could have difficulty determining, until they learn what information to consider, whether the object should be fully or only partly hidden behind the occluder. Finally, upon seeing a fast- or a slow-moving object disappear behind an occluder, infants could be unable to judge, until they learn what information to take into account, how soon each object should reappear from behind the occluder.

The present research began to explore 2.5-month-old infants' ability to predict when or under what conditions objects should be occluded. This research built on two sets of prior findings: the first, more general set came from experiments on the development of young infants' expectations about support, collision, and arrested-motion events (e.g., Baillargeon, 1991; Baillargeon, Needham, & DeVos, 1992; Kotovsky & Baillargeon, 1998; Needham & Baillargeon, 1993; see Baillargeon, 1995, 1998, and Baillargeon, Kotovsky, & Needham, 1995, for reviews); the second, more specific set of findings came from experiments on the development of young infants' expectations about occlusion events (e.g., Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991). The two sets of findings are described briefly in turn.

## HOW DO YOUNG INFANTS LEARN ABOUT PHYSICAL EVENTS?

Experiments conducted over the past 8 years on the development of young infants' expectations about support, collision, and arrested-motion events (see Baillargeon, 1995, 1998, and Baillargeon et al., 1995, for reviews) have brought to light a general pattern in infants' acquisition of knowledge about events. Specifically, it appears that when learning about an event category, infants first form an *initial concept* centered on a simple, all-or-none distinction. With further experience, infants identify *variables* that elaborate and refine this initial concept, resulting in increasingly accurate predictions and interpretations over time.

This developmental pattern can be illustrated by the results of recent experiments on infants' knowledge about support events (e.g., Baillargeon et al., 1992; Needham & Baillargeon, 1993; see Baillargeon, 1995, 1998, and Baillargeon et al., 1995, for reviews). Infants aged 3 to 6.5 months were presented with simple support problems involving a box and a platform; the box was released in one of several positions relative to the platform (e.g., off the platform, against the side of the platform, on the top of the platform, and so on), and the infants judged whether the box should remain stable when released. The results indicated that, by 3 months of age, infants have formed an initial concept centered on a *contact/no-contact* distinction: they expect the box to fall if released off the platform and to remain stable otherwise. At this stage, *any* contact with the platform is deemed sufficient to ensure the box's stability. At least two variables are identified between 3 and 6.5 months of age. First, infants become aware that the *type of contact* between the box and the platform must be taken into account when judging the box's stability. Infants initially assume that the box will remain stable if released either on the top or against the side of the platform. However, by 4 to 5.5 months of age (females precede males by a few weeks in this development), infants distinguish between these two types of contact and recognize that only the first can lead to stability. The second variable that infants identify concerns the *amount of contact* between the box and the platform. Initially, infants believe that the box will be stable even if only a small portion (e.g., the left 15%) of its bottom surface rests on the platform. By 6.5 months of age, however, infants expect the box to fall unless a large portion of its bottom surface is supported.

These and similar findings with other physical events (e.g., Baillargeon, 1991; Kotovsky & Baillargeon, 1998; see Baillargeon, 1995, 1998, and Baillargeon et al., 1995, for reviews) led us to examine the development of young infants' expectations about occlusion events, to determine whether this development would also lend itself to a description in terms of an initial concept and variables. In this research, we focused on young infants' ability to predict under what conditions objects should and should not be occluded. It seemed plausible that young infants could realize that objects continue to exist *after* they become occluded (e.g., Aguiar & Baillargeon, 1999; Baillargeon, 1987a, 1991; Baillargeon & DeVos, 1991; Hespos & Baillargeon 1999; Spelke et al., 1992; Wilcox et al., 1996), and still have difficulty predicting *when* they should be occluded. It also seemed plausible that this ability could develop gradually, with the identification of a sequence of relevant variables.

Two experiments with 3.5- and 3-month-old infants (Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991) provided initial evidence that significant changes do take place with age in young infants' ability to predict when objects should be occluded. These experiments are described in the next section; they provided the basis for the present research.

## WHEN SHOULD OBJECTS BE OCCLUDED?

Are young infants able to predict whether an object should remain continuously hidden or become temporarily visible when passing behind an occluder with an opening in its midsection? Two experiments with 3.5- and 3-month-old infants were designed to address this question (Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991). Both experiments made use of the violation-of-expectation paradigm (e.g., Baillargeon, 1998; Bornstein, 1985; Spelke, 1985). In a typical experiment conducted with this paradigm, infants see two test events, one consistent (expected event) and one inconsistent (unexpected event) with a physical belief or expectation. Evidence (with appropriate controls) that infants look reliably longer at the unexpected than at the expected event is taken to suggest that they (1) possess the expectation

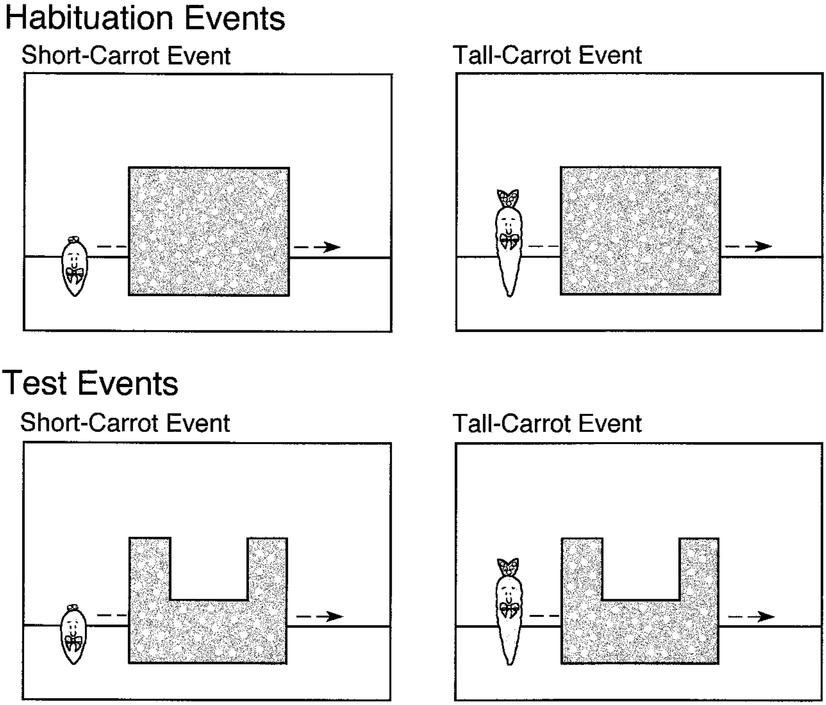

**FIG. 1.** Schematic drawing of the habituation and test events shown in the experiment of Baillargeon and DeVos (1991).

examined in the experiment; (2) detect the violation of this expectation in the unexpected event; and (3) are surprised or puzzled by this violation.[1]

In the first experiment (Baillargeon & DeVos, 1991; see Baillargeon & Graber, 1987, and Hespos, 1998, for similar results with older infants), 3.5- and 3-month-old infants saw test events involving a short or a tall object that moved behind an occluder with an opening in its *upper* half (see Fig. 1); the experiment tested whether the infants would take into account the height of the object to determine whether it should appear in the occluder's opening. To start, the infants were habituated to a toy carrot that moved back and forth behind a wide screen; the carrot disappeared at one edge of the screen and reappeared, after an appropriate interval, at the screen's other edge. On alternate trials, the infants saw a short and a tall carrot slide along

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[1] Although no formal evidence has yet been gathered involving facial or behavioral correlates of surprise and puzzlement, we have often observed such reactions in our laboratory and for this reason find the use of the terms ''surprise'' and ''puzzlement'' appropriate. Readers uncomfortable with these terms might want to view them simply as shorthand descriptions for infants' detection of violations of their expectations.

the track. Following habituation, a large window was created in the midsection of the screen's upper half. In one test event (short-carrot event), the short carrot moved along the track; this carrot was shorter than the bottom of the window and so did not become visible when passing behind the screen. In the other test event (tall-carrot event), the tall carrot moved along the track; this carrot was taller than the bottom of the window and hence should have appeared in the window but did not in fact do so.

The 3.5-month-old infants looked reliably longer at the tall- than at the short-carrot test event, suggesting that they (1) believed that each carrot continued to exist after it moved behind the screen; (2) realized that each carrot could not disappear at one edge of the screen and reappear at the other edge without traveling continuously between them; (3) recognized that the height of each carrot relative to the bottom of the window determined whether the carrot would become visible in the window; (4) expected the tall but not the short carrot to appear in the window; and hence (5) were surprised in the tall-carrot event when this expectation was violated. This interpretation was supported by the results of a control condition identical to the experimental condition, with one exception: at the start of the session, the infants received two pretest trials in which they saw two identical carrots standing motionless on either side of the habituation screen; the infants saw two short carrots in one trial and two tall carrots in the other. The infants looked about equally at the tall- and short-carrot test events, suggesting that they were able to use the information given in the pretest trials to make sense of the tall-carrot event: that is, they realized that no tall carrot appeared in the window because two tall carrots were involved in the event, one traveling to the left and one to the right of the window.

In contrast to the 3.5-month-olds, the 3-month-old infants tended to look equally at the tall- and short-carrot test events. One interpretation for this negative finding was that at 3 months of age, infants have not yet learned that when an object moves behind an occluder with an opening extending from its upper edge, the height of the object determines whether it will become visible in the opening. This interpretation left open the possibility that 3-month-old infants might be able to solve simpler occlusion problems that did not require reasoning about height. To explore this possibility, we recently conducted an experiment (Aguiar & Baillargeon, 1999) in which infants watched test events involving a short object and an occluder with an opening in its *upper* or *lower* half (see Fig. 2, left panel); the experiment examined whether infants would realize that the object had to become visible in the low opening. To start, the infants were habituated to a short toy mouse (‘‘Minnie Mouse’’) that moved back and forth behind a screen. Next, a large window was created in the screen's midsection, and the mouse again moved back and forth behind the screen. In one test event (high-window event), the window was in the screen's upper half; the mouse was shorter than the bottom of the window and so did not become visible when passing behind

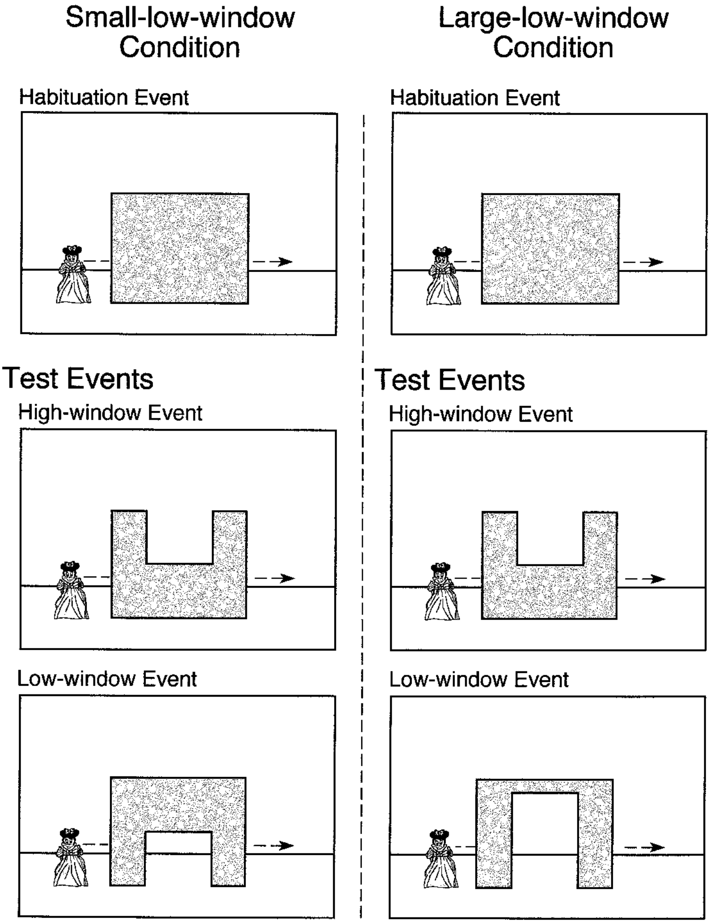

**FIG. 2.** Schematic drawing of the habituation and test events shown in the experiment of Aguiar and Baillargeon (1999) and in the small-low-window condition in Experiment 1 (left panel); schematic drawing of the habituation and test events shown in the large-low-window condition in Experiment 1 (right panel).

the screen. In the other test event (low-window event), the window was in the screen's lower half; although the mouse was shorter than the top of the window and hence should have been fully visible when passing behind the screen, it never appeared in the window.

The infants looked reliably longer at the low- than at the high-window event, suggesting that they (1) believed that the mouse continued to exist after it moved behind the screen; (2) realized that the mouse could not disappear at one edge of the screen and reappear at the other edge without traveling continuously between them; (3) expected the mouse to become temporarily visible when passing behind the screen with the low but not the high window; and so (4) were surprised in the low-window event when this expectation was violated. This interpretation was supported by the results of a control condition in which the screen was briefly lowered at the start of each trial to reveal two identical mice, one standing behind the right and the other behind the left edge of the screen. The infants tended to look equally at the test events, suggesting that, like the 3.5-month-old control infants tested by Baillargeon and DeVos (1991), the infants were able to use the information that two mice were present in the apparatus to make sense of the low-window event.

Together, the results of the experiments described in this section suggest that an important change takes place between 3 and 3.5 months of age in infants' expectations about when objects should and should not be occluded. At 3 months of age, infants apparently attend only to openings that extend from the *lower edges* of occluders. If an occluder presents such an opening (like the screen in our low-window test event), infants expect the object to become visible when passing behind the occluder and are surprised if it does not. If an occluder presents no such opening (like the screen in our high-window test event or the screen in the tall- and short-carrot test events of Baillargeon & DeVos, 1991), infants do not expect the object to become visible. By 3.5 months of age, infants have progressed to a more advanced stage and also attend to openings that extend from the *upper edges* of occluders. Infants realize that when an object passes behind an occluder with an upper opening, the object will become visible if its height is greater than that of the bottom of the opening.[2]

## THE PRESENT RESEARCH

The present research built on the findings discussed in the previous section and examined 2.5-month-old infants' expectations about when objects should be occluded. The goal of the experiments was to ascertain whether

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[2] Other interpretations were possible for the discrepant responses of the 3-month-old infants tested by Baillargeon and DeVos (1991) and Aguiar and Baillargeon (1999). For example, one could suggest that the infants tested by Baillargeon and DeVos (1) did realize that the height of an object relative to that of an occluder determines whether the object will be fully or only partly hidden when behind the occluder but (2) could not detect the relatively small height violation in the tall-carrot test event. This interpretation predicts that infants should do better if shown a larger height violation (i.e., one in which a greater portion of the object fails to appear in the screen window). To test this prediction, we showed 3-month-old infants the same high-window test event as in our original mouse experiment and another test event that was similar except that the window was enlarged so that only a short screen strip remained beneath the window; the mouse did not appear in this enlarged window, although most of the mouse should in fact have been visible above the screen strip (Aguiar & Baillargeon, 1999). The infants looked about equally at the two events. These data support the notion that 3-month-old infants have not yet identified height as an important variable in occlusion events.

2.5-month-old infants possess the same expectations as 3-month-old infants and, if not, to determine what expectations these young infants do possess.

It might be questioned whether it was plausible to expect any significant change in the physical knowledge of infants aged 2.5 and 3 months. There were two main reasons to believe that such changes were possible. The first reason was empirical: given that 3- and 3.5-month-old infants had been found to differ in their expectations about occlusion events (Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991), it was conceivable that 2.5- and 3-month-old infants might also be found to differ.

The second reason was more theoretical in nature and had to do with our hypotheses about how infants identify variables in the course of learning about event categories (e.g., Baillargeon, 1998, 1999). We believe that the age at which infants identify a variable depends in part on the age at which they become exposed to data—observations or manipulations—from which to abstract the variable (we return to these issues in the General Discussion). In the first few months of life, infants' visual perception improves at a very fast rate (see Banks & Salapatek, 1983; Kellman & Banks, 1998; and Slater, 1995, for reviews). In addition to substantial increases in acuity (e.g., Courage & Adams, 1990; Mohn & van Hof-van Duin, 1985; Norcia & Tyler, 1985; Suter, Suter, & Crow, 1991) and contrast sensitivity (e.g., Atkinson & Braddick, 1981; Norcia, Tyler, & Allen, 1986; Norcia, Tyler, & Hamer, 1990), the scanning of stimuli becomes more extensive (e.g., Bronson, 1990), and smooth pursuit eye movements develop rapidly (e.g., Aslin, 1981). All of these changes are likely to yield rapid improvements in infants' ability to track objects that disappear and reappear from behind occluders. For example, infants might become more likely to notice, when watching objects pass behind occluders with openings, whether the objects remain hidden or become temporarily visible. The rapid changes in infants' visual abilities would thus result in rapid changes in the quality of the occlusion data available to them, bringing about, in turn, rapid changes in their expectations about occlusion events.

## EXPERIMENT 1

The 2.5-month-old infants in Experiment 1 were assigned to one of two experimental conditions: the small- and the large-low-window conditions. The infants in the small-low-window condition saw the same habituation and test events (see Fig. 2, left panel) as the 3-month-old infants in our initial mouse experiment (Aguiar & Baillargeon, 1999). The infants in the large-low-window condition also saw the same habituation and test events, with one exception: the window in the low-window test event was enlarged to such an extent that only a short screen strip remained above the window to connect the left and right portions of the screen (see Fig. 2, right panel). We reasoned that if the infants in the small-low-window condition failed to show a reliable preference for the low-window test event, it could be simply because these young infants somehow failed to detect the presence of the low window. We hoped that the enlarged window would be more salient and hence easier for the infants to detect.

We predicted that if the 2.5-month-old infants in Experiment 1 possessed the same expectations about occlusion events as the 3-month-old infants in our initial experiment (Aguiar & Baillargeon, 1999), then they, too, should look reliably longer at the low- than at the high-window test event, at least in the large-low window condition, where the low window was particularly salient.

## Method

### *Participants*

Participants were 24 healthy term infants, 11 male and 13 female, ranging in age from 77 to 90 days ($M$ = 83.3 days). Twelve infants, 5 male and 7 female (range = 77 to 90 days, $M$ = 83.7 days), were randomly assigned to the small-low-window condition, and 12 infants, 6 male and 6 female (range = 78 to 87 days, $M$ = 83.0 days), to the large-low-window condition. An additional 16 infants were tested but eliminated[3]; they failed to contribute two valid test trials, 9 because they looked for the maximum amount of time allowed (90 s) on both test trials, 6 because of fussiness, and 1 because the primary observer had difficulty following the direction of the infant's gaze.

The infants' names in this and in the following experiments were obtained from birth announcements in the 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 wooden display box 124 cm high, 102 cm wide, and 33.5 cm deep that was positioned 76 cm above the room floor. The infant faced an opening 56 cm high and 95 cm wide in the front of the apparatus. The side walls of the apparatus were painted white and the floor was covered with a brightly lined contact paper. The back wall was constructed of gray foamcore board and had an opening 5 cm high and 94 cm wide centered along its lower edge; this opening was filled with a gray fringe.

Four cardboard screens were used in the experiment. All of the screens were 30 cm high and 38 cm wide and were supported at the back by a metal frame. The screen used in the habituation event was windowless. The screen used in the high-window test event had a win-

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[3] The large proportion of eliminated subjects in this and in the following experiments is not uncommon with very young infants (e.g., Baillargeon & DeVos, 1991; Canfield & Haith, 1991; Haith & McCarty, 1990; Hespos & Baillargeon, 1999). Nevertheless, one factor that contributed to the high number of eliminated subjects—maximum 90-s looks on both test trials—deserves comment. In piloting the procedure to be used in the present research, we tested infants using trials with a maximum length of 120, 90, and 60 s. Our observations suggested that infants tested with 120-s trials tended not to complete the habituation phase of the experiment (mainly due to fussiness) and that infants tested with 60-s trials generally completed the habituation phase but often looked 60 s during both test trials. The infants tested with 90-s trials did best: for the most part, they tended to both complete the habituation phase and be below ceiling on one or both test trials.

dow 15 cm high and 18 cm wide centered in its upper half. Finally, each of the two screens used in the low-window test event had a window centered in its lower half; this window was either 15 cm high and 18 cm wide (small-low-window condition) or 26 cm high and 18 cm wide (large-low-window condition). Each screen was centered between the apparatus's side walls and stood 10 cm in front of the back wall. The habituation screen was dark purple with large yellow dots, and its edges were outlined with black tape. The test screens were bright green with small red dots, and their edges were outlined with red tape. It was hoped that these changes would help make salient to the infants the introduction of the test screens.

Two identical plastic toy mice (Minnie Mouse dolls) were used in the habituation and test events. The mice were 14 cm high, 5 cm thick, and 7 cm wide (at their widest points), and they stood 2.5 cm from the apparatus's back wall. Each mouse was dressed in a red cotton skirt that fell past her feet. The mice were mounted on hidden carriers 0.5 cm above the apparatus floor so that, as the mice moved, only their skirts brushed noiselessly against the floor.

Each mouse carrier consisted of a thin, ''L''-shaped metal rod. The vertical portion of the rod stood in front of the apparatus's back wall; the top of the rod was bent and was inserted in the back of the mouse's head. The horizontal portion of the rod lay 3.75 cm above the apparatus floor and protruded through the opening in the back wall; behind the wall, the rod was attached to a small Plexiglas base. Each carrier base rested against a Plexiglas rail on a Plexiglas track that ran parallel to the back wall. To ensure that the carrier bases slid smoothly and silently along the rail and track, each base's front and bottom surfaces were covered with felt.

An experimenter moved one carrier base along the left half of the track and the other carrier base along the right half of the track. To help the experimenter slide the carriers at an even pace, equally spaced marks were placed above the opening in the back wall of the apparatus. In addition, the experimenter listened through headphones to a metronome that beat once per second.

Two call bells were used to draw the infants' attention to the left and right ends of the mouse's trajectory across the apparatus. One bell stood behind each end of the track and was rung (by depressing the chime at the top of the bell) every time the carrier paused in front of it.

The infants were tested in a brightly lit room. Three 20-w fluorescent light bulbs were attached to the front and back walls of the apparatus to provide additional light. Two wooden frames, each 182.5 cm high and 71 cm wide and covered with blue cloth, stood at an angle on either side of the apparatus; these frames served to isolate the infants from the experimental room. At the end of each trial, a curtain consisting of a muslin-covered frame 60 cm high and 101 cm wide was lowered in front of the apparatus.

## *Events*

In the following text, the numbers in parentheses indicate the number of seconds taken to perform the actions described.

*Small-low-window condition. Habituation Event*. At the start of the trial, the windowless screen stood in front of the back wall. The mouse on the left carrier stood visible in the left corner of the apparatus, 2.5 cm from the side wall; the mouse on the right carrier stood behind the screen's right edge and was not visible to the infant. The experimenter rang the bell behind the left carrier once (1 s) and then slid the left carrier at the speed of about 15 cm/s until the mouse had moved 30 cm (2 s) and stood behind the left edge of the screen, hidden from the infants. After a 2-s pause, the experimenter slid the right carrier at the same speed of about 15 cm/s until the mouse had moved 30 cm (2 s) and stood in the right corner of the apparatus, 2.5 cm from the side wall. Together, the motions of the left and right mice created the impression of a single mouse traveling at a constant speed across the apparatus and disappearing from view while behind the screen. Next, the entire process was repeated in reverse. First, the experimenter rang the bell behind the right carrier once (1 s). The right mouse was then returned to its starting position behind the screen's right edge (2 s); after a 2-s pause, the left mouse was moved from behind the screen's left edge back to its initial position in the left corner of the apparatus (2 s). Each event cycle thus lasted approximately 14 s. Cycles were repeated until the computer signaled that the trial had ended (see below). When this occurred, a second experimenter lowered the curtain in front of the apparatus.

*High- and low-window test events*. The high- and low-window test events were identical to the habituation event except that the windowless screen was replaced by the high-window screen in the high-window event and by the small-low-window screen in the low-window event.

*Large-low-window condition.* The habituation and the high- and low-window test events shown in the large-low-window condition were identical to those in the small-low-window condition, except that the large-low-window screen was used in the low-window event.

## *Procedure*

Each infant sat on a parent's lap in front of the apparatus, facing the screen. The infant's head was approximately 60 cm from the screen and 70 cm from the back wall of the apparatus. Parents were instructed not to interact with their infant during the experiment; they were also asked to close their eyes during the test trials.

The infant's looking behavior was monitored by two observers who viewed the infant through peepholes in the cloth-covered frames on either side of the apparatus. The observers could not see the events from their viewpoints and they did not know the order in which the test events were presented. Each observer held a button box linked to a DELL microcomputer and depressed the button when the infant attended to the events. The looking times recorded by the primary observer were used to determine when a trial had ended (see below). At the end of each trial, the observers rated on a coding sheet (1) the state of the infant (drowsy, quiet and alert, active, fussy, or crying) during the trial; (2) the infant's tracking behavior (i.e., whether the infant looked at least once to the left, center, and right portions of the mouse's path) during the trial; and (3) the visibility (high, medium, or low) of the infant's looking behavior during the trial.

The infants were tested using a two-phase procedure consisting of a habituation and a test phase. During the *habituation* phase, the infants in each condition saw the habituation event described above on successive trials. Each trial ended when the infant either (1) looked away from the event for 2 consecutive s after having looked at it for at least 7 cumulative s or (2) looked at the event for 90 consecutive s without looking away for 2 consecutive s. Habituation trials continued until the infant either (1) satisfied a habituation criterion 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, or (2) completed nine habituation trials. Therefore, the minimum number of habituation trials an infant could receive was six, and the maximum number was nine. Of the 24 infants in the experiment, 12 (6 in the small-low-window and 6 in the large-low-window condition) failed to satisfy the habituation criterion within 9 trials; the remaining 12 infants took an average of 6.9 trials (6.5 in the small-low-window and 7.3 in the large-low-window condition) to reach the criterion. Analyses revealed that the infants in the small- and large-low-window conditions did not differ significantly in: (1) the number of habituation trials they received, $F(1, 22) = 0.57$ (small-low-window, $M = 7.8$, $SD = 1.4$; large-low-window, $M = 8.2$, $SD = 1.3$); (2) their mean looking times during the first six habituation trials, $F(1, 22) = 2.89$, $p > .05$ (small-low-window, $M = 60.0$, $SD = 22.8$; large-low-window, $M = 74.5$, $SD = 18.7$); or (3) their mean looking times during the last six habituation trials, $F(1, 22) = 0.20$ (small-low-window, $M = 61.1$, $SD = 23.2$; large-low-window, $M = 65.0$, $SD = 19.7$).

During the *test* phase, the infants in each condition saw the high- and low-window test events appropriate for their condition on alternate trials. Half of the infants saw the high-window event on the first trial, and half saw the low-window event on the first trial. The criteria used to determine the end of each test trial were the same as for the habituation trials with one exception. As in our previous mouse experiment with 3-month-old infants (Aguiar & Baillargeon, 1999), the minimum value for the infants' looking time at each test event was increased from 7 to 9 s; these additional seconds gave the infants a greater opportunity to notice the mouse's reappearance to the right of the screen.

To measure interobserver agreement during the two test trials, each trial was divided into 100-ms intervals, and the computer determined in each interval whether the two observers agreed on the direction of the infant's gaze. Agreement was calculated for each trial on the basis of the number of intervals in which the computer registered agreement out of the total number of intervals in the trial. Agreement averaged 91% per test trial per infant.

In addition to measuring interobserver agreement throughout each test trial, we also examined how well the observers agreed on the ending of the trials. In the experiment, data were obtained from 48 test trials (24 infants × 2 trials per infant). Based on the primary observer's responses, 9 of the trials ended because the infant looked at the event for the maximum amount of time allowed (90 s), and 39 trials ended because the infant looked away from the event for 2 consecutive s. For each of the 90-s trials, the computer calculated the looking time registered by the secondary observer; the average looking time obtained across trials was 86.8 s. For each trial that ended with a 2-s look away, the computer inspected the 20 100-ms intervals corresponding to these 2 s to ascertain (1) whether the secondary observer agreed that the infant was looking away from the event in the final interval and, if yes, (2) for how many consecutive intervals prior to and including the final interval the secondary observer agreed that the infant was looking away. The secondary observer agreed that the infant was looking away during the final interval on 35 of the 39 trials; the average look away recorded by the secondary observer at the end of these trials was 1.9 s. The 4 trials with a disagreement in the final interval were retained in the analyses because on each trial the primary observer (who was typically the more experienced observer) reported high or medium visibility for the infant's looking behavior; infants were eliminated (in this and in the following experiments) if they had test trials with a final-interval disagreement and the primary observer reported only low visibility on those trials.

Preliminary analyses revealed no significant interaction between order and event, $F(1, 16) = 0.37$, or between sex and event, $F(1, 16) = 0.25$. The data were therefore collapsed across order and sex in subsequent analyses.

## Results

The infants' looking times at the low- and high-window test events were analyzed by means of a 2 × 2 mixed-model analysis of variance (ANOVA) with condition (small- or large-low-window) as a between-subjects factor and with event (low- or high-window) as a within-subject factor. The main effect of event was not significant, $F(1, 22) = 0.07$ (low-window; $M = 42.5$, $SD = 30.4$; high-window; $M = 44.6$, $SD = 31.0$). The condition x event interaction was also not significant, $F(1, 22) = 0.02$, suggesting that the infants in both the small-low-window condition (low-window, $M = 38.2$, $SD = 27.4$; high-window, $M = 41.5$, $SD = 31.0$) and the large-low-window condition (low-window, $M = 46.9$, $SD = 33.7$; high-window, $M = 47.8$, $SD = 32.1$) tended to look equally at the two test events.

Inspection of the individual infants' looking times (see Fig. 3) yielded similar results: only 5 of the 12 infants in the small-low-window condition, Wilcoxon $T = 39$, $p > .05$, and 4 of the 12 infants in the large-low-window

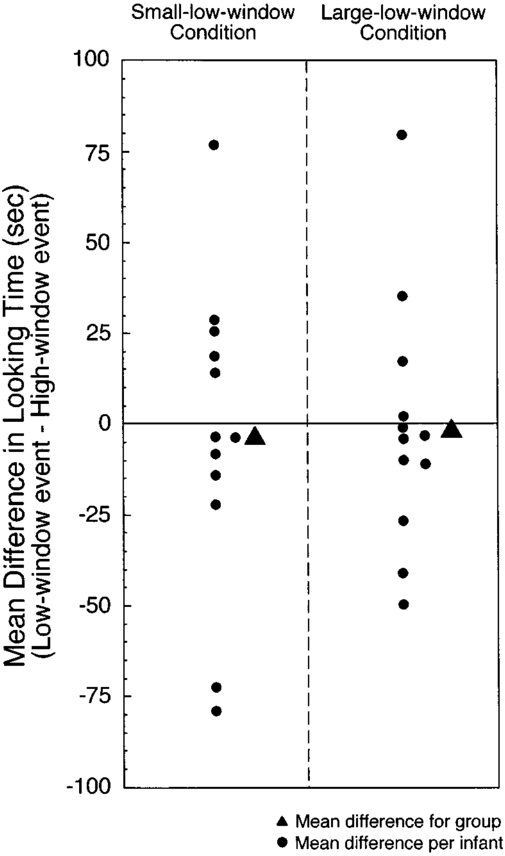

**FIG. 3.** Difference in the mean looking times of the infants in Experiment 1 at the low- and the high-window test events. Each dot represents an individual infant.

condition, Wilcoxon $T = 30$, $p > .05$, looked longer at the low- than at the high-window event.

## Discussion

Unlike the 3-month-old infants in our initial mouse experiment (Aguiar & Baillargeon, 1999), the 2.5-month-old infants in the small-low-window condition in Experiment 1 did not look reliably longer at the low- than at the high-window test event. Furthermore, the same negative result was obtained in the large-low-window condition, in which the low window was enlarged to make it more noticeable.

At least two explanations were possible for the negative findings of Experiment 1. A first explanation was that the infants (1) did not believe that the mouse continued to exist after it moved behind the screen and/or (2) failed to realize that the mouse could not disappear at one edge of the screen and reappear at the other edge without traveling continuously between them. This explanation seemed unlikely, however, given the positive results reported by Spelke et al. (1992) and Wilcox et al. (1996). These authors obtained evidence that 2.5-month-old infants (1) believe that objects continue to exist when occluded and (2) recognize that occluded objects, like visible objects, cannot move from one location to another without traveling continuously between them.

A second explanation for the negative findings of Experiment 1 was that the infants did believe that the mouse continued to exist and pursued its trajectory behind the screen, but lacked the knowledge necessary to realize that the mouse should appear in the low window. It could be that at 2.5 months of age infants' knowledge of the conditions under which objects should and should not be occluded is still extremely limited. In terms of our model of infants' acquisition of physical knowledge (e.g., Baillargeon, 1995, 1998, 1999; Baillargeon et al., 1995), infants would possess only an initial concept centered on a *behind/not-behind* distinction: they would expect objects to be hidden when behind other objects and to be visible otherwise. At this stage, infants would not have yet learned that the presence and location of openings in occluders can affect whether objects remain hidden or become temporarily visible when passing behind the occluders. Infants would expect any object to be hidden when behind any occluder, regardless of whether the latter presented an opening.

Experiment 2 was designed to test this last explanation. The infants saw the same habituation and test events as in Experiment 1, except that the low-window test event was modified. A portion of the screen above the window was removed so that the left and right sections of the screen now formed two separate screens (see Fig. 4). The low-window screen used in the small-low-window condition of Experiment 1 was modified to create two asymmetrical screens (asymmetrical-screens condition), and the low-window screen used in the large-low-window condition was modified to create two symmetrical screens (symmetrical-screens condition). In the two-screens event shown in each condition, the mouse disappeared behind the left edge of the left screen and reappeared from behind the right edge of the right screen *without* appearing in the gap between the screens. As in Experiment 1, the mouse's visible trajectory was thus identical in the habituation and the two test events.

Our reasoning was as follows. If the infants in Experiment 1 looked about equally at the low- and high-window test events because they possessed only a simple expectation that the mouse should be hidden when behind a screen and should be visible otherwise, then the infants in the asymmetrical- and symmetrical-screens conditions in Experiment 2 should expect the mouse (1) to be hidden when *behind* the screen in the high-window event and when

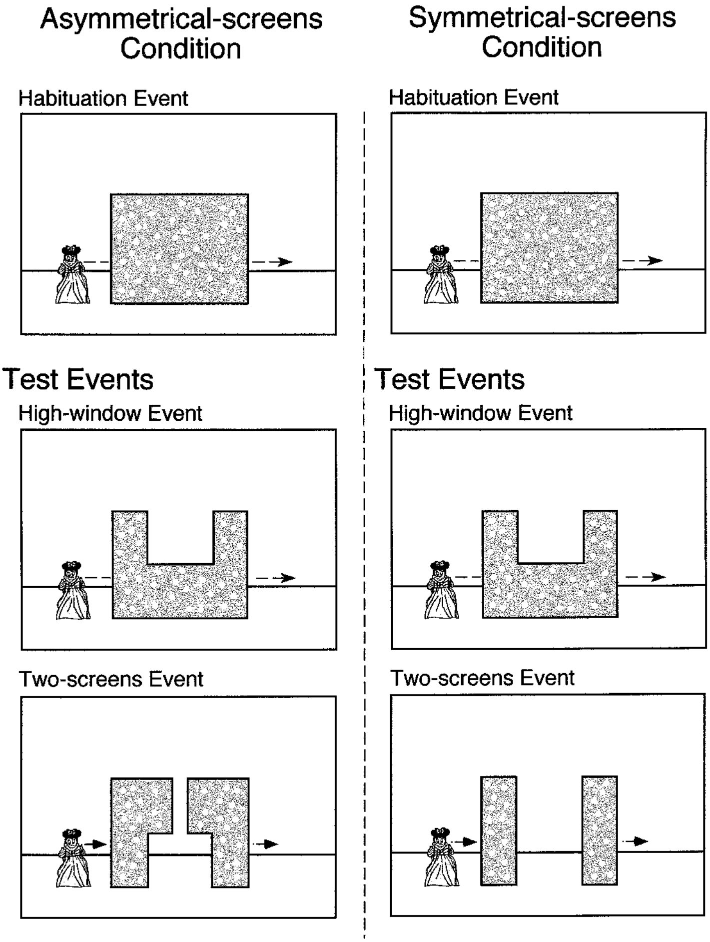

**FIG. 4.** Schematic drawing of the habituation and test events in the asymmetrical- and symmetrical-screens conditions of Experiment 2.

*behind* each screen in the two-screens event and (2) to be visible when *between* the screens in the two-screens event. The infants should be surprised when this last expectation was violated, and they should therefore look reliably longer at the two-screens than at the high-window event.

## EXPERIMENT 2

### Method

### *Participants*

Participants were 24 health term infants, 12 male and 12 female, ranging in age from 76 to 90 days ($M = 84.4$ days). Twelve infants, 6 male and 6 female (range = 76 to 88 days, $M$

= 82.8 days), were randomly assigned to the asymmetrical-screens condition, and 12 infants, 6 male and 6 female (range = 78 to 90 days, *M* = 85.8 days), to the symmetrical-screens condition. An additional 20 infants were tested but eliminated; they failed to contribute two valid test trials, 9 because they looked for 90 s on both trials, 6 because of fussiness, 3 because of drowsiness, and 2 because they failed to track the mouse along its entire trajectory in at least one of the habituation trials.

## *Apparatus*

The apparatus used in Experiment 2 was identical to that in Experiment 1 with two exceptions. First, a gap 6 cm wide and 15 cm high, centered above the window, was created in the low-window screen used in the small-low-window condition. This gap resulted in two screens, each in the shape of an inverted ‘‘L,’’ and located 6 cm apart at their closest point. Second, the screen strip 18 cm wide and 4 cm high that connected the left and right sections of the low-window screen used in the large-low-window condition was removed, resulting in two rectangular screens located 18 cm apart.

## *Events*

The habituation and high-window test events shown in Experiment 2 were identical to those in Experiment 1. The two-screens test event shown in Experiment 2 was similar to the low-window test event in Experiment 1, except that the low-window screen was replaced with the two inverted-L screens (asymmetrical-screens condition) or the two rectangular screens (symmetrical-screens condition).

## *Procedure*

The procedure used in Experiment 2 was identical to that in Experiment 1. Of the 24 infants in the experiment, 14 (6 in the asymmetrical-screens condition and 8 in the symmetrical-screens condition) failed to satisfy the habituation criterion within 9 trials; the remaining 10 infants took an average of 6.5 trials to reach the criterion (the average was 6.5 trials in each of the two conditions). Analyses revealed that the infants in the asymmetrical- and symmetrical-screens conditions did not differ significantly in: (1) the number of habituation trials they received, *F*(1, 22) = 0.57 (asymmetrical-screens, *M* = 7.8, *SD* = 1.4; symmetrical-screens, *M* = 8.2, *SD* = 1.3); (2) their mean looking times during the first six habituation trials, *F*(1, 22) = 0.21 (asymmetrical-screens, *M* = 68.4, *SD* = 22.8; symmetrical-screens, *M* = 64.5, *SD* = 19.1); or (3) their mean looking times during the last six habituation trials, *F*(1, 22) = 0.09 (asymmetrical-screens, *M* = 65.8, *SD* = 22.6; symmetrical-screens, *M* = 63.3, *SD* = 18.5).

Interobserver agreement during the two test trials averaged 90% per test trial per infant. Based on the primary observer’s responses, 9 of the 48 test trials (24 infants x 2 test trials) ended because the infant had looked at the event for 90 s; the remaining 39 trials ended because the infant looked away from the event for 2 s. The average looking time recorded by the secondary observer on the 90-s trials was 86.8 s. The secondary observer agreed that the infant was not looking at the end of 34 of the 40 trials that ended with a 2-s look away; the average look away registered by the secondary observer at the end of these trials was 1.9 s.

Preliminary analyses revealed no significant interaction between order and event, *F*(1, 16) = 0.10, or between sex and event, *F*(1, 16) = 0.20. The data were therefore collapsed across order and sex in subsequent analyses.

# Results

The infants’ looking times at the two-screens and high-window test events were analyzed by means of a 2 × 2 mixed-model ANOVA, with condition (asymmetrical- or symmetrical-screens) as a between-subjects factor and with event (two-screens or high-window) as a within-subject factor. The analysis revealed a significant main effect of event, $F(1, 22) = 23.00$, $p < .0001$, indicating that the infants looked reliably longer overall at the two-screens ($M = 58.6$, $SD = 29.7$) than at the high-window ($M = 29.4$, $SD = 19.9$) event. Planned comparisons indicated that this pattern obtained in both the asymmetrical-screens condition, $F(1, 22) = 11.47$, $p < .005$ (two-screens, $M = 61.6$, $SD = 31.1$; high-window, $M = 32.4$, $SD = 24.2$), and the symmetrical-screens condition; $F(1, 22) = 11.52$, $p < .005$ (two-screens, $M = 55.6$, $SD = 29.4$; high-window, $M = 26.4$, $SD = 14.9$). No other effect was significant.

Examination of the individual infants' mean looking times (see Fig. 5)

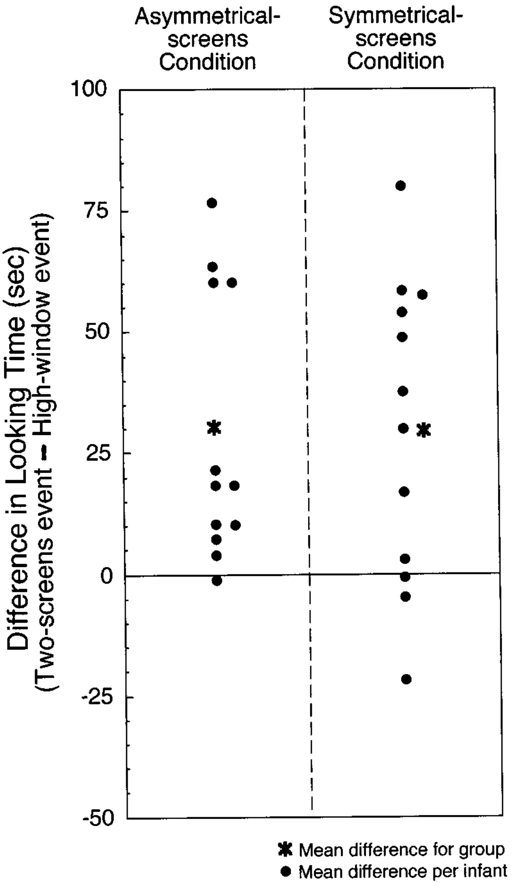

**FIG. 5.** Difference in the mean looking times of the infants in Experiment 2 at the two-screens and the high-window test events. Each dot represents an individual infant.

yielded similar findings: 11 of the 12 infants in the asymmetrical-screens condition, Wilcoxon $T = 77$, $p = .001$, and 9 of the 12 infants in the symmetrical-screens condition, Wilcoxon $T = 69$, $p < .025$, looked longer at the two-screens than at the high-window event.

## Discussion

The infants in both the asymmetrical- and the symmetrical-screens conditions of Experiment 2 looked reliably longer at the two-screens than at the high-window test event. These results suggest that, when shown the two-screens event, the infants (1) believed that the mouse continued to exist after it disappeared behind each screen; (2) realized that the mouse could not disappear behind one screen and reappear from behind the other screen without traveling the distance between them; (3) expected the mouse to appear between the two screens; and hence (4) were surprised when this expectation was violated.

Why did the infants in Experiments 1 and 2 expect the mouse to become visible between the two asymmetrical or symmetrical screens, but not in the small or large low window? These results are especially striking when one considers two factors. First, the differences between these various test screens were rather small: recall, for example, that the only difference between the symmetrical screens and the large-low-window screen was that the narrow strip above the window was removed. Second, the differences between these test screens all involved portions of the screens located *above* the mouse's path, which meant that they could have no effect on the mouse's visible trajectory: that is, the mouse should have been visible in full and for the same length of time when passing between the asymmetrical or symmetrical screens or behind the small or large low window. Hence, why should the changes in the test screens have elicited a reliably different looking pattern from the infants?

The most likely answer, we believe, has to do with the infants' knowledge of the conditions under which objects should and should not be occluded. The results of Experiments 1 and 2 suggest that 2.5-month-old infants possess only an initial concept centered on a behind/not behind distinction: they expect objects to be hidden when behind other objects and to be visible otherwise. At this stage, infants do not take into account the presence and location of openings in occluders when judging whether objects should be hidden or visible: objects are expected to be hidden as long as they are *behind* occluders, whether or not these present openings.

According to this explanation, the infants in the present research did not expect the mouse to become visible when passing behind the screen with the high window, the small low window, or the large low window, because in each case the screen constituted a single occluder and the infants' initial concept suggested that the mouse would be hidden when behind this occluder. In contrast, the infants expected the mouse to become visible when passing between the two asymmetrical or symmetrical screens because these constituted distinct occluders; the infants' initial concept of when objects should be occluded, coupled with their beliefs that occluded objects exist and move continuously (e.g., Spelke et al., 1992; Wilcox et al., 1996), dictated that the mouse would be hidden when behind each screen but would be visible when between the screens.

There was, however, an alternative interpretation for the results of Experiments 1 and 2. One might propose that the infants looked longer at the events involving the two asymmetrical and symmetrical screens than at the events involving the high-window, small-low-window, and large-low-window screens, simply because they preferred seeing *two* screens rather than *one* screen. Because there is evidence that infants sometimes exhibit baseline preferences for displays containing two as opposed to one object (e.g., Simon et al., 1995; Wynn, 1992; Xu & Carey, 1996), it was important to test this alternative interpretation. Experiment 3 was designed to do so.

Experiment 3 used a procedure similar to that of the control condition in our initial mouse experiment with 3-month-old infants (Aguiar & Baillargeon, 1999). Recall that in that condition the screen was lowered at the start of each trial to reveal two identical mice. The infants in Experiment 3 were assigned to an asymmetrical- or a symmetrical-screens condition and were shown the same habituation and test events as in Experiment 2 with one exception: at the start of each trial, the screen (habituation and high-window test event) or screens (two-screens test event) were lowered to reveal two mice (see Fig. 6). After a few seconds, the screen or screens were rotated upward, the left mouse was moved to the left end of the track, and the trial proceeded exactly as before.

Our reasoning was as follows. If the infants in Experiment 2 preferred the two-screens over the high-window test event simply because they preferred seeing two screens rather than one, then the infants in Experiment 3 should also prefer the two-screens test event. On the other hand, if the infants in Experiment 2 looked reliably longer at the two-screens test event because they were surprised that the mouse did not appear between the screens, then a different looking pattern might obtain in Experiment 3. If the infants were able to use the information that two mice were present in the apparatus to make sense of the two-screens test event, then they should look about equally at this event and at the high-window test event.

There was, however, one potential difficulty with the design of Experiment 3. The infants might look equally at the two-screens and high-window test events, not because they realized how the two-screens event was produced, but because they were confused by the rotation of the screen or screens at the start of each trial (e.g., Bogartz, Shinskey, & Speaker, 1997). The rotation made each trial more complex; it was plausible that this added complexity could prove too taxing for the limited processing resources of 2.5-month-

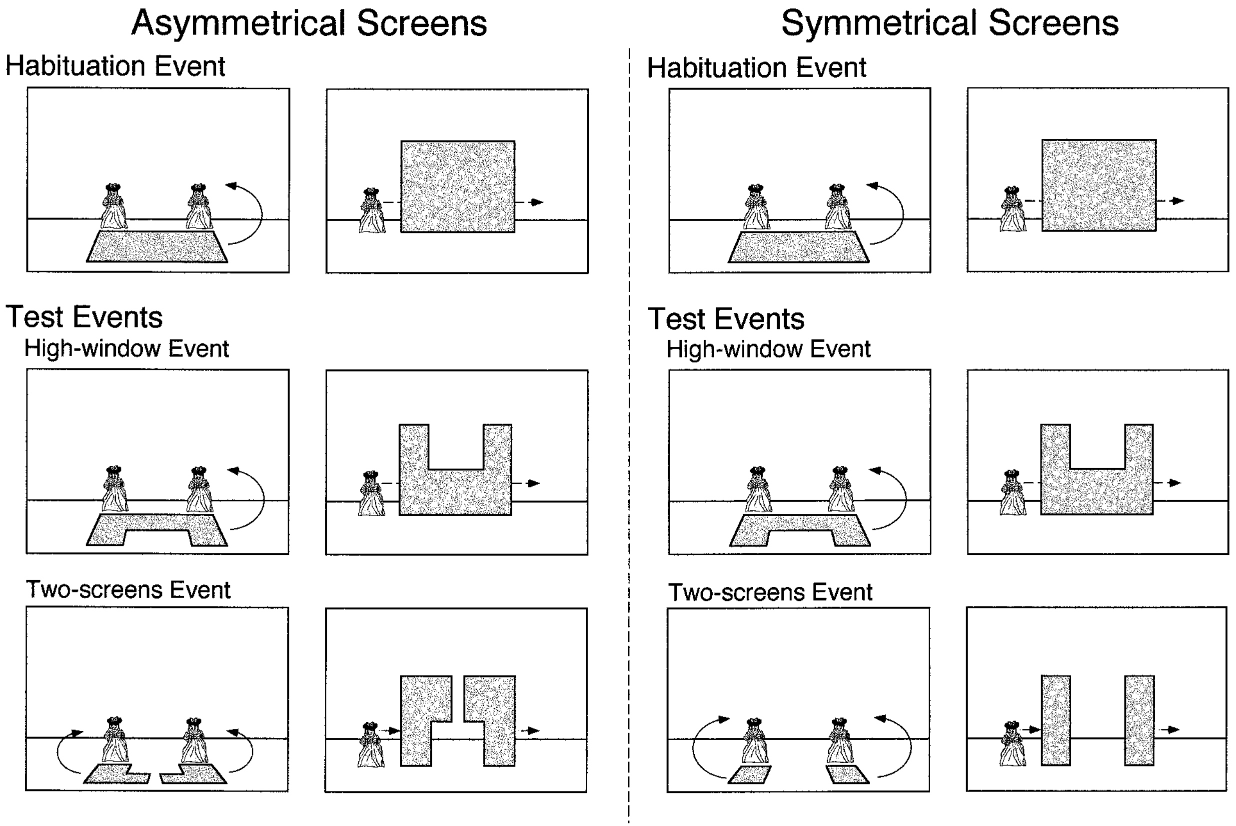

**FIG. 6.** Schematic drawing of the habituation and test events in the two-mice condition of Experiment 3.

old infants. To control for this possibility, a second group of infants were tested in Experiment 3 (one-mouse condition). These infants saw the same habituation and test events as the infants in the two-mice condition, except that only one mouse was revealed at the start of each trial (see Fig. 7). Evidence that the infants in the one-mouse condition looked reliably longer at the two-screens than at the high-window test event would serve two purposes. First, it would render less plausible the notion that 2.5-month-old infants could be overwhelmed by habituation and test trials involving an initial rotation. Second, it would serve to confirm the positive findings of Experiment 2.

## EXPERIMENT 3

### Method

### *Participants*

Participants were 32 healthy term infants, 16 male and 16 female, ranging in age from 79 to 90 days, $M = 84.6$ days). Eight infants, 4 male and 4 female, were assigned to each of the four conditions formed by crossing the two mice conditions (two-mice or one-mouse) and the two screens conditions (asymmetrical or symmetrical screens): two-mice/asymmetrical-screens condition (range = 80 to 89 days, $M = 85.6$ days), two-mice/symmetrical-screens condition (range = 81 to 89 days, $M = 85.3$ days), one-mouse/asymmetrical-screens condition (range = 81 to 89 days, $M = 83.6$ days), and one-mouse/symmetrical-screens condition (range = 79 to 90 days, $M = 84.0$ days). An additional 42 infants were tested but eliminated; they failed to contribute two valid test trials, 19 because they looked for 90 s on both trials, 15 because of fussiness, 5 because the primary observer had difficulty following the direction of the infant's gaze, 2 because of drowsiness, and 1 because the infant failed to track the mouse along its entire trajectory in at least one of the habituation trials.

### *Apparatus*

The apparatus used in Experiment 3 was identical to that in Experiment 2 with two exceptions. First, the screens in the habituation and test events were mounted on a wooden dowel 120 cm long and 1.25 cm in diameter that lay on the apparatus floor, 10 cm in front of the back wall. The dowel protruded through small holes in each side wall; by rotating a metal knob attached to the dowel's right end, an experimenter could rotate the screen 90° upward. Second, a door 12 cm high and 8 cm wide was cut in the back wall of the apparatus; this door was hidden by the screen's right end in the habituation and high-window test events and by the right screen in the two-screens test event.

### *Events*

The habituation and test events shown in Experiment 3 were identical to those in Experiment 2 except that a brief pretrial preceded each trial. The pretrial event shown in the two-mice and one-mouse conditions are described below. Two experimenters were needed to produce the two-mice pretrial and three to produce the one-mouse pretrial.

*Two-mice condition.* At the start of each pretrial, the screen or screens to be used in the trial lay flat on the apparatus floor, toward the infant. Two mice stood visible, behind the left and right ends of the screen (habituation and high-window test events) or behind the left and

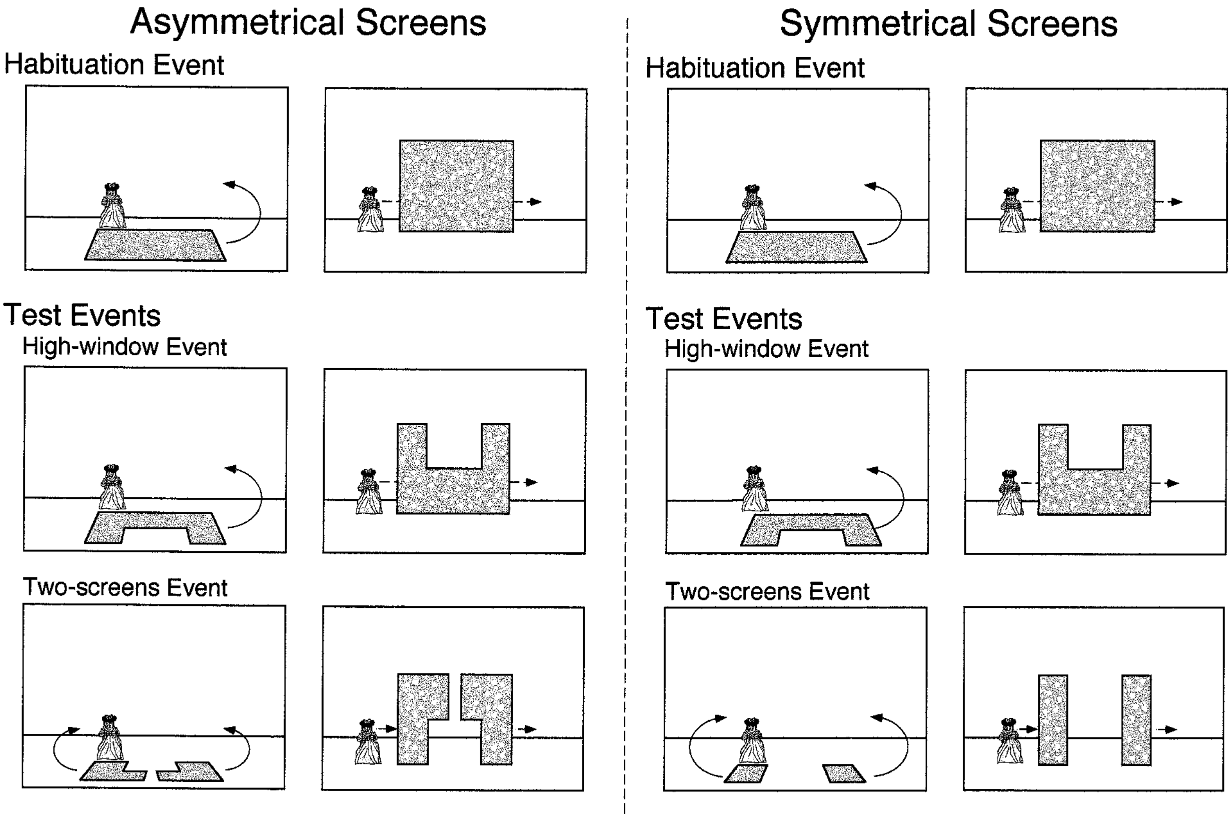

**FIG. 7.** Schematic drawing of the habituation and test events in the one-mouse condition of Experiment 3.

right screens (two-screens test event). The first experimenter rang the right bell once per second until the computer signaled that the infant had looked at the area behind the screen or screens for 3 cumulative s (this was done to help the infants notice that two mice were present in the apparatus). Next, the second experimenter rotated the screen or screens 90° upward (2 s). After a 1-s pause, the first experimenter slid the left mouse to its starting position in the left corner of the apparatus (2 s). After another 1-s pause, the trial proceeded exactly as in Experiments 1 and 2.

*One-mouse condition.* The pretrial event shown in the one-mouse condition was identical to that in the two-mice condition with two exceptions. First, only the left mouse was present. Second, while the first experimenter slid the left mouse to its starting position, the third experimenter surreptitiously inserted the second mouse into the apparatus and placed it behind the right end of the screen (habituation and high-window test events) or behind the right screen (two-screens test event).

### *Procedure*

The procedure in Experiment 3 was identical to that in Experiments 1 and 2. Of the 32 infants in the experiment, 15 (6 in the two-mice condition and 9 in the one-mouse condition) failed to satisfy the habituation criterion within 9 trials; the remaining 17 infants took an average of 6.8 trials (6.9 in the two-mice condition and 6.6 in the one-mouse condition) to reach the criterion. Analyses revealed that the infants in the two-mice and one-mouse conditions did not differ significantly in: (1) the number of habituation trials they received, $F(1, 28) = 0.25$ (two-mice, $M = 7.7$, $SD = 1.4$; one-mouse, $M = 7.9$, $SD = 1.4$); (2) their mean looking times during the first six habituation trials, $F(1, 28) = 0.00$, (two-mice, $M = 61.8$, $SD = 17.9$; one-mouse, $M = 62.0$, $SD = 19.7$); or (3) their mean looking time during the last six habituation trials, $F(1, 28) = 0.75$ (two-mice, $M = 54.2$, $SD = 14.5$; one-mouse, $M = 59.7$, $SD = 20.5$).

Interobserver agreement during the test trials averaged 93% per test trial per infant. Based on the primary observer's responses, 13 of the 64 test trials (32 infants × 2 test trials) ended because the infant had looked at the event for 90 s; the remaining 51 trials ended because the infant looked away from the event for 2 s. The average looking time recorded by the secondary observer on the 90-s trials was 88.4 s. The secondary observer agreed that the infant was not looking at the end of 48 of the 51 trials that ended with a 2-s look away; the average look away registered by the secondary observer at the end of these trials was 1.8 s.

Preliminary analyses revealed no significant interaction among order, mice condition, and event, $F(1, 16) = 0.29$, or among sex, mice condition, and event $F(1, 16) = 0.41$. The data were therefore collapsed across order and sex in subsequent analyses.

## Results

The infants' looking times at the two-screens and high-window test events were analyzed by means of a 2 × 2 × 2 mixed-model ANOVA, with mice condition (two-mice or one-mouse) and screens condition (asymmetrical-screens or symmetrical-screens) as between-subjects factors and with event (two-screens or high-window) as a within-subject factor. The analysis revealed a significant main effect of event, $F(1, 28) = 4.24$, $p < .05$, and a significant mice condition x event interaction, $F(1, 28) = 4.67$, $p < .05$. Planned comparisons indicated that the infants in the one-mouse condition looked significantly longer at the two-screens ($M = 60.0$, $SD = 30.2$) than at the high-window ($M = 32.5$, $SD = 22.8$) event, $F(1, 28) = 8.91$, $p < .01$, whereas the infants in the two-mice condition tended to look equally at

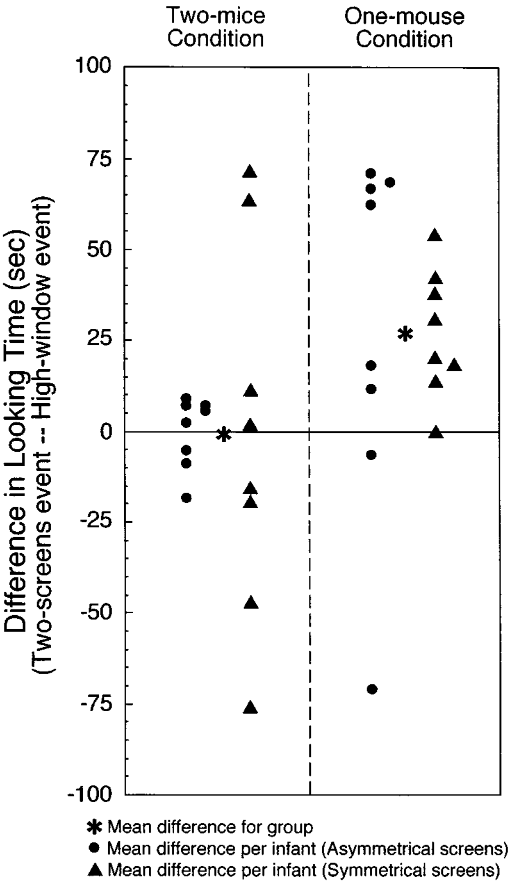

**FIG. 8.** Difference in the mean looking times of the infants in Experiment 3 at the two-screens and high-window test events. Each dot represents an individual infant.

the events, *F*(1, 28) = 0.01 (two-screens, *M* = 46.2, *SD* = 29.7; high-window, *M* = 46.9, *SD* = 29.8). No other effect was significant.

Examination of the individual infants' mean looking times (see Fig. 8) yielded similar findings: whereas 13 of the 16 infants in the one-mouse condition looked longer at the two-screens than at the high-window event, Wilcoxon $T = 104$, $p = .01$, only 9 of the 16 infants in the two-mice condition did so, Wilcoxon $T = 63$, $p > .05$.

In addition to the preceding analyses, four more comparisons were performed to determine whether the same looking patterns would obtain in each of the two mice conditions when the responses of the infants in the two screens conditions were examined separately. The results of these analyses were identical to those of the overall analyses. In the one-mouse condition, the infants who saw the asymmetrical screens looked reliably longer at the two-screens ($M = 67.6$, $SD = 27.4$) than at the high-window ($M = 40.0$, $SD = 26.0$) event, $F(1, 28) = 4.50$, $p < .05$, as did the infants who saw the symmetrical screens, $F(1, 28) = 4.42$, $p < .05$ (two-screens, $M = 52.3$, $SD = 32.7$; high-window, $M = 24.9$, $SD = 17.4$). Similarly, in the two-mice condition, the infants who saw the asymmetrical screens tended to look equally at the two-screens ($M = 44.1$, $SD = 32.6$) and the high-window ($M = 44.4$, $SD = 31.7$) events, $F(1, 28) = 0.00$, as did the infants who were presented with the symmetrical screens, $F(1, 28) = 0.01$ (two-screens, $M = 48.4$, $SD = 28.4$; high-window, $M = 49.4$, $SD = 29.6$). In both Experiments 2 and 3, the infants thus responded in the same manner whether they were shown asymmetrical or symmetrical screens in the two-screens test event.

## Discussion

The infants in the one-mouse condition in Experiment 3 looked reliably longer at the two-screens than at the high-window event. These results suggest that, upon seeing the two-screens event, the infants (1) believed that the mouse continued to exist after it disappeared behind each screen; (2) realized that the mouse could not disappear behind one screen and reappear from behind the other screen without traveling the distance between them; (3) expected the mouse to appear between the two screens; and hence (4) were surprised when this expectation was violated.

These results suggest three conclusions. First, they confirm the findings obtained in Experiment 2 and, as such, provide further evidence that, at 2.5 months of age, infants expect an object to become visible when passing between occluders. The present data also make the point that 2.5-month-old infants who see an object move back and forth behind a screen or screens assume that a single object is present, whether or not they are first given unambiguous spatiotemporal information specifying the presence of a single object. Unlike the infants in Experiment 3, those in Experiment 2 were never shown that a single mouse was present in the apparatus, yet both groups of infants responded in the same manner (see Wilcox & Baillargeon, 1998a, 1998b). Finally, the results of the one-mouse condition make clear that 2.5-month-old infants are not overwhelmed by habituation and test events that involve an initial screen rotation; this last point bears on the interpretation of the results of the two-mice condition.

In contrast to the infants in the one-mouse condition, those in the two-mice condition tended to look equally at the two-screens and high-window test events. These results suggest that, like the control 3-month-old infants in our initial mouse experiment (Aguiar & Baillargeon, 1999), the 2.5-month-old infants in the present experiment (1) remembered that two identical mice were present in the apparatus after the screen or screens were rotated upward at the end of each pretrial and (2) used this information to make sense of the two-screens test event: they realized that no mouse appeared between the screens because the left mouse traveled along the left side of the track and the right mouse along the right side of the track.

The results of the two-mice condition provide evidence against the notion that the infants in Experiment 2 and in the one-mouse condition in Experiment 3 looked reliably longer at the two-screens than at the high-window test event because they preferred seeing two screens as opposed to one screen. The infants in the two-mice condition did not look reliably longer at the two-screens event, whether it involved two asymmetrical or symmetrical screens. These results support the hypothesis that the infants in Experiment 2 and in the one-mouse condition in Experiment 3 looked reliably longer at the two-screens event because they were surprised that the mouse did not appear between the screens (and were not able to spontaneously generate a two-mice explanation for this event).

## OVERALL ANALYSES OF EXPERIMENTS 1 TO 3

In the preceding analyses, we examined the results of each experiment separately and asked in each case whether the infants tended to look equally at the two test events they were shown or reliably preferred one event over the other. In a final series of analyses, we compared the infants' responses *across* all three experiments. For the purposes of these analyses, the infants in Experiment 1 and in the two-mouse condition of Experiment 3, who tended to look equally at two test events they were shown, were grouped into one condition (no-preference condition; $n = 40$), and the infants in Experiment 2 and in the one-mouse condition of Experiment 3, who reliably preferred the two-screens over the high-window test event they were shown, were grouped into another condition (preference condition; $n = 40$). Two separate sets of analyses were conducted; the first focused on the infants' responses during the two test trials alone, and the second on the infants' responses during the last four habituation trials and two test trials (see Fig. 9).

### Test Data

The infants' test responses were compared by means of a 2 x 2 mixed-model ANOVA, with condition (preference or no-preference) as a between-subjects factor and with event (high-window or low-window/two-screens) as a within-subject factor. Planned comparisons confirmed that the infants in the preference condition looked reliably longer at the two-screens ($M = 59.2$, $SD = 29.5$) than at the high-window ($M = 30.6$, $SD = 20.9$) event, $F(1, 78) = 27.98$, $p < .0001$, whereas the infants in the no-preference condition looked about equally at the low-window/two-screens ($M = 44.0$, $SD$

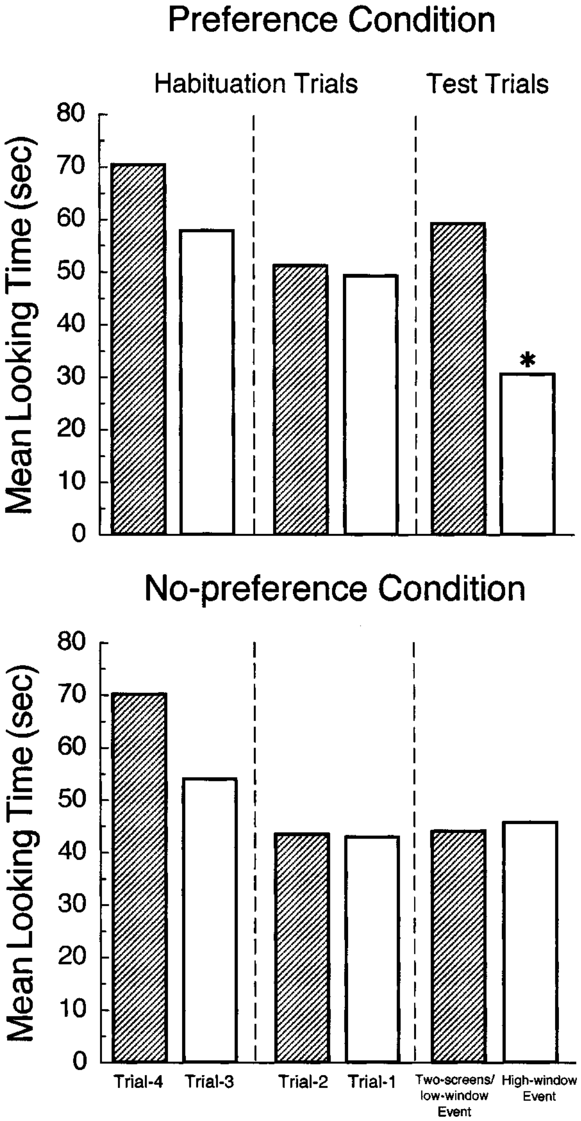

**FIG. 9.** Looking times at the habituation and test trials of the infants in the preference and no-preference conditions.

= 29.8) and the high-window ($M = 45.5$, $SD = 30.2$) events, $F(1, 78) = 0.08$.[4]

In addition to examining the infants' test responses *within* each condition, we compared these responses *across* the two conditions. Planned comparisons revealed that the mean looking times of the no-preference infants at their two test events (1) were reliably shorter than the mean looking time of the preference infants at the two-screens event, $F(1, 78) = 9.48$, $p < .005$, and (2) were reliably longer than the mean looking time of the preference infants at the high-window event, $F(1, 78) = 9.17$, $p < .005$.

Why were the no-preference infants' test looking times midway between and significantly different from the preference infants' looking times at the two-screens and high-window test events? The most likely answer, we believe, lies in the nature of the novel elements introduced during the test trials in each condition. Both the preference and the no-preference infants saw novel screens during the test trials that differed from the habituation screen in shape, pattern, and color. However, only the preference infants saw a test event—the two-screens event—that was inconsistent with their physical knowledge. Together, these points suggest the following analysis. The no-preference infants, who saw only events consistent with their physical knowledge, tended to focus on the test screens' novel appearance. In contrast, the preference infants, who were shown an event that violated their physical knowledge, tended to focus on the mouse's displacement and to largely ignore the relative perceptual novelty of the test screens (recall that the preference infants looked at the high-window event reliably less than the no-preference infants looked at their two test events, one of which was in fact the same high-window event).

## Habituation and Test Data

Our second series of analyses compared the looking times of the preference and no-preference infants during the last four habituation trials and two test trials. These six trials were organized into three blocks of two trials; the first block contained the fourth and third to last habituation trials; the second block contained the second to last and last habituation trials; and the third block contained the two test trials (high-window followed by low-window/two-screens or the reverse, depending on the infants' order condition).

The infants' looking times were compared by means of a 2 × 2 × 3 ×

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[4] To compare the test responses of the preference and no-preference infants who satisfied the habituation criterion in six to nine trials ($n = 39$) and who did not ($n = 41$), this analysis was repeated with habituation status (habituated versus not-habituated) as an additional between-subjects factor. Planned comparisons revealed that the preference and no-preference infants who were *habituated* differed reliably in their responses to the high-window and low-window/two-screens events, $F(1, 76) = 4.68$, $p < .05$, as did the preference and no-preference infants who were *not habituated*, $F(1, 76) = 9.50$, $p < .005$.

2 mixed-model ANOVA, with condition (preference or no-preference) and order (high-window or low-window/two-screens first) as between-subjects factors and with block (first, second, or third block of trials) and trial (first or second trial in each block) as within-subject factors. Two sets of planned comparisons were performed. The first compared the looking times of the infants in each condition during the first and second blocks of trials. The preference infants showed a reliable decline in looking time between the first ($M = 64.1$, $SD = 32.8$) and second ($M = 50.1$, $SD = 34.8$) blocks of trials, $F(1, 152) = 7.19$, $p < .01$. The no-preference infants produced the same pattern: there was again a reliable decline in looking time between the first ($M = 62.0$, $SD = 31.8$) and second ($M = 43.1$, $SD = 31.8$) blocks of trials, $F(1, 152) = 12.87$, $p < .0005$.

The second set of planned comparisons focused on the looking times of the infants in each condition during the second and third blocks of trials. Of particular interest was how the infants' looking times during the second block of trials compared to their looking time during each of the test trials. In the preference condition, the infants' mean looking times during the second to last and last habituation trials (second to last trial, $M = 51.1$, $SD = 35.0$; last trial, $M = 49.1$, $SD = 35.0$) were found to be both (1) reliably *shorter* than their mean looking time during the two-screens test trial, ($M = 59.2$, $SD = 29.5$), $F(1, 228) = 4.33$, $p < .05$, and (2) reliably *longer* than their mean looking time during the high-window trial ($M = 30.6$, $SD = 20.9$), $F(1, 228) = 19.98$, $p < .0001$. In the no-preference condition, in contrast, no difference was found between the infants' mean looking times during the last two habituation trials (second to last trial, $M = 43.4$, $SD = 31.3$; last trial, $M = 42.9$, $SD = 32.8$) and either (1) the low-window/two-screens trial ($M = 44.0$, $SD = 29.8$), $F(1, 228) = 0.04$, or (2) the high-window trial ($M = 45.5$, $SD = 30.2$), $F(1, 228) = 0.30$.

Together, these results suggest the following picture. In the no-preference condition, looking times declined between the first and second blocks of habituation trials, presumably because the infants were becoming familiar with the habituation event. No further decline occurred between the second and third blocks of trials, however, because the novel test screens held the infants' interest and caused them to maintain the same level of looking as in the last two habituation trials. Like the no-preference infants, the preference infants showed a reliable decline in looking time between the first and second blocks of habituation trials. Unlike the no-preference infants, however, the preference infants did not simply maintain in each test trial the level of looking they had produced during the last two habituation trials. Instead, the infants showed an *increase* in their level of looking during the two-screens trial and a *decrease* during the high-window trial. These results suggest that the infants were focusing on the mouse's displacement and recognized that (1) the two-screens event differed from the habituation event in that it violated their expectations about when the mouse should be occluded and (2) the high-window event was similar to the habituation event in that both conformed to their expectations about when the mouse should be occluded.

The two distinct response patterns of the preference and no-preference infants have implications for recent criticisms of the ‘‘two-test habituation design’’ (Bogartz et al., 1997) commonly used in investigations of young infants’ expectations about occlusion and other physical events. Bogartz et al. have argued that experiments that simply present infants with an habituation event followed by two test events cannot provide ‘‘clear contrasts between impossibility-based explanations and the explanations based on relational effects between events in habituation and events in test’’ (p. 418). However, the present findings make clear that such criticisms are unfounded: comparison of the habituation and test responses of the preference and no-preference infants was sufficient to reveal two reliably different test patterns, one focused on the possibility or impossibility of the mouse’s displacement (preference infants) and the other on the relative novelty of the test screens (no-preference infants).

## GENERAL DISCUSSION

The present research yielded four main findings. *First,* when watching a toy mouse that moved back and forth behind two screens separated by a gap, 2.5-month-old infants expected the mouse to appear between the screens and were surprised when it failed to do so. The same positive finding was obtained whether the screens were simple symmetrical screens separated by a large gap or more complex asymmetrical screens separated by a smaller gap. The same positive response was also observed whether the screens were kept upright throughout the experiment or were lowered at the start of each trial to reveal that only one mouse was present in the apparatus. Together, these results suggest that the infants (1) believed that the mouse continued to exist after it disappeared behind each screen and (2) realized that the mouse could not disappear behind one screen and reappear from behind the other screen without traveling the distance between them. Such a finding is consistent with recent reports that 2.5-month-old infants (1) believe that objects continue to exist when occluded and (2) expect occluded objects to follow continuous paths (Spelke et al., 1992; Wilcox et al., 1996).

*Second,* the infants’ surprise at the mouse’s failure to appear between the two screens was eliminated when the screens were lowered at the start of each test trial to reveal that two mice were present in the apparatus. This result suggests that the infants were able to use this information to make sense of the two-screens event: they realized that one mouse traveled to the left and one mouse to the right of the two screens. This finding is consistent with prior results obtained with infants aged 3 to 5.5 months (Aguiar & Baillargeon, 1999; Baillargeon & Graber, 1987; Baillargeon & DeVos, 1991). The infants in those experiments no longer showed surprise at an apparent violation of their occlusion knowledge after receiving a ‘‘hint’’ that two identical objects were present in the apparatus. The present data indicate that infants as young as 2.5 months of age can take advantage of such a hint to generate an explanation that reconciles what they observe with what they know (Baillargeon, 1994b).

*Third,* the infants’ surprise at the mouse’s failure to appear between the two screens was eliminated when the screens were connected at the top to form a single screen. The size of the connection had no effect on the infants’ performance: the same response was obtained when the screens were connected by a very short strip (large-low-window condition in Experiment 1) or by a strip half as tall as the screen (small-low-window condition in Experiment 1). These results suggest that at 2.5 months of age infants possess only a very limited knowledge of when objects should and should not be occluded. Specifically, infants seem to possess only an initial concept centered on a behind/not-behind distinction: they expect objects to be hidden when behind other objects and to be visible otherwise. At this stage, infants do not take into account the presence and location of openings in occluders; rather, infants expect *any* object to be hidden when behind *any* occluder.

Alternative interpretations could be offered for the last two findings described. It might be suggested that the infants were not surprised at the mouse’s failure to appear between the two screens after seeing the two mice because this sight either confused them or induced them to focus exclusively on the mice. Similarly, it might be proposed that the infants were not surprised that the mouse failed to appear between the screens that were connected at the top because these screens were sufficiently similar to the habituation screen that the infants did not detect the change that had been introduced. Both of these interpretations are unlikely, however, given a *fourth* finding that emerged from overall analyses of the data obtained with these (no-preference) infants during the last four habituation trials and two test trials. These analyses revealed that the infants showed a reliable decline in looking time between their next to last and last pair of habituation trials, but not between their last pair of habituation trials and test trials. These results suggest that (1) the infants realized that the test screens differed from the habituation screen in shape, pattern, and color and (2) these changes caused the infants to maintain during the test trials the same level of attention as in the last pair of habituation trials. The finding that the infants detected the novelty of the test screens is consistent with the evidence in the perceptual development literature that even very young infants can detect salient changes in the form, pattern, or arrangement of stimuli (see Dodwell, Humphrey, & Muir, 1987, for a review of this research).

## Developmental Sequence

In the Introduction, we reviewed recent evidence on 3- and 3.5-month-old infants’ expectations about when objects should and should not be occluded

(Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991). These findings, together with the present results, suggest the following developmental sequence. At about 2.5 months of age (if not earlier), infants possess only a primitive, all-or-none initial concept: they expect objects to be hidden when behind other objects and to be visible otherwise. Over the course of the next month, infants rapidly progress beyond their initial concept. At about 3 months, infants add a first variable: they now expect an object that passes behind an occluder with an opening extending from its lower edge to appear in the opening. At about 3.5 months, infants add a second variable: when watching an object pass behind an occluder with an opening extending from its upper edge, infants expect the object to become visible if it is taller than the bottom of the opening.

What factors might lead 2.5-month-old infants to progress beyond their limited initial concept of when objects should be occluded, and to identify the presence of low openings in occluders as an important variable (we return later on to the progress that takes place between 3 and 3.5 months)? One possibility, already mentioned in the Introduction, is that this development occurs when infants' visual abilities improve sufficiently to enable them to reliably detect (1) the presence of low openings in occluders and (2) the (typically rapid) passage of objects through these openings (see Banks & Salapatek, 1983; Kellman & Banks, 1998; and Slater, 1995, for reviews of infants' early visual abilities).

A second possibility is that infants' learning about the presence of low openings in occluders stems less from a general improvement in their visual abilities and more from a specific change in their tracking of objects that move behind occluders. Piaget (1954) observed that very young infants who are tracking an object that moves out of sight typically continue to look at the point where the object disappeared: ''the child limits himself to looking at the place where the object vanished...if nothing reappears, he soon gives up'' (p. 11). Older infants, Piaget reported, are more likely to search for the object further along its trajectory. These observations have implications for the issue at hand. If very young infants, when tracking an object that moves behind an occluder with a low opening, continue looking at the occluder edge where the object disappeared, they will not be able to detect the passage of the object in the opening; as a result, they will have no data contradicting their initial notion that objects are always hidden when behind nearer objects. Only when infants' tracking improves and they begin to visually sweep past the point where the object disappeared will they have available data from which to learn that objects typically become temporarily visible when passing behind occluders with low openings.

The possibility just discussed may seem inconsistent with the present findings: had the infants in Experiment 2 and in the one-mouse condition of Experiment 3, when watching the two-screens test event, continued looking at the left edge of the left screen after the mouse disappeared there, they would have had no opportunity to notice that the mouse failed to appear between the screens; yet the infants' responses made clear that they did detect this violation. However, it should be kept in mind that the infants in the present research received multiple habituation trials in which they saw the mouse move back and forth across the apparatus. It seems plausible that, across repetitions, the infants came to look for the mouse, after it disappeared, further along its trajectory. The infants' knowledge of when an object should and should not be occluded would then have dictated what they should expect in the high-window, low-window, and two-screens test events. In everyday life, young infants must not often see objects move repeatedly back and forth behind nearer objects. Under these conditions, it may take infants some time to overcome their tendency to look for an object where it disappeared and to develop the more sophisticated strategy of looking for the object further along its trajectory.

Despite their differences, the two possibilities discussed here reflect the same underlying assumption that infants identify the presence of low openings in occluders as an important variable when they finally have available data from which to abstract this variable. Further research is needed to determine whether this assumption is correct and, if so, whether relevant data become available to infants as a result of improvements in their general visual abilities, in their tracking of objects that move behind occluders, or both.

The preceding speculations give rise to numerous questions about the processes by which infants attain and revise their knowledge about when objects should and should not be occluded. For example, how do infants encode and store relevant observations? How do infants use these observations to abstract new knowledge? And what is the precise nature of the initial concept and variables infants identify? Due to space limitations, we focus here only on the last of these questions.

## Do Infants Acquire Contrastive Knowledge?

Our description of the development of infants' knowledge about when objects should be occluded assumes that the initial concept and variables infants acquire are tantamount to *contrastive conditions for outcomes*: they specify what outcome is to be expected when a certain condition is met and what outcome is to be expected when that same condition is not met. Thus, according to our account, 2.5-month-old infants expect an object to be hidden when behind an occluder and to be visible when not; 3-month-old infants expect an object to remain hidden when passing behind an occluder with a continuous lower edge and to become visible when passing behind an occluder with a discontinuous lower edge; and so on.

However, an alternative account could be offered for the present results and for those of Aguiar and Baillargeon (1999) and Baillargeon and DeVos (1991) that does *not* share the assumption that infants' initial concept and variables are akin to contrastive conditions for outcomes.[5] To illustrate, consider the results of Experiments 1 and 2. One could suggest that the infants (1) were surprised that the mouse failed to appear between the two screens because they had a clear expectation that objects should be visible when not behind occluders and (2) were not surprised that the mouse failed to appear when the screens were connected at the top because they had *no* clear expectation as to whether objects should remain hidden or become visible when behind occluders. This interpretation differs from the one we proposed earlier in that it grants infants the ability to acquire *single* as opposed to contrastive condition-outcome relations. When an object's path does not lie behind an occluder (condition is met), infants expect the object to be visible (outcome is specified). However, when an object's path does lie behind an occluder (condition is not met), infants do not know what outcome is to be expected (outcome is not specified).

How could we decide between the interpretation we offered earlier and the one just discussed? One possibility would be to test, at each stage of development, whether infants hold expectations not only for when objects *should* appear, but also for when they should *not* appear. In the case of 2.5-month-old infants, for example, an experiment could be conducted using the large-low-window test event shown in Experiment 1 and the symmetrical-screens test event shown in Experiment 2, with one exception: in both events, the mouse would become visible when passing behind the screen(s). Evidence that infants look reliably longer at the large-low-window than at the symmetrical-screens event, together with the present results, would indicate that infants this age expect *both* that objects should be occluded when passing behind nearer objects and visible when not. Such findings would support the notion that the knowledge infants acquire as they learn about events involves contrastive conditions for outcomes rather than single condition–outcome relations. In the case of 3-month-old infants, one could conduct an experiment using the large-low-window test event from Experiment 1 and a novel large-high-window test event similar to the high-window event from Experiments 1 and 2 but with the window enlarged so that only a short screen strip remained below the window; again, the mouse would appear in the window in both test events. Evidence that infants look reliably longer at the large-high-window than at the large-low-window event, together with the results of Baillargeon and DeVos (1991) and Aguiar and Baillargeon (1999), would indicate that infants this age expect *both* that objects should remain hidden when passing behind occluders with continuous lower edges and should become temporarily visible when passing behind occluders with discontinuous lower edges. Such findings would further support the notion that infants

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[5] Both of the interpretations examined here assume that young infants can represent occluded objects; for a discussion of recent work that does not share this assumption (e.g., Bogartz et al., 1997; Haith & Benson, 1997), see Baillargeon (1999).

identify contrastive conditions for outcomes, rather than single condition–outcome relations.[6]

## The Contrastive-Evidence Hypothesis

We have recently undertaken experiments on occlusion as well as support, collision, and containment events, to ascertain whether infants' physical knowledge involves contrastive conditions for outcomes. The results we have obtained to date suggest that the knowledge infants acquire is indeed contrastive in nature. Such a finding is consistent with recent speculations from our laboratory (e.g., Baillargeon, 1998, 1999) that infants identify initial concepts and variables—or contrastive condition–outcome relations—through exposure to *contrastive evidence*. By contrastive evidence, we mean observations indicating that (1) a certain outcome occurs when a condition is met and (2) a different outcome occurs when that same condition is not met. On this view, infants would acquire the variable height in occlusion events after observing, for example, that (1) tall objects become visible when passing behind short occluders and (2) short objects do not. Comparison of these two types of observations (which could be collected over time and involve distinct objects) would highlight for infants the variable height and its effects on occlusion events.

The notion that infants identify concepts and variables through the analysis of contrastive evidence—henceforth referred to as the *contrastive evidence hypothesis*—if valid would have several crucial implications for theory and research on infants' acquisition of physical knowlege. Below, we briefly consider two of these implications.

### *Age of Acquisition*

If exposure to contrastive evidence is necessary for infants to identify initial concepts and variables, then it follows that the age at which infants identify any given concept or variable will depend at least in part on the age at which they become exposed to appropriate contrastive evidence. In some cases, this requirement may introduce significant delays in infants' knowledge acquisition.

As an illustration, consider the finding discussed in the Introduction that

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[6] One intriguing feature of the experiments just proposed is that they examine infants' responses to two physically possible events and test whether infants view one of the events as more surprising than the other. In the present research and, indeed, in most of the research conducted with the violation-of-expectation paradigm to date, infants have been shown a possible and an impossible event (from an adult perspective). The results of these experiments have generally suggested, very plausibly, that older infants typically detect more violations—or respond with prolonged looking to more impossible events—than do younger infants. Positive findings in the proposed occlusion experiments would add to this conclusion: they would indicate that with age infants not only come to detect more and more violations, but also cease viewing possible events as surprising or unexpected.

it is not until infants are about 6.5 months of age that they consider the amount of contact between an object and a support when judging the object's stability (Baillargeon et al., 1992). In their daily lives, infants often see caretakers deposit objects on surfaces (e.g., plates on tables or bottles on counters). In most instances, however, objects are deposited with sufficient contact with the surfaces to be stable; only in rare accidental cases are objects released with too little contact to ensure stability. According to the contrastive evidence hypothesis, infants cannot identify the variable amount of contact from these observations alone—from observing *only* that objects remain stable when released with all or most of their bottom surface supported. In order to identify the variable amount of contact, infants *also* need to observe that objects fall when only a small portion of their bottom surface is supported. Such observations most likely occur when infants themselves begin to engage in the act of depositing objects on surfaces (this may happen especially after about 6 months of age, when infants begin to sit without support and as such are more likely to be seated in highchairs, sassy seats, and so on; e.g., Rochat, 1992). In the course of their manipulations, infants no doubt have repeated opportunities to notice that objects typically fall when released on the edges of supports (e.g., cups, spoons, and balls all fall when deposited on the edges of tables). At that point, infants have available the contrastive data necessary to identify the variable amount of contact.

What we are suggesting is that for some variables, such as amount of contact in support events or width in containment events (caretakers rarely attempt to insert large rigid objects into small containers), age of acquisition crucially depends on infants' being able to engage in manipulations that can produce the contrastive data necessary for learning.[7] We do not mean to imply, however, that this is the only factor that contributes to the acquisition process. For many variables, simple day-to-day observation no doubt yields a rich profusion of contrastive evidence. In the case of occlusion events, for example, it seems likely that daily observation simultaneously provides infants with information about the effects of discontinuous lower edges as well as height. Why then do infants identify the one variable a few weeks ahead of the other (Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991)? One possibility is that infants learn about discontinuous lower edges sooner because the contrastive pattern relating condition and outcome is easier to detect. To identify this pattern, infants do not need to encode any information

[7] These speculations suggest that infants might acquire some variables sooner if presented in the laboratory with contrastive observations from which to abstract them. Infants could be shown, for example, that objects fall when a small but not a large portion of their bottom surface is supported or that a small but not a large rigid object can be lowered into a small container. We have recently undertaken experiments (see Baillargeon, 1998, 1999, for reviews) in which we attempt to teach infants variables they have not yet acquired. Although preliminary, the results of these experiments already make clear that infants can acquire variables sooner through a brief exposure to appropriate contrastive observations.

about the object moving behind the occluder; they only need to encode whether the occluder has a continuous or a discontinuous lower edge, and whether the object remains hidden or becomes temporarily visible when passing behind it (e.g., ‘‘if the occluder has a discontinuous edge, the object becomes temporarily visible; if not, it does not’’). In the case of height, however, the situation is somewhat more complex: infants must encode the height of the object and that of the occluder, compare the one to the other, and relate the output of this comparison to the observed outcome (e.g., ‘‘if the object is taller than the occluder, it becomes temporarily visible; if not, it does not’’). It seems plausible that variables that require attending to and processing more information, and especially continuous as opposed to discrete information (e.g., Baillargeon, 1994a, 1995) would be more difficult to detect and hence would be learned later.

### *Innate Structures*

The infants in Experiments 2 and 3 were surprised when the mouse failed to appear between the two asymmetrical or symmetrical screens. These findings, like those of Spelke et al. (1992) and Wilcox et al. (1996), suggest that 2.5-month-old infants believe that (1) objects continue to exist after they disappear behind occluders and (2) objects cannot disappear behind one occluder and reappear from behind another occluder without traveling the distance between them. How do infants attain these beliefs about occluded objects?

If the contrastive-evidence hypothesis is correct, and infants acquire physical knowledge only through exposure to appropriate contrastive observations, then it is difficult to see how infants could ever acquire their beliefs about occluded objects. For infants can never experience observations of the following type: when a certain condition holds, occluded objects exist and move continuously; when that same condition does not hold, they do not. In the world of naive physics, the probability of such observations is nil.

How else, then, could infants come by their beliefs about occluded objects? The most likely answer, we suspect, is that proposed by Spelke (1994; Spelke, Phillips, & Woodward, 1995). She has argued that a small number of core principles constrain from the start infants’ representations of objects’ displacements and interactions. According to Spelke, a continuity principle—a global conception of objects as entities that persist in time and move continuously through space—is one of infants’ innate core principles.

It might be objected that the present findings do not entirely support the notion that infants are born with a continuity principle. After all, the infants in Experiment 1 were not surprised when the mouse failed to appear in the screen’s small or large low window. If infants cannot detect such marked continuity violations, it might be argued, in what sense can they be said to possess an innate principle of continuity?

We believe that these objections arise from the mistaken view that infants who possess an innate principle of continuity should be able to detect *any and all* violations of this belief. It seems to us very plausible that infants could possess an innate notion of continuity and still not be able to detect all or even many continuity violations. In the case of occlusion events, infants' principle of continuity would lead them to assume, upon first seeing an object disappear and reappear from behind an occluder, that the object continued to exist and pursued its trajectory while behind the occluder. At the same time, however, infants would also notice that the object, although visible when on either side of the occluder, ceased to be visible when behind it. This would mark the beginning of infants' learning when objects should and should not be occluded. Over time, as we have discussed previously, infants would gradually refine their expectations about occlusion events. During this long acquisition process, infants could fail to detect many continuity violations, not because they did not realize that the objects continued to exist behind the occluders, but because they still lacked the variable knowledge necessary to accurately predict whether the objects should become visible or remain fully hidden when behind the occluders.

The perspective suggested here may seem at first puzzling; from an adult standpoint, to know continuity is also to know, for example, that objects will become visible when passing behind occluders with low windows or that tall objects will remain partly visible when passing behind short occluders. What our results are leading us to suspect, however, is that infants slowly work out for themselves in the course of development all of the consequences of continuity for occlusion, containment, and other physical events. These consequences are not immediately apparent to infants, but are uncovered one by one as they pursue their efforts to better make sense of the world around them.

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Accepted March 15, 1999