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Reasoning about containment events in very young infants

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Abstract

The present research examined very young infants' expectations about containment events. In Experiment 1, 3.5-month-old infants saw a test event in which an object was lowered inside a container with either a wide opening (open-container condition) or no opening (closed-container condition) in its top surface. The infants looked reliably longer at the closed- than at the open-container test event. These and baseline data suggested that the infants recognized that the object could be lowered inside the container with the open but not the closed top. In Experiment 2, 3.5-month-old infants saw a test event in which an object was lowered either behind (behind-container condition) or inside (inside-container condition) a container; next, the container was moved forward and to the side, revealing the object behind it. The infants looked reliably longer at the inside- than at the behind-container test event. These and baseline results suggested that the infants in the inside-container condition realized that the object could not pass through the back wall of the container and hence should have moved with it to its new location. Experiments 3 and 4 extended the results of Experiments 1 and 2 to 2.5-month-old infants. Together, the present results indicate that even very young infants possess expectations about containment events. The possible origins and development of these expectations are discussed in the context of Baillargeon's model (*Advances in infancy research* 9 (1995) 305. Norwood, NJ: Ablex) of infants' acquisition of physical knowledge, and of Spelke's proposal (*Cognition* 50 (1994) 431) that, from birth, infants interpret physical events in accord with a solidity principle. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

Traditionally, researchers assumed that infants understand very little of the physical events that they observe (e.g. Piaget, 1952, 1954). With the advent of more sensitive methodologies, however, investigators have come to realize that infants as young as 2.5–3.5 months of age already possess expectations about several categories of physical events, including support, occlusion, and collision events (e.g. Aguiar & Baillargeon, 1999; Baillargeon, 1987; Baillargeon & DeVos, 1991; Kotovsky, 1994; Needham, 1993; Spelke, Breinlinger, Macomber, & Jacobson, 1992; Wilcox, Nadel, & Rosser, 1996). The present research built on these results and examined 2.5- and 3.5-month-old infants' expectations about containment events.[1]

There were two main reasons for conducting this research. One was to examine whether the development of infants' expectations about containment events follows the same general pattern identified for other categories of physical events (e.g. Baillargeon, 1994, 1995, 1998). The second reason was to provide additional tests of the claim, first put forth by Spelke (e.g. Spelke, 1994; Spelke et al., 1992; Spelke, Phillips, & Woodward, 1995), that from birth infants interpret physical events in accord with a solidity principle, which states that objects cannot move through space occupied by other objects. Each of these reasons is explained more fully below.

1.1. How do infants learn about physical events?

1.1.1. Infants' knowledge about support, occlusion, and other events

Research over the past 10 years on the development of infants' expectations about support, occlusion, collision, and other events has brought to light a regular pattern in infants' acquisition of knowledge about physical events (e.g. Baillargeon, 1994, 1995, 1998). Specifically, it appears that when learning about an event category, infants first form an *initial concept* centered on a primitive, all-or-none distinction. With further experience, infants identify *variables* that elaborate this initial concept, resulting in increasingly accurate predictions and interpretations over time. To illustrate this developmental pattern, we briefly describe the results of experiments on young infants' expectations about support and occlusion events.

In the *support* experiments (e.g. Baillargeon, Needham, & DeVos, 1992; Hespos, 1998; Hespos & Baillargeon, 2000; Needham & Baillargeon, 1993; for reviews, see Baillargeon, 1994, 1995, 1998; Baillargeon, Kotovsky, & Needham, 1995), infants aged 3–6.5 months were presented with simple problems involving a box and a platform; the box was released in one of several positions relative to the platform, and the infants judged whether the box should remain stable or fall when released. The results indicated that by 3 months of age infants have formed an initial concept

[1] In the present context, *occlusion* events are defined as events in which an object becomes hidden behind a nearer object (e.g. a ball that rolls behind a box), and *containment* events as events in which an object is placed inside a container (e.g. a ball that is lowered inside a box). From an adult perspective, containment of course often involves occlusion. However, this occlusion is of a different form than that defined above: the contained object is occluded because it is lowered *inside*, not *behind*, the container. As we will see, this distinction appears to be crucially important to infants.

of support centered on a simple contact/no-contact distinction: they expect the box to be stable if released in contact with the platform, and to fall 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, at about 4.5–5.5 months of age (females precede males by a few weeks in this development), infants become aware that the type of contact between the box and the platform affects the box's stability. Infants now expect the box to remain stable when released on but not against the platform. Second, at about 6.5 months of age, infants begin to consider the amount of contact between the box and the platform. Infants now expect the box to remain stable if a large but not a small portion of its bottom surface rests on the platform.

In the *occlusion* experiments (e.g. Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991; for a review, see Baillargeon, 1998), infants aged 2.5–3.5 months first watched an object move back and forth behind a screen; next, a portion of the screen was removed, and the infants judged whether the object should remain hidden or become visible when passing behind the screen. The results indicated that by 2.5 months of age infants have formed an initial concept of occlusion centered on a simple behind/not-behind distinction: they expect the object to be hidden when behind the screen, and to be visible otherwise. At this stage, *any* object is expected to be hidden when behind *any* screen. Over the next month, infants rapidly progress beyond their initial concept. At about 3 months, infants add a first variable: they now expect the object to become visible when passing behind a screen with an opening extending from its lower edge. At about 3.5 months of age, infants add a second variable: they begin to take into account the height of the object relative to that of the screen. When the object passes behind a screen with an opening extending from its upper edge, infants expect the object to become visible if it is taller but not shorter than the bottom of the opening.

Does the general developmental pattern identified for support, occlusion, and other physical events (e.g. Baillargeon, 1994, 1995, 1998) also hold for containment events? Before addressing this question, we first review previous findings on the development of infants' knowledge about containment events.

1.1.2. Infants' knowledge about containment events

Until recently, the research on infants' expectations about containment events tended to focus on two main questions. First, do infants realize that an object can be lowered inside a container with an open but not a closed top? And second, do infants appreciate that an object that has been lowered inside a container can be removed from it through its open top but not its closed side and bottom surfaces? Experiments were conducted with infants aged 6–20 months using a variety of object-manipulation and visual-attention methods (e.g. Caron, Caron, & Antell, 1988; Leslie, 1991; MacLean & Schuler, 1989; Piaget, 1954; Pieraut-Le Bonniec, 1985).[2] The results of

[2] In these early investigations, containers were used sometimes upright and sometimes upside-down. We gloss over this distinction here, but note that recent research suggests that infants may perceive events involving containers and covers as belonging to different event categories (e.g. Wang & Paterson, 2000).

these experiments suggested that by 6–9 months of age infants already possess expectations about these two basic facets of containment events.

Over the past few years, investigators have built on these early findings to explore what developments take place in infants' knowledge about containment events. Two main findings have been obtained to date. One is that 6- but not 4-month-old infants realize that the *width* of an object relative to that of a container determines whether the object can be lowered inside the container (e.g. Aguiar & Baillargeon, 1998, 2000; Sitskoorn & Smitsman, 1995). The other finding is that 7.5- but not 6.5-month-old infants appreciate that the *height* of an object relative to that of a container determines how much of the object can be lowered inside the container (e.g. Hespos, 1998; Hespos & Baillargeon, 2000, in press).

Infants' acquisition of first width and then height as containment variables provided partial evidence that infants' knowledge about containment events develops according to the same general pattern that has been identified for other physical events (e.g. Baillargeon, 1994, 1995, 1998). However, additional evidence was needed about the initial phase of this development. We speculated that young infants, although unable to reason about the width or height of objects and containers, might still possess a primitive, all-or-none concept of containment, akin to the initial concepts identified for support, occlusion, and other physical events.

To explore this possibility, we took up again the two main questions addressed in early investigations of infants' expectations about containment events (e.g. Caron et al., 1988; Leslie, 1991; MacLean & Schuler, 1989; Piaget, 1954; Pieraut-Le Bonniec, 1985). Experiment 1 examined whether 3.5-month-old infants appreciate that an object can be lowered inside a container with an open but not a closed top. Experiment 2 asked whether 3.5-month-old infants also realize that an object that has been lowered inside a container can be removed from it through its open top but not its closed side surfaces. Experiments 3 and 4 explored the same issues with younger, 2.5-month-old infants.

We reasoned that positive findings in the first pair or in both pairs of experiments, together with the evidence discussed earlier that young infants do not reason about the width or height of objects in containment events (e.g. Hespos, 1998; Hespos & Baillargeon, 2000, in press; Sitskoorn & Smitsman, 1995), could be taken to suggest that infants aged 3.5 or 2.5 months possess an initial concept of containment centered on an *open/closed* distinction: they appreciate that an object can be lowered into or removed from a container through an open but not a closed surface. In time, this initial concept would become elaborated with the identification of width, height, and other containment variables, following the same overall pattern observed for support, occlusion, and other physical events.

1.2. The solidity principle

Spelke (Spelke, 1994; Spelke et al., 1992, 1995) has suggested that from birth infants interpret physical events in accord with a core solidity principle, which states that an object cannot move through space occupied by another object. If such a principle exists, one might expect two predictions to be true: first, infants should give evidence of the principle at a very young age; and second, infants should give evidence of the principle across a wide range of event categories. The first prediction is straightforward: if infants possess a core principle designed to guide their reasoning about physical events, one would expect this principle to operate as soon as infants begin to reason about relevant events.

The second prediction may require more explanation. Recent evidence suggests that infants 'sort' physical events into event categories and learn separately how each category operates (e.g. Aguiar & Baillargeon, 2000; Baillargeon, 1991, 1995; Hespos, 1998; Hespos & Baillargeon, 2000, in press; Wilcox & Baillargeon, 1998). To illustrate, recall that infants reason about height in occlusion events at about 3.5 months of age (e.g. Baillargeon & DeVos, 1991), but do not reason about height in containment events until about 7.5 months of age (e.g. Hespos, 1998; Hespos & Baillargeon, 2000, in press). To adults, this lag (or 'décalage', to use a Piagetian term; e.g. Flavell, 1963) is surprising because the same physical principles apply when predicting how much of an object can be lowered behind (occlusion) or inside (containment) a container. Yet young infants reason successfully about the first but not the second of these situations. These results suggest that infants view occlusion and containment as two distinct event categories and do not generalize knowledge acquired about occlusion to containment.

However, if infants reason in accord with a principle of solidity, one might expect this principle to affect their reasoning about *all* relevant event categories. In contrast to the *event-specific* expectations infants acquire about occlusion, containment, and other event categories, infants' sensitivity to solidity should thus be *event-general*.

To our knowledge, there are only two published experimental reports indicating that infants as young as 3.5 and 2.5 months of age reason in accord with a solidity principle (Baillargeon, 1987; Spelke et al., 1992). In one experiment (Baillargeon, 1987), 3.5-month-old infants were habituated to a screen that rotated in depth through a 180° arc. Next, a box was placed behind the screen, and the infants saw two test events. In one (112° event), the screen rotated until it reached the occluded box. In the other (180° event), the screen rotated through a full 180° arc as though the box were no longer behind it. The infants who were fast habituators (about half of the infants tested) looked reliably longer at the 180° than at the 112° test event.[3] These and control results indicated that the infants (1) believed that the box continued to exist, in its same location, after it was occluded by the screen, (2) realized that the screen could not rotate through the space occupied by the box, and hence (3) expected the screen to stop against the box and were surprised that it failed to do so.

In the other experiment (Spelke et al., 1992), 2.5-month-old infants sat in front of a wide platform; at the right end of the platform was a large, thin barrier. The infants

[3] Habituation trials continued until the infant (1) met a habituation criterion of a 50% or greater decrease in looking time on three consecutive trials, relative to the first three trials, or (2) completed nine habituation trials. Infants were said to be fast habituators if they met the habituation criterion in six or seven trials, and to be slow habituators otherwise. It is unclear to this day why only fast habituators were successful at detecting the violation in the 180° event. At 4.5 months of age, both fast and slow habituators succeed in detecting the violation (Baillargeon, 1987).

were habituated to the following event: first, a screen was lowered in front of the right half of the platform; next, a ball rolled from left to right along the platform and disappeared behind the screen; after a pause, the screen was raised to reveal the ball resting against the barrier at the end of the platform. Following habituation, the infants saw two test events similar to the habituation event except that a second barrier was placed on the platform to block the path of the ball; this second barrier was taller than the end barrier and protruded above the screen. At the end of the test events, the screen was removed to reveal the ball resting against either the tall barrier (tall-barrier event) or the end barrier (end-barrier event). The infants looked reliably longer at the end- than at the tall-barrier event. These and control results indicated that the infants (1) believed that the ball continued to exist, and pursued its trajectory, after it rolled behind the screen, (2) realized that the ball could not roll through the space occupied by the tall barrier, and hence (3) expected the ball to stop against the tall barrier and were surprised that it did not.

The two experiments just described provide evidence that infants aged 3.5 and 2.5 months interpret very different arrested-motion events in accord with a solidity principle.[4] We reasoned that positive findings in the present research would extend these results by showing that young infants also interpret containment events in accord with solidity: they recognize that objects can neither be inserted into nor removed from containers through closed surfaces. Such evidence would provide additional support for Spelke's (Spelke, 1994; Spelke et al., 1992, 1995) proposal that, from birth, infants show sensitivity to solidity when reasoning about events.

2. Experiment 1

Experiment 1 examined whether 3.5-month-old infants realize that an object can be lowered inside a container with an open but not a closed top.

The experiment made use of the violation-of-expectation method (e.g. Baillargeon, 1998; Bornstein, 1985; Spelke, 1985). In a typical experiment conducted with this method, infants see two test events: one is consistent with the expectation examined in the experiment, and the other violates this expectation. With suitable

[4] In the present context, *collision* events are defined as events in which an object hits another object (e.g. a toy car hitting a ball), and *arrested-motion* events as events in which an object hits a broad, two-dimensional surface such as a wall or floor (e.g. a toy car hitting a wall). From an adult perspective, a collision in which a small object hits a large object that is not displaced may appear similar to an arrested-motion event. However, there is evidence that young infants initially expect a collision between any two objects (but not between an object and a surface) to result in a displacement (for reviews, see Baillargeon, 1995, 1998). It is unclear whether the Baillargeon (1987) infants viewed the test events they were shown (1) as combined collision (between the screen and box) and arrested-motion (between the box and apparatus floor) events, or (2) simply as arrested-motion events (with the box becoming, as it were, an extension of the apparatus floor). It is also unclear whether the infants tested by Spelke et al. (1992) perceived the test events they were shown as arrested-motion events because (1) the barriers were tall and thin and as such wall-like (indeed, Spelke et al. described the end barrier as a 'wall'), and/or (2) the ball always stopped against the end barrier during the habituation trials, rather than displacing it. Regardless of these ambiguities, the main point remains that the infants in these experiments were surprised by events inconsistent with the solidity principle.

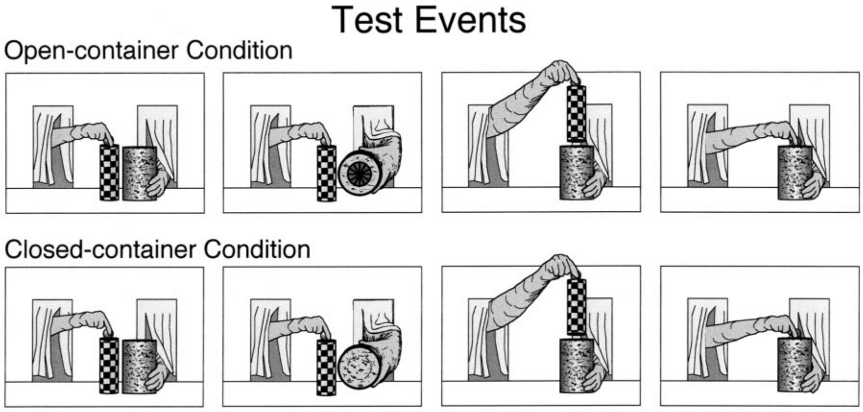

Fig. 1. Schematic drawing of the test events in Experiment 1. The faint circular line on the top of the closed container indicates the location of the false-top opening.

controls, reliably longer looking at the inconsistent than at the consistent event provides evidence that infants (1) detect the violation shown in the inconsistent event, and hence (2) possess the expectation under examination.

The infants were assigned to an open- or a closed-container condition (see Fig. 1). The infants in each condition saw a single test event. At the beginning of the test event shown in the *open-container* condition, a tall cylindrical object and a tall cylindrical container stood a short distance apart on an apparatus floor. An experimenter's right hand grasped a knob attached to the top of the object, and the same experimenter's left hand grasped the container's midsection. The container was as tall as the object minus the knob. To start, the left hand rotated the container forward so that the infants could see its top surface (this surface was not visible to the infants when the container was held upright). Centered in the container's top surface was a large opening through which the infants could see the hollow interior of the container. After a few seconds, the container was returned to its original position on the apparatus floor. The right hand then lifted the object above the container and lowered it until only the knob protruded above the container's rim. Next, the right hand lifted the object out of the container and returned it to the apparatus floor. The infants in the *closed-container* condition saw the same test event with one exception: the opening in the container's top surface was closed, so that it should have been impossible for the object to be lowered inside the container (in actuality, the container had a magnetic false top that adhered to the bottom of the object and hence could be lowered with it).

Prior to the test trials, the infants in the open- and closed-container conditions received baseline trials identical to the test trials, except that the object was lifted above the container and then immediately returned to the apparatus floor; the object was never lowered inside the container (see Fig. 2). The baseline trials served two purposes. First, the trials helped acquaint the infants with the object, the container, the hands, and their motions. Second, the trials provided a baseline assessment of the

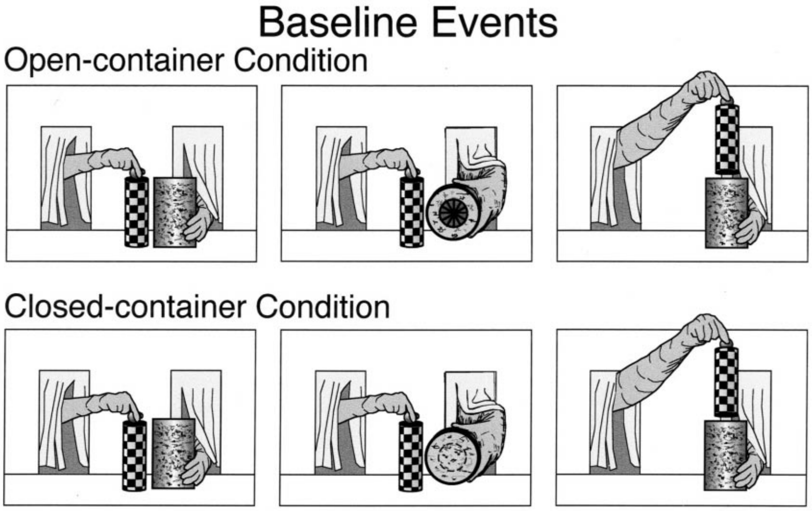

Fig. 2. Schematic drawing of the baseline events in Experiment 1.

infants' intrinsic preferences for the open and closed containers. The test events shown in the open- and closed-container conditions were perceptually identical except when the containers were rotated forward. Because the baseline events also were perceptually identical except when the containers were rotated forward, the data from the baseline trials could be used to assess whether one of the containers was intrinsically more attractive than the other to the infants.

Our reasoning was as follows. If the infants looked about equally at the closed- and open-container baseline events, but looked reliably longer at the closed- than at the open-container test event, then it would suggest that the infants (1) remembered whether the container had an open or a closed top after it was returned to the upright position, and (2) realized that the object could be lowered inside the container with the open but not the closed top.

A final comment about the design of Experiment 1 might be in order. Readers might wonder why a between-subjects rather than a within-subjects design was chosen – that is, why the infants were shown either the closed- or the open-container test event rather than both test events. This choice was motivated by a concern that the infants might become confused after the container was rotated upright and have difficulty remembering whether they were facing the container with the open or the closed top (e.g. Kolstad, 1991; for discussion, see Baillargeon, 1995). Using a between-subjects design, and thus showing the infants a single container throughout the experiment, prevented any such confusion from arising.

2.1. Method

2.1.1. Participants

Participants were 14 healthy term infants, seven male and seven female, ranging in age from 3 months, 11 days to 4 months, 2 days (mean 3 months, 22 days). Seven infants, four male and three female (mean age 3 months, 23 days), were randomly assigned to the closed-container condition, and seven infants, three male and four female (mean age 3 months, 20 days), were assigned to the open-container condition. An additional eight infants failed to complete six valid test trials and were eliminated from the analysis, seven because of fussiness and one because of straining.[5]

The infants' names in this and in the subsequent 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.

2.1.2. Apparatus

The apparatus consisted of a wooden display box 58 cm high, 101 cm wide, and 52 cm deep that was mounted 76 cm above the room floor. The infant faced an opening 36 cm high and 96 cm wide in the front of the apparatus. A white contact paper with a floral pattern covered the floor of the apparatus, and a white contact paper with a marbled pattern covered the side walls. The back wall was made of white foam core and had two rectangular windows, each 34 cm high and 20 cm wide, cut out of the bottom edge. The windows were 22.5 cm apart and were partly covered with a cream-colored muslin fringe. The experimenter's left and right hands were inserted into the apparatus through the right and left windows, respectively (from the infant's point of view). The hands were covered with bright yellow rubber gloves.

Centered between the two windows, 44 cm above the apparatus floor, was a small hole 5 cm high and 13 cm wide that was used by the experimenter to monitor his or her actions on the object and container. The hole was cut through the back wall on the sides and bottom only, leaving the top attached to form a flap; this flap served as a visor and prevented eye contact between the infant and experimenter.

The object used in the closed- and open-container conditions was a cylinder 16.5 cm tall and 6 cm in diameter made of PVC pipe. The top of the cylinder was made of balsa wood and the bottom of flexible magnetic strip. The entire object was covered with black and white checkered contact paper. A red spherical knob 3.5 cm in diameter was glued to the top of the cylinder. The total height of the object, with the knob, was 20 cm.

The container used in the open-container condition was a cylinder 16.5 cm tall and 11.5 cm in diameter made of PVC pipe. The bottom of the container was made of cardboard and the top of flexible magnetic strip. Centered in the top of the container was an opening 6.5 cm in diameter; the magnetic rim surrounding the opening was 2.5 cm wide and 0.2 cm thick. The exterior of the container was

[5] The large proportion of eliminated subjects in this and in the following experiments is not uncommon with very young infants (e.g. Aguiar & Baillargeon, 1999; Baillargeon & DeVos, 1991; Canfield & Haith, 1991; Haith & McCarthy, 1990).

covered with gray granite-textured contact paper; the interior was painted white and was decorated with bright red stripes to attract the infant's attention.

The container used in the closed-container condition was identical to the open container except for one additional feature. A thin metal disk, 10 cm in diameter and covered with the same granite-textured contact paper as the container, was placed under and adhered to the container's magnetic rim. The disk lay 0.2 cm below the top of the rim, so that the faint outline of the container's opening was discernible to adults.

During the closed-container condition test event, the metal disk adhered to the object's magnetic bottom, making it possible for the object to be lowered inside the container. When the object was lifted out of the container, the metal disk adhered once again to the magnetic rim, thereby restoring the container's closed-top appearance.

The infants were tested in a brightly lit room. Four 60 W and one 100 W lamps affixed to the front and back walls of the apparatus provided additional light. Two frames, each 182.5 cm high and 71 cm wide and covered with green 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 61 cm high and 100 cm wide was lowered in front of the apparatus.

2.1.3. Events

In the following text, the numbers in parentheses indicate the number of seconds the experimenter took to perform the actions described. To help the experimenter adhere to the events' scripts, a metronome beat softly once per second.

2.1.3.1. Closed-container condition.

2.1.3.1.1. Baseline event. At the start of the event, the experimenter's right hand held the knob at the top of the object, and the left hand held the closed container. The object was centered between the two side walls, 37 cm from the front of the apparatus. The container was positioned 8.75 cm to the right of the object. To start, the left hand rotated the container toward the infant (1 s) and then tilted it to the right (1 s) and then the left (1 s); this gave the infant some time to inspect the container's closed top. After the container was returned to its initial position (1 s), the object was lifted vertically 18.5 cm (1 s) and then moved to the right 17.5 cm until it was centered 2 cm above the container (1 s). After a 1 s pause, the object was moved to the left (1 s) and lowered to its initial position on the apparatus floor (1 s), where it remained for another 1 s pause. The 10 s event cycle just described was repeated continuously until the computer signaled that the trial had ended (see below).

2.1.3.1.2. Test event. The test event was identical to the baseline event except that the 1 s pause during which the object was held above the container was replaced with a new 5 s segment. During this segment, the object was lowered inside the container until only its knob protruded above the container's rim (2 s). After a 1 s pause, the object was lifted out of the container (2 s). The event then proceeded exactly as in the baseline event. The 14 s event cycle was repeated until the trial ended.

2.1.3.2. Open-container condition. The baseline and test events shown in the open-container condition were identical to those in the closed-container condition except that the open container was substituted for the closed container.

2.1.4. Procedure

Prior to the experiment, each infant was shown and allowed to touch the object and the yellow gloves worn by the experimenter. During the experiment, the infant sat on a parent's lap in front of the apparatus. The infant's head was approximately 50 cm from the front of the apparatus. The parents were asked to refrain from interacting with their infant during the experiment, and 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 condition to which the infant was assigned. Each observer held a button box linked to a Dell microcomputer and depressed the button when the infant looked at the events. The looking times recorded by the primary observer were used to determine when a trial had ended. At the end of each trial, the observers rated on a coding sheet (1) the state of the infant (drowsy, quiet, active, fussy, or crying) during the trial and (2) the visibility (high, medium, or low) of the infant's looking behavior during the trial.

The infants in the closed- and open-container conditions were tested using a two-phase procedure that consisted of a baseline and a test phase. During the *baseline* phase, the infants saw the event appropriate for their condition on six successive trials. Each trial ended when the infant either (1) looked away for 1 consecutive second after having looked at the event for at least 10 cumulative seconds or (2) looked for 60 cumulative seconds without looking away for 1 consecutive second.

During the *test* phase, the infants saw the event appropriate for their condition on six successive trials. Each trial ended when the infant (1) looked away for 1 consecutive second after having looked at the event for at least 12.5 cumulative seconds or (2) looked for 60 cumulative seconds without looking away for 1 consecutive second. The 12.5 s minimum value was chosen to ensure that the infants had ample opportunity to see the object being lowered into and removed from the container.

Interobserver agreement during the baseline and test trials was measured for all of the infants. 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. Percent 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 96% per trial per infant.

Interobserver agreement on the ending of each test trial was also measured. In the experiment, data were obtained from 84 test trials (14 infants × 6 test trials). Based on the primary observer's responses, 17 trials ended because the infant looked at the event for the maximum amount of time allowed (60 s), and 67 trials ended because the infant looked away from the event for 1 consecutive second. For each of the 60 s trials, the computer calculated the looking time registered by the secondary observer; the average looking time obtained in these trials was 59.7 s. For each trial that ended with a 1 s look away, the computer recorded (1) whether the secondary observer agreed that the infant was looking away from the event in the final 100 ms interval and, if yes, (2) for how many consecutive intervals prior to and including the final interval the secondary observer registered that the infant was looking away. The secondary observer agreed that the infant was looking away during the final interval on 60 of the 67 trials; the average look away recorded by the secondary observer at the end of these trials was 0.98 s. The seven 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 visibility for the infant's looking behavior. Comparable trial-ending agreement results were obtained in the other experiments included in this report.

Preliminary analyses revealed no significant effect of sex on the looking times of the infants in the closed- and open-container conditions during the baseline and test trials (all $F < 3.71$, $P > 0.05$); the data were therefore collapsed across sex in subsequent analyses.

2.2. Results

Fig. 3 presents the mean looking times of the infants in the closed- and open-container conditions during the six baseline and test trials. It can be seen that the infants in the two conditions tended to look equally during the baseline trials, but that the infants in the closed-container condition looked longer than those in the open-container condition during the test trials.

2.2.1. Baseline trials

The infants' looking times during the six baseline trials were averaged and analyzed by means of a one-way analysis of variance (ANOVA) with condition (closed- or open-container) as a between-subjects factor. The main effect of condition was not significant ($F(1,12) = 0.02$), suggesting that the infants in the closed- (mean 34.9, SD 9.8) and open-container (mean 35.7, SD 11.6) conditions did not differ reliably in their responses to the baseline events.

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the closed- and open-container conditions looked about equally during the baseline trials ($W = 51$, $P > 0.05$).

2.2.2. Test trials

The infants' looking times during the six test trials were averaged and analyzed in the same manner as the baseline data. The analysis revealed a significant main effect of condition ($F(1,12) = 6.35$, $P < 0.05$), indicating that the infants in the closed-container condition (mean 37.4, SD 11.4) looked reliably longer than did those in the open-container condition (mean 25.1, SD 6.0).

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the closed-container condition looked reliably longer than did those in the open-container condition during the test trials ($W = 37$, $P < 0.05$, one-tailed).

2.2.3. Comparison of baseline and test trials

A final analysis compared the response patterns of the infants in the closed- and open-container conditions during the baseline and test trials. The infants' looking

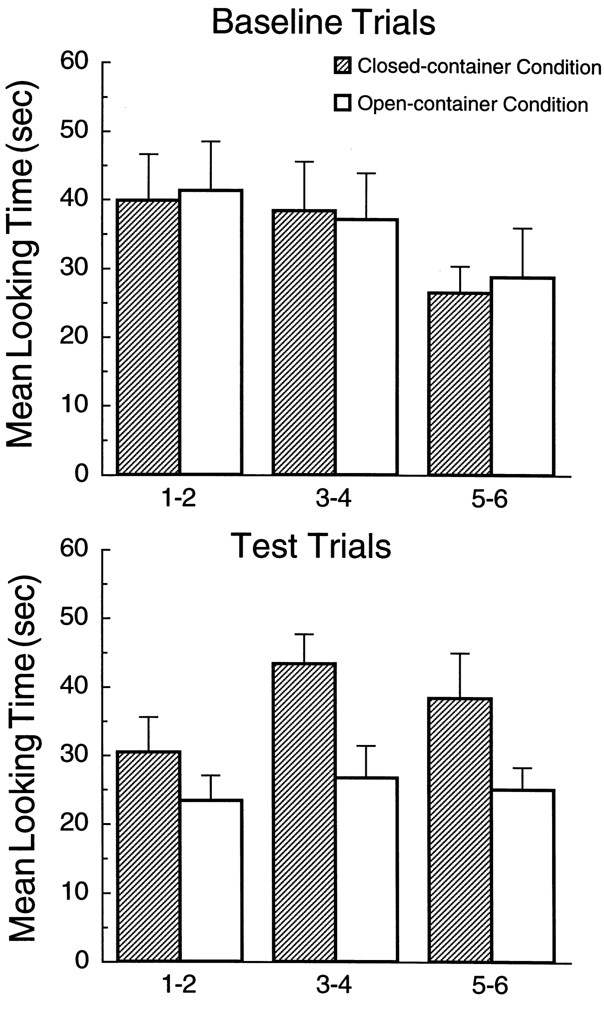

Fig. 3. Mean looking times of the infants in the closed- and open-container conditions of Experiment 1 during the baseline and test trials.

times in each block of trials were averaged and analyzed by means of a 2×2 ANOVA, with condition (closed- or open-container) as a between-subjects factor and block (baseline or test) as a within-subjects factor. The analysis yielded a significant condition × block interaction ($F(1, 12) = 5.45$, $P < 0.05$). Planned comparisons confirmed that the infants in the two conditions tended to look equally during the baseline ($F(1, 12) = 0.05$) but not the test ($F(1, 12) = 9.48$, $P < 0.01$) trials. No other effect was significant.

2.3. Discussion

During the baseline trials, the infants in the closed- and open-container conditions tended to look equally. During the test trials, however, the infants in the closed-container condition looked reliably longer than did those in the open-container condition. Together, these results suggest that the infants (1) remembered whether the container had an open or a closed top after it was rotated upright, and (2) realized that the object could be lowered inside the container with the open but not the closed top.

The results also argue against the possibility that the infants looked reliably longer at the closed- than at the open-container test event simply because of a baseline preference for some superficial aspect of the closed-container event. Recall that the closed- and open-container *test* events were identical to the closed- and open-container *baseline* events, respectively, except for a brief, identical segment that was added to each baseline event (during this segment, the object was lowered into and then removed from the container). Since (1) the infants did not respond differentially to the perceptual differences between the closed- and open-container baseline events and (2) the same exact segment was added to the two baseline events to form the test events, it follows that the infants' differential test responses were unlikely to be due to low-level perceptual differences between the two test events. Rather, it is more likely that the infants realized that, with the segment added, the closed- but not the open-container test event became inconsistent with their physical knowledge.

The results of Experiment 1 thus suggest that infants as young as 3.5 months of age already possess expectations about containment events: they appreciate that an object can be inserted into a container through an open but not a closed surface. Experiment 2 asked whether 3.5-month-old infants also realize that an object that has been inserted into a container can be removed from it through an open but not a closed surface.

3. Experiment 2

The fact that an object that has been lowered inside a container can be removed from it only through its opening has several physical consequences. It means, for example, that an object that is dropped into a container held in midair should remain in it and not fall through its bottom. It also means that an object that is lowered inside a container resting on a table should be displaced with the container, rather than be left behind, when the container is lifted or slid to a new location. Previous investigations have used all of these approaches and more to examine whether infants aged 6–20 months recognize that an object in a container can be removed from it through an open but not a closed surface (e.g. Caron et al., 1988; Leslie, 1991; MacLean & Schuler, 1989; Pieraut-Le Bonniec, 1985).

To illustrate, Leslie (1991, 1995) showed 6-month-old infants a vanish and a no-object test event. In the vanish event, an object was covered with an inverted container which was then slid to a new position; next, the container was removed to reveal no object, as though it had vanished into thin air. The no-object event was similar except that no object was present throughout the event. The infants looked reliably longer at the vanish than at the no-object test event. Leslie took these and additional results to suggest that by 6 months of age infants realize that an object in a container cannot pass through its closed surfaces and hence must remain in it, and move with it, until removed through its opening.

Experiment 2 used an approach similar to that used by Leslie (1991, 1995) in that the infants were shown a violation event in which an object placed in a container failed to move with the container when slid to a novel location. Our violation event differed from that of Leslie in one crucial way, however: rather than being shown that the container was empty following its displacement, the infants were led to believe that the object had been left behind when the container was displaced. We speculated that this violation might be easier for 3.5-month-old infants to detect as it involved an object appearing where it should not have appeared (a violation by commission), rather than an object not appearing where it ought to have appeared (a violation by omission).

The infants were assigned to a behind- or an inside-container condition and saw a single test event (see Fig. 4). At the start of the event shown in the *behind-container* condition, an experimenter's right hand rested on an apparatus floor next to a cylindrical object; the same experimenter's left hand grasped the midsection of a tall container standing to the right of the object. To start, the left hand rotated the container forward so that the infants could see its open top and hollow interior. After a few seconds, the container was placed upright next to the object and then slid

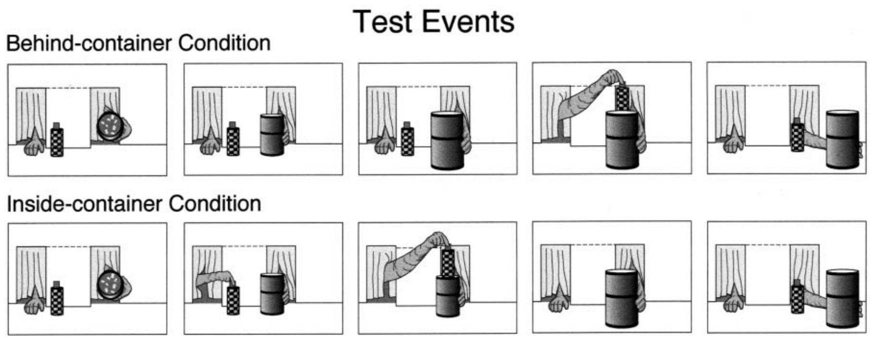

Fig. 4. Schematic drawing of the test events in Experiment 2. The dashed line between the windows in the back drop indicates the upper edge of the hidden compartment where the second object was stored.

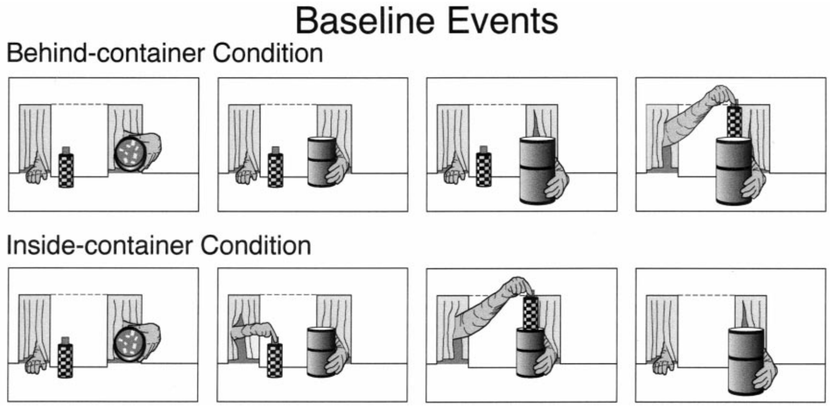

Fig. 5. Schematic drawing of the baseline events in Experiment 2.

forward. Next, the right hand grasped the object, moved it above and behind the container, and lowered it until it disappeared behind the container. The left hand then moved the container to the right, revealing the object standing behind it. After a pause, the container was slid back to the left, concealing the object, and the object and container were returned to their initial positions on the apparatus floor. The infants in the *inside-container* condition saw the same test event except that the object was lowered inside the container before the latter was moved forward; hence, it should have been impossible for the object to be revealed when the container was moved to the right (to create this effect, a second, identical object was surreptitiously introduced into the apparatus; it was this second object that was revealed when the container was moved to the side).[6]

Prior to the test trials, the infants in the behind- and inside-container conditions received baseline trials identical to the test trials, with one exception: the container was never moved to the right to reveal the object behind it (see Fig. 5). The baseline trials served two purposes. First, the trials helped acquaint the infants with the object, the container, the hands, and their motions. Second, the trials provided a baseline assessment of whether the infants had an intrinsic preference for seeing the object being lowered behind or inside the container. The test events shown in the two conditions were perceptually identical except for the fact that in one condition the container was moved forward and the object was then lowered behind it, whereas in the other condition the object was lowered inside the container which was then moved forward. Because the baseline events also were perceptually identical except

[6] In principle, the baseline and test events in Experiment 2 could have been conducted without moving the container forward. However, there were two practical reasons for doing so. First, by moving the container forward, the object could be lowered and revealed in exactly the same location in the apparatus across events. Second, moving the container forward generated additional kinetic depth cues (e.g. Yonas & Granrud, 1984) which might help the infants accurately perceive the spatial relations between the object and container in each event.

for this difference, the data from the baseline trials could be used to assess whether seeing the object lowered behind or inside the container was intrinsically more attractive to the infants.

We reasoned that if the infants tended to look equally at the inside- and behind-container baseline events, but looked reliably longer at the inside- than at the behind-container test events, then it would suggest that the infants (1) believed that the object continued to exist after it disappeared from sight, (2) remembered whether it had been lowered inside or behind the container, (3) realized that the object, when lowered inside the container, could not pass through its closed sides and hence had to move with it when displaced, and consequently (4) expected the object to be revealed when the container was moved to the right in the behind- but not the inside-container condition.

3.1. Method

3.1.1. Participants

Participants were 14 healthy term infants, seven male and seven female, ranging in age from 3 months, 7 days to 3 months, 29 days (mean 3 months, 19 days). Seven infants, four male and three female (mean age 3 months, 20 days), were randomly assigned to the inside-container condition, and seven infants, three male and four female (mean age 3 months, 18 days), were assigned to the behind-container condition. An additional 16 infants failed to complete six valid test trials and were eliminated from the analysis, ten because of fussiness, five because they looked the maximum amount of time allowed (60 s) on five or more test trials, and one because of drowsiness.

3.1.2. Apparatus

The apparatus and stimuli used in Experiment 2 were similar to those in Experiment 1 except for the changes noted below.

Between the two rectangular windows in the back wall of the apparatus was added a hiding compartment made of the same material as the back wall (white foam core). This compartment consisted of a top and front surface and was 34 cm high, 22.5 cm wide, and 8 cm deep. The compartment was used during the test events to conceal the second object (see below).

The object that was lowered inside or behind the container in the baseline and test events (henceforth referred to as the first object) was similar to that in Experiment 1 with two exceptions. First, the red knob at the top of the object was a 2.5 cm cube. Second, the cylindrical portion of the object was 13 cm tall, so that the total height of the object, including the knob, was 15.5 cm.

The object that was surreptitiously moved in and out of the hiding compartment during the test events (henceforth referred to as the second object) was identical to the first object with one exception: a thin metal rod 17 cm long and 0.3 cm in diameter extended from its back surface. The rod protruded from the back wall of the apparatus through a narrow channel and was used by an experimenter to slide the object into position. To ensure that the object slid silently, its bottom was covered with felt. The experimenter who manipulated the second object was hidden from the infants' view by the back wall of the apparatus and the muslin fringe covering the right rectangular window; as an added precaution, the experimenter also wore a cream-colored glove that blended with the fringe.

The container used in the baseline and test events was a cylinder 19 cm tall and 11.5 cm in diameter. It was made of PVC pipe, with a cardboard bottom. The exterior of the container was covered with green contact paper and decorated with three horizontal red stripes. The interior of the container was painted white, except for the bottom which was painted red and decorated with small yellow squares. Finally, the top rim of the container, which was 0.75 cm wide, was painted black.

3.1.3. Events

Two experimenters worked together to produce the events. The first experimenter manipulated the first object and container, and the second experimenter manipulated the second object.

3.1.3.1. Inside-container condition.

3.1.3.1.1. Baseline event. At the start of the baseline event, the first experimenter's right hand rested on the apparatus floor to the left of the first object; his or her left hand grasped the container's midsection. The object was centered between the two side walls, 37 cm from the front of the apparatus. The container was positioned 29 cm to the right of the object. To start, the first experimenter's left hand rotated the container toward the infant (1 s) and then tilted it to the right (1 s) and then the left (1 s); this gave the infant the opportunity to inspect the container's opening and hollow interior. After the container was returned to its initial position (1 s), it was slid to the left 22 cm (1 s) until it stood 7 cm to the right of the object (the container was placed on the right and moved to the left, rather than simply being placed on the left from the start, to make clear to the infants that no object was hidden behind it). Next, the first experimenter's right hand grasped the knob at the top of the object (1 s), lifted it vertically 21 cm (1 s), and moved it to the right 15.75 cm until it was centered 2 cm above the container (1 s). The first experimenter's right hand then slowly lowered the object inside the container (2 s), and then returned to the apparatus floor (1 s). Next, the first experimenter's left hand slid the container forward 18 cm (1 s). After a 1 s pause, the entire sequence was repeated in reverse: the first experimenter's left hand slid the container backward (1 s), and the first experimenter's right hand grasped the knob at the top of the object (1 s), lifted it (2 s), moved it to the left (1 s), and lowered it to the apparatus floor (1 s). The right hand then resumed its resting position on the apparatus floor next to the object (1 s). Finally, the first experimenter's left hand slid the container to its starting position (1 s). The 21 s event cycle just described was repeated until the trial ended.

3.1.3.1.2. Test event. The test event was identical to the baseline event, except that the 1 s pause after the container was slid forward 18 cm was replaced with a new 3 s segment. During this segment, the container was moved 22 cm to the right (1 s) to reveal the second object standing centered in the space the container had occupied before it was moved forward, when the first object was lowered inside it. After a 1 s pause, the container was moved back to the left (1 s), concealing the object, and the event then proceeded exactly as in the baseline event. The 23 s event cycle was repeated until the trial ended.

The second experimenter surreptitiously slid the second object out of the hiding compartment after the container was moved next to the first object, and slid the second object into its final position while the container was moved forward. The second object was returned to the hiding compartment while the container was slid backward and the first object lifted out of it.

3.1.3.2. Behind-container condition.

3.1.3.2.1. Baseline event. The baseline event shown in the behind-container condition was similar to that in the inside-container condition, except that some actions were performed in a different order: rather than lowering the object inside the container and then moving the container forward, the first experimenter moved the container forward and then lowered the object behind it.

To start, as before, the first experimenter's left hand rotated the container toward the infant (1 s), tilted it to the right (1 s) and left (1 s), and then returned it to its initial position (1 s). Next, the first experimenter's left hand slid the container first toward the object (1 s) and then forward 18 cm (1 s). At that point, the first experimenter's right hand grasped the knob at the top of the first object (1 s), lifted it (1 s), and moved it to the right until it was centered above and behind the container (1 s). Next, the first experimenter's right hand lowered the first object behind the container (2 s), and then resumed its initial position on the apparatus floor (1 s). After a 1 s pause, the same actions were repeated in reverse. The first experimenter's right hand grasped the object (1 s), lifted it (2 s), moved it to the left (1 s), and lowered it to the apparatus floor (1 s). The first experimenter's right hand then returned to its resting position (1 s). Finally, the first experimenter's left hand slid the container first backward (1 s) and then to the right (1 s), to its starting position. The 21 s event cycle was repeated until the trial ended.

3.1.3.2.2. Test event. The test event was identical to the baseline event except that the 1 s pause after the first object was lowered to the apparatus floor was replaced with a new 3 s segment identical to that described for the inside-container condition test event. During this segment, the container was first moved to the right (1 s) to reveal the first object; after a 1 s pause, the container was moved back to the left (1 s) to again conceal the object. The 23 s event cycle was repeated until the trial ended.

To help equate whatever faint cues were associated with the introduction of the second object into the apparatus, the second object was again slid into the apparatus after the container was moved next to the first object. The second object was returned to the hiding compartment while the container was moved forward (to prevent the infants seeing both the first and second objects when the container was moved to the right).

3.1.4. Procedure

The procedure used in Experiment 2 was similar to that in Experiment 1. The infants saw the baseline event appropriate for their condition on six successive trials.

Each trial ended when the infant either (1) looked away from the event for 1 consecutive second after having looked at it for at least 18 cumulative seconds or (2) looked for 60 cumulative seconds without looking away for 1 consecutive second. Next, the infants saw the test event appropriate for their condition for six test trials. Each trial ended when the infant (1) looked away from the event for 1 consecutive second after having looked at it for at least 21 cumulative seconds or (2) looked for 60 cumulative seconds without looking away for 1 consecutive second. The 21 s minimum value corresponded to one event cycle and was chosen to ensure that the infants had the opportunity to see the first object lowered inside or behind the container and then revealed when the container was moved to the side.

Interobserver agreement during the test trials was calculated for 13 of the infants (only one observer was present for the other infant). Agreement averaged 96% per trial per infant.

Preliminary analyses revealed no significant effect of sex on the looking times of the infants in the inside- and behind-container conditions during the baseline and test trials (all $F < 0.66$); the data were therefore collapsed across sex in subsequent analyses.

3.2. Results

Fig. 6 presents the mean looking times of the infants in the inside- and behind-container conditions during the baseline and test trials. It can be seen that the infants in the two conditions tended to look equally during the baseline trials, but that the infants in the inside-container condition looked longer than those in the behind-container condition during the test trials.

3.2.1. Baseline trials

The infants' looking times during the six baseline trials were averaged and analyzed by means of one-way ANOVA with condition (inside- or behind-container) as a between-subjects factor. The main effect of condition was not significant ($F(1, 12) = 1.67$, $P > 0.05$), indicating that the infants in the inside- (mean 47.6, SD 4.3) and behind-container (mean 51.1, SD 5.6) conditions did not differ reliably in their responses to the baseline events.

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the inside- and behind-container conditions looked about equally during the baseline trials ($W = 43$, $P > 0.05$).

3.2.2. Test trials

The infants' looking times during the six test trials were averaged and analyzed in the same manner as the baseline data. The analysis revealed a significant main effect of condition ($F(1, 12) = 9.09$, $P < 0.025$), indicating that the infants in the inside-container condition (mean 48.4, SD 6.0) looked reliably longer than did those in the behind-container (mean 36.8, SD 8.3) condition.

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the inside-container condition looked reliably longer than those in the behind-container condition during the test trials ($W = 33$, $P < 0.025$, one-tailed).

3.2.3. Comparison of baseline and test trials

A final analysis compared the response patterns of the infants in the inside- and behind-container conditions during the baseline and test trials. The infants' looking times in each block of trials were averaged and analyzed by means of a 2×2 ANOVA, with condition (inside- or behind-container) as a between-subjects factor and block (baseline or test) as a within-subjects factor. The analysis yielded significant main effects of condition ($F(1, 12) = 4.75$, $P < 0.05$), and block ($F(1, 12) = 6.05$, $P < 0.05$), and a significant condition × block interaction ($F(1, 12) = 7.62$, $P < 0.025$). Planned comparisons confirmed that the infants in

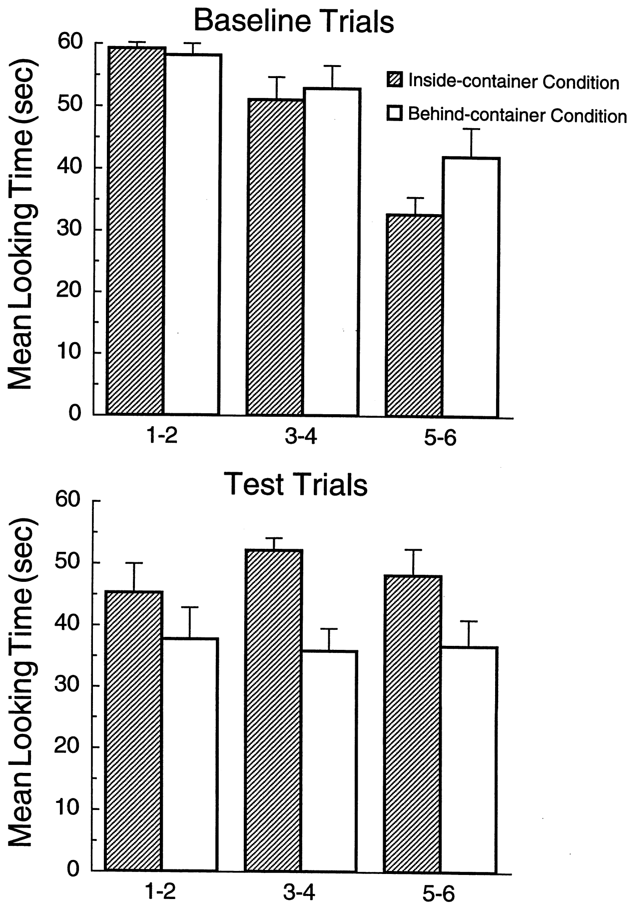

Fig. 6. Mean looking times of the infants in the inside- and behind-container conditions of Experiment 2 during the baseline and test trials.

the two conditions tended to look equally during the baseline ($F(1, 12) = 0.79$), but not the test ($F(1, 12) = 9.08$, $P < 0.025$) trials.

3.3. Discussion

During the baseline trials, the infants in the inside- and behind-container conditions tended to look equally. During the test trials, however, the infants in the inside-container condition looked reliably longer than did those in the behind-container condition. Together, these results suggest that the infants (1) believed that the object continued to exist after it disappeared from sight, (2) remembered whether it had been lowered inside or behind the container, (3) realized that the object, when lowered inside the container, could not pass through its closed sides and thus had to move with it when displaced, and therefore (4) expected the object to be revealed when the container was moved to the right in the behind- but not the inside-container condition.[7] These results confirm and extend those of Leslie (1991, 1995) in that they indicate that 3.5-month-old infants expect an object in a container to move with it when displaced. The present results are also consistent with previous reports that very young infants can represent the existence and location of hidden objects (e.g. Aguiar & Baillargeon, 1999; Baillargeon, 1987; Baillargeon & DeVos, 1991; Spelke et al., 1992; Wilcox et al., 1996).

The results of Experiment 2 also argue against the possibility that the infants looked reliably longer at the inside- than at the behind-container test event simply because of a baseline preference for some superficial aspect of the inside-container event. Recall that the inside- and behind-container *test* events were identical to the inside- and behind-container *baseline* events, respectively, except for a brief, identical segment added to each baseline event (during this segment, the container was moved to the right, to reveal the object, and then moved back to the left). Since (1) the infants did not respond differentially to the perceptual differences between the inside- and closed-container baseline events and (2) the same exact segment was added to the two baseline events to form the test events, it follows that the infants' differential test responses were unlikely to be due to low-level perceptual differences between the two test events. Rather, it is more likely that the infants realized that with the segment added, the inside- but not the behind-container test event became inconsistent with their physical knowledge.

Together, the results of Experiments 1 and 2 suggest that by 3.5 months of age infants already possess expectations about containment events: they appreciate that an object can be inserted into or removed from a container through an open but not a

[7] It might be suggested that the infants in Experiment 2 could have responded with prolonged looking to the inside-container test event, not because they realized that the object should not have been revealed behind the container, but for a more sophisticated reason. Perhaps the infants (1) immediately concluded, upon seeing the object behind the container, that they must be facing a second, identical object and (2) were puzzled as to how this second object had suddenly appeared in the apparatus. Both interpretations assume that infants realize that an object cannot pass through the closed sides of a container. However, the second interpretation attributes to infants a more complex reasoning process than the first, and for this reason will not be considered further.

closed surface. Experiments 3 and 4 examined whether even younger, 2.5-month-old infants, hold the same expectations.

4. Experiment 3

Experiment 3 asked whether 2.5-month-old infants realize that an object can be inserted into a container with an open but not a closed top. The procedure used in Experiment 3 was similar to that of Experiment 1, with two exceptions: the maximum length of the baseline and test trials was increased from 60 to 90 s, and the infants received two rather than six test trials. Pilot data collected using the same procedure as in Experiment 1 indicated that infants tended to look for 60 s on most trials. Increasing the length of the trials made it less likely that infants would remain at ceiling during the test trials. At the same time, however, this change increased the length of the experimental session, with the result that infants tended to become fussy or distracted as the session progressed. Giving infants only two test trials helped alleviate this problem.

4.1. Method

4.1.1. Participants

Participants were 18 healthy term infants, eight male and ten female, ranging in age from 2 months, 14 days to 2 months, 28 days (mean 2 months, 23 days). Nine infants, four male and five female (mean age 2 months, 24 days), were randomly assigned to the closed-container condition, and nine infants, four male and five female (mean age 2 months, 22 days), were assigned to the open-container condition. An additional 11 infants failed to complete two valid test trials and were eliminated from the analysis, six because of fussiness, three because they looked the maximum amount of time allowed (90 s) on both test trials, one because of drowsiness, and one because she was distracted and inattentive.

4.1.2. Apparatus, events, and procedure

The apparatus, events, and procedure used in Experiment 3 were identical to those in Experiment 1, except that, as already noted, the maximum length of the baseline and test trials was increased to 90 s and the infants received only two test trials. Interobserver agreement was calculated for all 18 infants and averaged 96% per trial per infant.

Preliminary analyses revealed no significant effect of sex on the looking times of the infants in the closed- and open-container conditions during the baseline and test trials (all $F < 1.97$, $P > 0.05$); the data were therefore collapsed across sex in subsequent analyses.

4.2. Results

Fig. 7 presents the mean looking times of the infants in the closed- and open-container conditions during the baseline and test trials. It can be seen that the infants

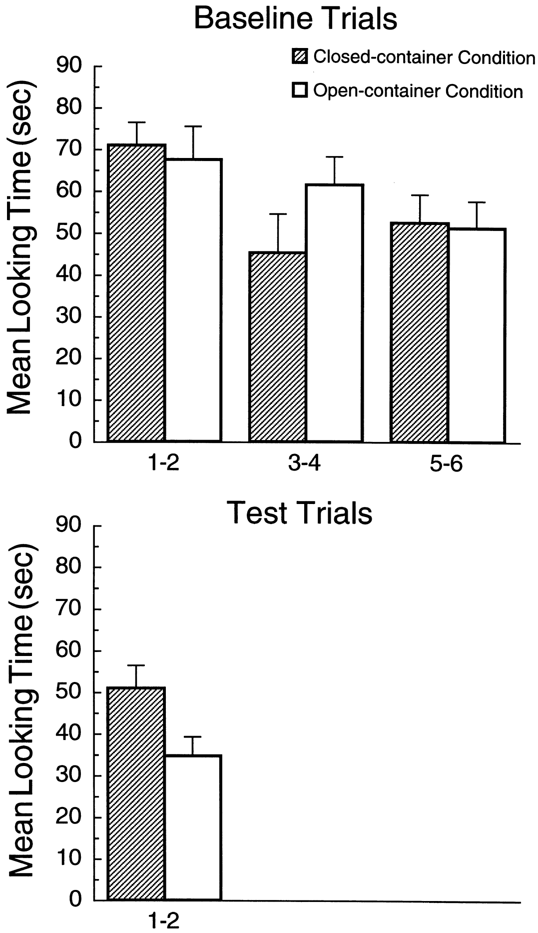

Fig. 7. Mean looking times of the infants in the closed- and open-container conditions of Experiment 3 during the baseline and test trials.

in the two conditions tended to look equally during the baseline trials, but that the infants in the closed-container condition looked longer than those in the open-container condition during the test trials.

4.2.1. Baseline trials

The infants' looking times during the six baseline trials were averaged and analyzed as in Experiment 1. The main effect of condition was not significant ($F(1, 16) = 0.19$), indicating that the infants in the closed- (mean 56.2, SD 17.8) and open-container (mean 60.1, SD 19.5) conditions did not differ reliably in their responses to the baseline events.

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the closed- and open-container conditions looked about equally during the baseline trials ($W = 81.5$, $P > 0.05$).

4.2.2. Test trials

The infants' looking times during the two test trials were averaged and analyzed as in Experiment 1. The analysis yielded a significant main effect of condition ($F(1, 16) = 5.07$, $P < 0.05$), indicating that the infants in the closed-container condition (mean 51.0, SD 17.0) looked reliably longer than did those in the open-container condition (mean 34.7, SD 13.6).

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the closed-container condition looked reliably longer than those in the open-container condition during the test trials ($W = 61$, $P < 0.025$, one-tailed).[8]

4.3. Discussion

The results of Experiment 3 were similar to those of Experiment 1. During the baseline trials, the infants looked about equally at the closed- and open-container events. During the test trials, however, the infants looked reliably longer at the closed- than at the open-container event. These results suggest that infants as young as 2.5 months of age recognize that an object can be lowered inside a container with an open but not a closed top.

Experiment 4 asked whether 2.5-month-old infants also realize that an object that has been lowered inside a container cannot pass through its closed sides and hence must remain in it, and move with it, until removed through its opening.

5. Experiment 4

The procedure used in Experiment 4 was identical to that of Experiment 2, except for the same two changes as in Experiment 3: the maximum length of each baseline and test trial was 90 s, rather than 60 s, and the infants received two rather than six test trials.

5.1. Method

5.1.1. Participants

Participants were 18 healthy term infants, six male and 12 female, ranging in age from 2 months, 14 days to 2 months, 29 days (mean 2 months, 21 days). Nine

[8] No attempt was made in Experiments 3 and 4 to directly compare the patterns of responses observed in the baseline and test trials because the infants were given six baseline trials but only two test trials. In principle, we could of course have compared the responses observed in the last two baseline trials and two test trials. However, analyses focusing on the last two baseline trials and first two test trials in Experiments 1 and 2 failed to produce significant condition × block interactions (Experiment 1: $F(1, 12) = 0.87$; Experiment 2: $F(1, 12) = 3.46$, $P > 0.05$). These results suggested that comparable analyses in Experiments 3 and 4 were unlikely to yield positive results, and indeed they did not (Experiment 3: $F(1, 16) = 1.78$, $P > 0.05$; Experiment 4: $F(1, 16) = 0.21$).

infants, three male and six female (mean age 2 months, 21 days), were randomly assigned to the inside-container condition, and nine infants, three male and six female (mean age 2 months, 21 days), were assigned to the behind-container condition. An additional 18 infants failed to complete two valid test trials and were eliminated from the analysis, 13 because they looked the maximum amount of time allowed (90 s) on both test trials and five because of fussiness.

5.1.2. Apparatus, events, and procedure

The apparatus, events, and procedure used in Experiment 4 were identical to those in Experiment 2 except for the two procedural changes noted above. Interobserver agreement was calculated for all 18 infants and averaged 97% per trial per infant.

Preliminary analyses revealed no significant effect of sex on the looking times of the infants in the inside- and behind-container conditions during the baseline and test trials (all $F < 0.77$); the data were therefore collapsed across sex in subsequent analyses.

5.2. Results

Fig. 8 presents the mean looking times of the infants in the inside- and behind-container conditions during the baseline and test trials. It can be seen that the infants in the two conditions tended to look equally during the baseline trials, but that the infants in the inside-container condition looked longer than those in the behind-container condition during the test trials.

5.2.1. Baseline trials

The infants' looking times during the six baseline trials were averaged and analyzed as in Experiment 2. The main effect of condition was not significant ($F(1, 16) = 0.13$), indicating that the infants in the inside- (mean 71.8, SD 12.8) and behind-container (mean 69.6, SD 12.7) conditions did not differ reliably in their responses to the baseline events.

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the inside- and behind-container conditions looked about equally during the baseline trials ($W = 82$, $P > 0.05$).

5.2.2. Test trials

The infants' looking times during the two test trials were averaged and analyzed as in Experiment 2. The analysis yielded a significant main effect of condition ($F(1, 16) = 6.62$, $P < 0.025$), indicating that the infants in the inside-container condition (mean 69.1, SD 15.4) looked reliably longer than did those in the behind-container condition (mean 51.6, SD 13.2).

Non-parametric Wilcoxon Rank-Sum tests confirmed that the infants in the inside-container condition looked reliably longer than did those in the behind-container condition during the test trials ($W = 60$, $P < 0.025$, one-tailed).[8]

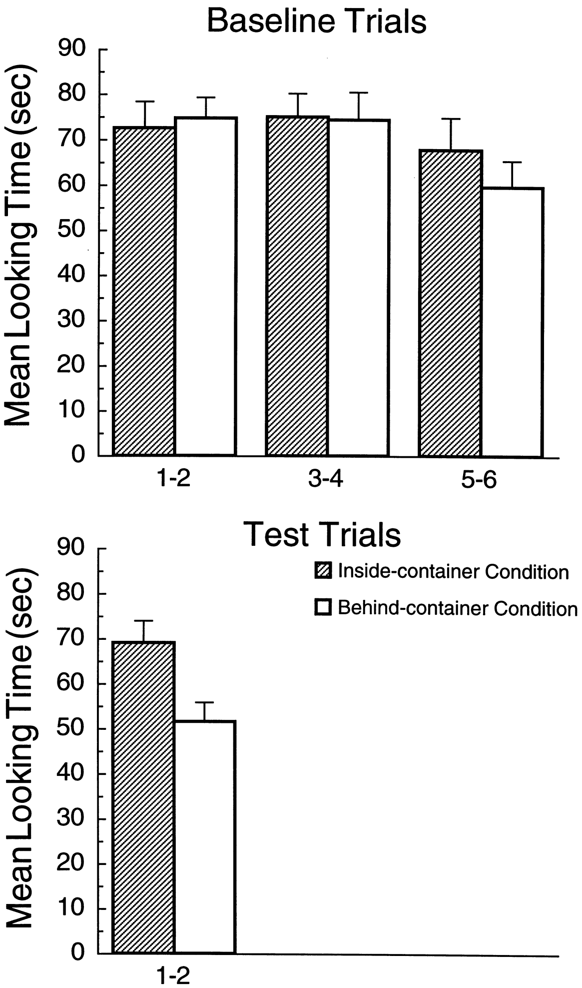

Fig. 8. Mean looking times of the infants in the inside- and behind-container conditions of Experiment 4 during the baseline and test trials.

5.3. Discussion

Like the 3.5-month-old infants in Experiment 2, the 2.5-month-old infants in Experiment 4 tended to look equally at the inside- and behind-container baseline events, but looked reliably longer at the inside- than at the behind-container test event. These results suggest that by 2.5 months of age infants already recognize that an object that has been lowered inside a container can be removed from it through its open top but not its closed sides. Infants respond with prolonged looking when shown a violation event in which an object is lowered inside a container which is then moved aside to reveal the object.

The results of Experiment 4 are consistent with those of Experiment 3: they suggest that 2.5-month-old infants realize that an object can neither be inserted into nor removed from a container through a closed surface. The findings of Experiment 4 are also consistent with prior evidence that infants as young as 2.5 months of age can represent the existence and location of hidden objects (e.g. Aguiar & Baillargeon, 1999; Spelke et al., 1992; Wilcox et al., 1996). Had the infants in Experiment 4 construed the object as an impermanent entity that ceased to exist when it ceased to be visible and began existing anew whenever and wherever it came back into view (e.g. Piaget, 1954), they would have had no reason to expect the object to be revealed, when the container was moved to the side, in the behind- but not the inside-container test event.

The findings of Experiments 2 and 4 are not consistent, however, with recent results reported by Wynn and Chiang (1998). These authors found that 9-month-old infants do not respond with prolonged looking when shown a violation event in which an object is removed from behind a screen which is then lowered to reveal the object. The infants in their experiment saw an expected- and a magical-appearance test event on six alternate trials. In the expected-appearance event, a cylinder stood to the right of center on the apparatus floor. Next, a screen was rotated upward to hide the center of the apparatus. A hand then entered the apparatus and pushed the cylinder behind the screen. Finally, the screen was lowered to reveal the cylinder. In the magical-appearance event, the cylinder stood centered on the apparatus floor. After the screen was rotated upward to hide the cylinder, the hand entered the apparatus, reached behind the screen, and removed the cylinder from the apparatus. The screen was then lowered to reveal the cylinder, as before. The infants tended to look equally at the two test events; they did not respond with prolonged looking when the screen was lowered in the magical-appearance event to reveal the cylinder.

Why did the 3.5- and 2.5-month-old infants in Experiments 2 and 4 detect the magical appearance of the object behind the container (to borrow the language of Wynn & Chiang, 1998), but the 9-month-old infants in these authors' experiment not detect the magical appearance of the cylinder behind the screen? One possible explanation has to do with the different memory and attention demands of the experiments. For example, the present research used a between-subjects rather than a within-subjects design: the infants were presented with *either* the inside- or the behind-container test event. It is possible that the subjects of Wynn and Chiang, who were tested with a within-subjects design, failed because they became confused across test trials as to which event had preceded the lowering of the screen (e.g. 'I guess this must have been the event in which the hand pushed the cylinder behind the screen'). Further research is necessary to determine whether the information-processing explanation offered here is correct.

6. General discussion

The 3.5-month-old infants in Experiment 1 and the 2.5-month-old infants in Experiment 3 looked about equally at the closed- and open-container baseline events, but looked reliably longer at the closed- than at the open-container test event. Together, these results suggest that the infants viewed the closed-container test event as inconsistent with their knowledge of containment events, and more specifically with their expectation that an object can be lowered into a container with an open but not a closed top.

The results of Experiments 2 and 4 were analogous to those of Experiments 1 and 3. The 3.5-month-old infants in Experiment 2 and the 2.5-month-old infants in Experiment 4 tended to look equally at the inside- and behind-container baseline events, but looked reliably longer at the inside- than at the behind-container test event. These results suggest that the infants viewed the inside-container test event as inconsistent with their knowledge of containment events, and more specifically with their expectation that an object that has been lowered inside a container can be removed from it through its open top but not its closed sides.

The present results have implications for three broad issues: what changes take place with age in infants' knowledge about containment events; what factors are responsible for these developments; and what contribution, if any, does a solidity principle (e.g. Spelke, 1994; Spelke et al., 1992, 1995) make to infants' reasoning about containment and other events. Each issue is addressed in turn.

6.1. How does infants' knowledge about containment events develop?

In Section 1, we mentioned two recent series of experiments on infants' expectations about containment events. The first series indicated that 6- but not 4-month-old infants realize that the width of an object relative to that of a container determines whether the object can be lowered into the container (e.g. Aguiar & Baillargeon, 1998, 2000; Sitskoorn & Smitsman, 1995). The second series showed that 7.5- but not 6.5-month-old infants recognize that the height of an object relative to that of a container determines how much of the object can be lowered into the container (e.g. Hespos, 1998; Hespos & Baillargeon, 2000, in press).

The negative findings obtained with the 4- and 6.5-month-old infants in these two series of experiments, together with the positive results obtained with the 2.5- and 3.5-month-old infants in the present research, suggest the following sequence in the development of infants' knowledge about containment events. By 2.5 months of age, infants have acquired an initial concept centered on a simple *open/closed* distinction: they realize that an object can be inserted into or removed from a container through an open but not a closed surface. At some point between 4 and 6 months of age, infants add a variable to their initial concept: they begin to take into account the *width* of an object when judging whether it can be inserted into a container (e.g. Aguiar & Baillargeon, 2000; Sitskoorn & Smitsman, 1995). Finally, at about 7.5 months of age, infants begin to consider the *height* of an object when determining whether it can be fully or only partly lowered inside a container (e.g. Hespos, 1998; Hespos & Baillargeon, 2000, in press). This developmental sequence follows the same general pattern that has been reported for support, occlusion, collision, and other physical events (for reviews, see Baillargeon, 1994, 1995, 1998).

Of course, other descriptions of infants' knowledge of containment events could be offered that are consistent with the evidence reported here. For example, it might be suggested that at 2.5 months of age infants possess two distinct rules about containment: (1) objects can be lowered into open but not closed containers; and (2) objects inside containers move with them when displaced. At this point in time, it is not possible to conclusively determine whether 2.5-month-old infants' knowledge of containment is better described in terms of a single open/closed rule, as argued above, or two distinct rules. Our intuition is that the single-rule approach is better, partly because it is more parsimonious, and partly because it suggests that infants' reasoning about these interrelated facets of containment – the insertion of objects in containers, the removal of objects from containers, the displacements of objects with their containers, and so on – is tightly linked to infants' understanding of solidity, a notion we return to later on.[9]

6.2. What factors contribute to the development of infants' knowledge about containment events?

How do infants progress beyond their initial concept of containment and identify width and height as important containment variables? Our current hypothesis is that the acquisition of a variable in an event category is typically triggered by exposure to contrastive outcomes that are not predicted by infants' current knowledge of the category. Upon noticing these outcomes, infants seek out the conditions that are responsible for them. Identification of these condition–outcome relations signals the identification of a new variable.[10]

Consider first infants' acquisition of the variable width in containment events. Based on their initial concept of containment, infants would at first believe that any object can be lowered into any container with an open top. In the course of observing the outcomes of their own or others' actions on containers, however, infants would come to notice that objects in fact cannot always be inserted into open containers: sometimes they can and sometimes they cannot and simply rest against the openings of the containers. Infants would then begin searching for the conditions that map onto these two distinct outcomes, and would eventually recognize that an object can

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[9] Our discussion of infants' expectations about containment events has focused primarily on their knowledge of the conditions under which objects can be inserted into or removed from containers. However, it is likely that, as with occlusion events (e.g. Aguiar & Baillargeon, 2000; Baillargeon & DeVos, 1991), infants also learn about the conditions under which objects can be fully or only partly *hidden* inside containers. The same complexity arises with other physical events; for example, in the case of collision events, infants must learn both whether objects should be displaced when hit, and how far they should be displaced when hit (e.g. Kotovsky & Baillargeon, 1994, 1998, 2000).

[10] From the present perspective, a variable is thus akin to a dimension; conditions correspond to values on the dimension, with each value (or discernable range of values) being associated with a distinct outcome (hence the emphasis placed here on contrastive outcomes). The variable width in containment events would have two values, 'the object is narrower than the opening of the container' and 'the object is wider than the opening of the container'. Each value would be associated with a distinct outcome, specifically 'the object can be inserted into the container' for the first value, and 'the object cannot be inserted into the container' for the second value. In setting up the dimension, infants would begin by registering the distinct outcomes, and then would identify the conditions that produce them.

be lowered into an open container if it is narrower but not wider than the opening of the container. A similar process would be involved in infants' acquisition of the variable height in containment events: to start, infants would notice that objects sometimes can be fully lowered inside containers and sometimes protrude above them; next, infants would seek out the conditions responsible for these outcomes, and would eventually realize that an object can be fully lowered inside a container if it is shorter but not taller than the container.

The preceding discussion suggests how infants might acquire the variables width and height in containment events – but it does not explain why width should be acquired several weeks before height (e.g. Aguiar & Baillargeon, 2000; Hespos, 1998; Hespos & Baillargeon, 2000, in press; Sitskoorn & Smitsman, 1995). How can we account for this developmental difference? At least two possibilities come to mind. One is that infants are exposed to contrastive outcomes for width (and hence begin the process of identifying width as a variable) earlier than they are exposed to contrastive outcomes for height. According to this hypothesis, infants typically would have the opportunity to observe that objects sometimes can and sometimes cannot be inserted into containers several weeks before they have the opportunity to observe that objects sometimes can and sometimes cannot be fully lowered inside containers.[11]

Another (perhaps more likely) explanation for why width is acquired before height in containment events is that infants generally have less difficulty identifying the conditions that map onto the width as opposed to the height contrastive outcomes. Prior research (e.g. Baillargeon, 1994, 1995) suggests that when infants begin to reason about a continuous variable in an event category they can reason about the variable qualitatively but not quantitatively: they are not able at first to encode absolute amount information. In the case of width in containment, this means that infants can compare the relative widths of an object and container only when one is held *above* the other. Similarly, in the case of height in containment, this means that infants can compare the relative heights of an object and container only when they stand *next* to each other. We suspect that this difference may help explain why width is acquired before height in containment events. As infants watch their caretakers lower objects into containers, they will usually be able to compare their relative widths; as a result, infants will have available the data they need to learn that objects can be inserted into wider but not narrower containers. In contrast, infants may not often see their caretakers place objects first next to and then inside containers; in most instances, caretakers will place the objects directly into the containers. Infants will thus have limited opportunities (perhaps until they themselves produce the requisite actions) to learn that objects can be fully lowered in taller but not shorter containers.

[11] We remain deliberately neutral here as to why infants might be exposed to contrastive outcomes for some variables before others. For example, it might be in some cases that caretakers produce some actions more than others (for a related argument involving the variable amount of contact in support events, see Baillargeon et al., 1992). In other cases, it might be that infants themselves typically produce the relevant actions, and that some actions are motorically more challenging (and hence performed later) than others.

The two explanations proposed above can be used to explain not only the gap in the acquisition of width and height in containment events, but also the gap in the acquisition of height in occlusion and containment events. Recall that infants are able to reason about height in occlusion events at about 3.5 months of age and in containment events at about 7.5 months of age (e.g. Baillargeon & DeVos, 1991; Hespos, 1998; Hespos & Baillargeon, 2000, in press). In line with the first explanation, one could suggest that in their daily lives infants observe many more occlusion than containment events, and hence can learn about occlusion earlier. In line with the second explanation, one could point out that infants are likely to have more opportunities to collect qualitative data about the relative heights of objects and occluders than objects and containers. In the case of occlusion, infants will not only see objects being lowered from above behind occluders, they will also see objects being pushed from the side behind occluders (e.g. as when a parent slides a cup behind a box, or a sibling steps behind an armchair). In these side occlusion situations, it will usually be possible for infants to qualitatively compare the heights of the objects and their occluders; infants will then be in a position to begin mapping conditions onto outcomes.

In the approach presented here, the age of identification of variables thus crucially depends on the availability of appropriate data on *relevant outcomes* (first explanation) and *relevant conditions* (second explanation).[12] To test this general approach, we are planning experiments in which we will attempt to 'teach' infants younger than 7.5 months of age the variable height in containment events. Infants will watch objects being placed next to (to facilitate height comparisons) and then inside containers of varying heights. Evidence that infants can be taught the variable height in containment events at an early age would provide strong support for the notion that the ages at which infants acquire variables mainly reflect the ages at which they are exposed to relevant outcome and condition data for the variables (for a review of related teaching experiments, see Baillargeon, 1998, 1999).

Before concluding this section, we would like to acknowledge that other approaches are of course possible for explaining why infants acquire some variables before others in learning about event categories. For example, in the case of width and height in containment events, one might suggest that width information is perceptually more salient to infants than is height information, resulting in earlier learning. From this perspective, evidence that height in containment events can be taught at an early age would simply mean that a perceptual dimension can be made more salient for infants through the use of focused observations.

Although much research is needed before we achieve a clear understanding of the factors that determine what expectations infants acquire when, we tend to doubt

[12] Of course, other factors may at times come into play. For example, in some event categories, there is a logical sequence to the variables that are identified. Consider, in particular, the support variables type and amount of contact which were discussed in Section 1. It is obvious that infants could not acquire these two variables in the reverse order, as the second variable is really a refinement of the first (e.g. Baillargeon, 1995; Baillargeon et al., 1992; see also Aguiar & Baillargeon, 1999, for a discussion of additional factors that may affect what variables are identified when).

explanations that rest primarily on information processing factors such as attention to different perceptual dimensions and increases in working memory span. Part of the reason for our skepticism is that new findings point to tremendous variation across event categories in the ages at which height, width, and other variables are identified. For example, new evidence suggests that in occlusion events width, like height, is acquired at about 3.5 months of age (Baillargeon & Brueckner, 2000). Furthermore, although infants can reason about height in containment events at about 7.5 months of age, they do not succeed in reasoning about height in covering events (events in which covers are lowered over objects) until several months later (Wang & Paterson, 2000). Such results cast doubt on models that attribute developments in infants' physical knowledge to global changes in their attention or memory abilities.

6.3. The solidity principle

Until now, we have been concerned mainly with the experiences that might contribute to infants' acquisition of the variables width and height in containment events. But what of the initial concept of containment events that was the focus of the present research? How do infants acquire their knowledge that objects can pass through open but not closed surfaces of containers? Because 3.5- and 2.5-month-old infants typically have little experience acting on containers, it seems unlikely that they would acquire their initial knowledge about containment events through such actions.

Our intuition is that infants' initial concept of containment is informed by a solidity constraint. As was mentioned earlier, Spelke (Spelke, 1994, 1999; Spelke et al., 1992, 1995) has proposed that infants' representations of physical events are constrained from birth by a core principle of solidity, which states that two objects cannot exist in the same space at the same time. When infants represent an object being lowered through the closed top of a container (as in the closed-container test event of Experiments 1 and 3), their solidity constraint marks the event as a violation – a departure from what normally occurs in the physical world. Similarly, when infants represent an object being lowered inside a container which is then displaced, their solidity constraint leads them to expect that the object is being displaced with the container; finding the object behind the container (as in the inside-container test event of Experiments 2 and 4) contradicts the solidity constraint and as such is again marked as a violation.

Part of our reason for suspecting that a solidity principle constrains from birth infants' event representations has to do with the contrast between two sets of empirical findings. On the one hand, sensitivity to solidity has been demonstrated in very young infants across different event categories. We mentioned in Section 1 that very young infants have been found to interpret arrested-motion events in accordance with a solidity principle (Baillargeon, 1987; Spelke et al., 1992). The present results add to these reports by showing that very young infants also interpret containment events in a manner consistent with solidity. Finally, preliminary findings by Wang and Baillargeon (2000) suggest that covering events are also interpreted by very young infants in accordance with solidity. On the other hand, sensitivity to height, width, and other variable information seems to emerge at different ages in different event categories. Recall, for example, that infants begin to consider height information at about 3.5 months in occlusion events, at about 7.5 months in containment events, and at some later age still in covering events (e.g. Baillargeon & DeVos, 1991; Hespos, 1998; Hespos & Baillargeon, 2000, in press; Wang & Paterson, 2000). The contrast between these two types of expectations – some *event-general* and present very early in development, and others *event-specific* and emerging at widely different ages – leads us to suspect that they have distinct origins. The event-general expectations would reflect the application of innate core principles, and the event-specific expectations the operation of a learning mechanism designed to form event categories and identify variables separately for each category.

Although our discussion has focussed primarily on infants' principle of solidity, it should be noted that the general argument presented here also applies to another core principle proposed by Spelke (Spelke, 1994; Spelke et al., 1992, 1995), that of continuity; this principle states that objects exist and move continuously in time and space. There are now several published reports indicating that infants aged 3.5 and 2.5 months realize that objects continue to exist when hidden behind occluders (e.g. Aguiar & Baillargeon, 1999; Baillargeon, 1987; Baillargeon & DeVos, 1991; Spelke et al., 1992; Wilcox et al., 1996). The present experiments extend these reports by showing that very young infants also recognize that objects continue to exist when hidden inside containers. Had the infants in Experiments 2 and 4 not represented the existence and location of the object after it disappeared behind or inside the container, they would have had no reason to be surprised by the inside-container test event. Finally, the research by Wang and Baillargeon (2000) suggests that 2.5-month-old infants also appreciate that objects continue to exist when hidden under covers. As with solidity, the evidence that sensitivity to continuity is present in very young infants across different event categories – in contrast to the event-specific expectations infants later acquire about occlusion, containment, covering, and other events – suggests to us that it is innate, rather than acquired.

Of course, several alternative explanations could be offered for infants' two types of expectations. For example, one might propose that infants' event-general expectations reflect the operation of a different learning mechanism, rather than innate core principles; on this view, infants would thus possess two learning mechanisms, one capable of acquiring event-general and one event-specific expectations. Alternatively, one might suggest that infants possess no event-general expectations, and that those identified above are really no more than collections of separate event-specific expectations, acquired very early in life, that together masquerade as event-general expectations (e.g. infants would learn separately that objects continue to exist when hidden behind occluders, inside containers, or under covers). Obviously, before we can determine which, if any, of the approaches presented here is correct, much research will be needed about the nature and development of infants' expectations and learning mechanisms.

6.4. The solidity principle: some apparent counter-evidence

We suggested in the previous section that infants' reasoning about containment events is informed by an innate principle of solidity (e.g. Spelke, 1994; Spelke et al., 1992, 1995). It might be objected that there already exists evidence contradicting such a proposal. Recall, for example, that infants aged 4 months and younger are not surprised when shown a wide object being lowered inside a narrow container (e.g. Sitskoorn & Smitsman, 1995). If infants were innately sensitive to solidity, how could they fail to detect such a violation? (for additional examples of solidity violations that 4.5- and 6.5-month-old infants fail to detect, see Baillargeon, 1991).

We assume that when faced with an event such as a containment event, infants build a *physical representation* of the event. What information is included in this representation depends in large part on the infants' knowledge about containment events. Thus, infants who have not yet identified width as a containment variable are unlikely to include information about the relative widths of the object and container in their physical representation of the event. Because the solidity principle operates at the level of infants' physical representations, *it cannot constrain information that is not represented – only information that is*. If all that is represented is 'object being lowered inside open container', the event will be deemed consistent with solidity, and the infant will fail to detect what is in fact a solidity violation.

The approach presented here makes an interesting prediction: if young infants could be induced to include width information in their physical representation of a containment event, they should then succeed in detecting width violations they would otherwise have failed to detect. The representation 'wide object being lowered into narrow container' would be deemed inconsistent with solidity, and the event marked as a violation. Earlier we discussed one way in which infants might be induced to include variable information in their representations of containment events, through *teaching* experiences (e.g. Baillargeon, 1998, 1999). In the case of width in containment, an appropriate teaching experience might involve showing the infants a container and three or more pairs of objects; each pair would involve a wide and a narrow object, and the infants would be shown that whereas the narrow object could be lowered inside the container, the wide object could not.

There is another, superficially very different way in which infants might perhaps be induced to include width information in their representations of containment events. *Priming* experiences generally highlighting width information might lead infants to include such information when next faced with containment events. These augmented representations would then be evaluated in terms of the solidity principle, and violations recognized as such.

A recent series of experiments by Wilcox (Chapa & Wilcox, 1998; Wilcox, 1999) provides a nice example of infants benefiting from what we are calling here a priming experience. In preliminary experiments (Wilcox, 1999), infants saw an object move behind one side of a screen; after a pause, a different object emerged from behind the opposite side of the screen. The screen was either too narrow or sufficiently wide to hide the two objects simultaneously. The results indicated that by 9.5 months of age infants showed surprise at the narrow-screen event when the objects on the two sides of the screen differed in size, shape, and pattern, but not color; only 11.5-month-old infants showed surprise at a narrow-screen event involving a red and a green ball (red–green event). In subsequent experiments, Chapa and Wilcox (1998) attempted to induce 9.5-month-old infants to include color information in their physical representation of the red–green event. Infants received two pairs of priming trials. In the first, a red cup was used to pour salt and a green cup to pound a wooden peg; the second pair was similar except that different red and green objects were used. After receiving these priming trials, infants showed surprise at the red–green event. In line with our speculations above, we would argue that the infants were primed to include color information in their physical representation of the red–green event; this added information then became subject to infants' continuity ('objects continue to exist when hidden') and solidity ('two objects cannot occupy the same space at the time') constraints, and the event was correctly marked as a violation event.[13]

Following Chapa and Wilcox (1998), a similar experiment could be designed to prime young infants to include width information in their physical representations of containment events. For example, infants could see wide objects being pushed off supports and narrow objects being used to pound pegs; next, infants would watch test events involving a wide and a narrow object being lowered into a narrow container. If the analysis presented here is correct, infants should then be more likely (1) to include information about the widths of the objects and container in their representations of the test events, and hence (2) to detect the violation shown in the wide-object test event.

Positive results in such a priming experiment would give rise to many fascinating questions for future research. For example, what properties must priming observations have in order to be effective? How similar or different are the short-term and long-term effects of teaching and priming experiences on infants' physical reasoning? Finally, the preceding speculations suggest that priming should be useful for event categories that are subject to innate principles, but not for other event categories. As an example, consider the finding (discussed in Section 1) that infants aged less than 6.5 months do not consider the amount of contact between a box and a platform when judging the box's stability (Baillargeon et al., 1992). If there are no core principles having to do with support events (e.g. Spelke, 1994; Spelke et al., 1992, 1995), then one would expect priming amount of contact to be ineffective in helping infants detect relevant violations. A key direction for future research, with far-ranging implications, will therefore involve contrasting the effects of priming observations across different event categories.

[13] In additional experiments, Chapa and Wilcox (1998) found that priming trials were ineffective if (1) the red and green objects were simply moved differently (e.g. the red cup was tilted back and forth above the salt and the green cup was moved up and down above the peg; having color predict participation in distinct events seemed important), or (2) the same objects were used in both pairs of priming trials (having two sets of red and green objects participate in the two distinct events also seemed important; see Baillargeon, 1998, for similar effects in teaching experiments).

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