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PAPER

Object individuation in young infants: Further evidence with an event-monitoring paradigm

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Abstract

Recent results indicate that, when tested with an event-monitoring task, 7.5- and 9.5-month-olds give evidence that they can individuate objects in different-objects occlusion events – events in which two distinct objects appear successively on either side of an occluder (Wilcox and Baillargeon, in press). The present research sought to confirm and extend these findings. The experiments examined 7.5- and 4.5-month-olds' ability to correctly interpret a different-objects (ball-box condition) and a same-object (ball-ball condition) occlusion event. The infants in the ball-box condition saw a test event in which a ball disappeared behind the left edge of a screen; after a pause, a box emerged from behind the screen's right edge. For half of the infants (wide-screen event), the screen was wide and could occlude the ball and box simultaneously; for the other infants (narrow-screen event), the screen was narrow and should not have been able to occlude the ball and box at the same time. The infants in the ball-ball condition saw identical wide- and narrow-screen events except that the ball appeared on both sides of the screen. The infants in the ball-box condition looked reliably longer at the narrow- than at the wide-screen event, whereas those in the ball-ball condition tended to look equally at the events. These results suggest that the ball-box infants (a) were led by the featural differences between the ball and box to view them as distinct objects; (b) judged that the ball and box could both be occluded by the wide but not the narrow screen; and (c) were surprised in the narrow-screen event when this judgment was violated. In contrast, the ball-ball infants (a) assumed, based on the featural similarities of the balls that appeared on either side of the screen, that they were one and the same ball, and (b) realized that the ball could be occluded by either the wide or the narrow screen. These results indicate that, by 4.5 months of age, infants are able to use featural information to correctly interpret different-objects and same-object occlusion events. These findings are discussed in the context of the newly-drawn distinction between event-monitoring and event-mapping paradigms (Wilcox and Baillargeon, in press).

As they look about them, infants often observe occlusion events: a parent may leave a room or kneel behind a counter, a sibling may slide under a blanket or crouch behind a sofa, a toy car may roll into a box or under a bed. How well do infants understand such events? Traditionally, investigators assumed that infants possess very little knowledge about occlusion events (e.g., Piaget, 1954). This conclusion was based primarily on results obtained with object-manipulation measures. With the advent of more sensitive, visual-attention measures, however, researchers have come to realize that even young infants are able to represent and to reason[1] about occlusion events (for reviews, see Baillargeon, 1993; Mandler, in press; and Spelke, Breinlinger, Macomber, and Jacobson, 1992).

Many of the investigations of infants' responses to occlusion events that have been conducted using visual-attention measures have shared the same general approach. In a typical experiment, infants first see one or more objects in an otherwise empty apparatus; infants are thus given unambiguous spatiotemporal information

[1] The term 'reason' is used here very generally to refer to the mental processes involved in the representation and manipulation (e.g., selection, retrieval, comparison) of information (e.g., perceptual representations, images, concepts). One reason for preferring the term 'reason' to other terms is that it conveys an element of directedness (Gleitman, 1991): it suggests that infants' mental activities are aimed at a particular goal (e.g., determining whether or not two objects can be simultaneously occluded when behind a narrow screen).

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about the number of objects present in the apparatus. Next, a screen is introduced and the objects are occluded. Test trials are designed to examine whether infants realize that the occluded objects (a) continue to exist; (b) retain their featural and spatial properties; and (c) remain subject to the physical regularities that govern the behavior of visible objects (e.g., Arterberry, 1993; Baillargeon, 1986, 1987; Baillargeon, Graber, DeVos, and Black, 1990; Baillargeon, Spelke, and Wasserman, 1985; Peterson, 1997; Spelke *et al.*, 1992; Wilcox, Nadel, and Rosser, 1996).

As an illustration of this approach, consider an experiment conducted by Spelke *et al.* (1992) with 4-month-olds. The infants were habituated to the following event sequence. First, a ball was held above a gap in a large horizontal surface positioned above an apparatus floor; the ball was slightly smaller than the gap. Next, a screen was raised to hide the gap, and the ball was dropped behind the screen. After a pause, the screen was removed to reveal the ball resting on the apparatus floor, below the gap. Following habituation, the infants saw a possible and an impossible test event. These events were identical to the habituation event except that a smaller (possible event) or a larger (impossible event) ball was used. The infants looked reliably longer at the impossible than at the possible event, suggesting that they (a) believed that each ball continued to exist and retained its width behind the screen; (b) realized that the width of each ball relative to that of the gap determined whether the ball could pass through the gap; and therefore (c) were surprised when the large but not the small ball was revealed below the gap.

In contrast to the experiments discussed above, recent investigations of infants' responses to occlusion events have tended to focus on a different set of issues. In a typical experiment, infants first see objects appear successively at the opposite edges of a screen; infants are thus *not* given unambiguous spatiotemporal information about the number of objects in the apparatus. Test trials are designed to examine whether infants are capable of using alternative sources of information, such as featural information, to determine how many objects are present behind the screen – or, in other words, to individuate the objects involved in the event (e.g., Leslie, Hall, and Tremoulet, 1996; Spelke, Kestenbaum, Simons, and Wein, 1995; Wilcox and Baillargeon, in press; Xu and Carey, 1996). The present experiments built on these results and examined 7.5- and 4.5-month-olds' ability to use featural information to individuate objects in occlusion events. Before describing this research, we first review recent findings in this area.

Event monitoring and event mapping

Are infants, like adults, able to use featural information to determine how many objects are involved in an occlusion event? Recent findings indicate that the answer to this question depends on the paradigm that is used to ask it: experiments conducted with *event-mapping* tasks have typically yielded negative results, whereas experiments conducted with *event-monitoring* tasks have typically produced positive results. In event-mapping tasks, infants first see an occlusion event in which one or two objects move back and forth behind a screen. Next, the screen is removed, and infants are shown a test display involving either one or two objects. In order to respond correctly to each test display, we have argued (Wilcox and Baillargeon, in press), infants must retrieve a representation of the occlusion event, map it onto the display before them, and judge whether the two are consistent. In event-monitoring tasks, infants again watch an occlusion event in which one or two objects move back and forth behind a screen. However, the screen is *not* removed; infants simply monitor the event as it unfolds, and judge whether successive portions of the event are consistent. Below, we illustrate the contrast between event-mapping and event-monitoring tasks with two examples. In the first, we consider experiments that presented infants with occlusion events in which the same object appeared on either side of the occluder (same-object events); in the second example, we focus on experiments in which different objects appeared on the two sides of the occluder (different-objects events).

Same-object occlusion events

Spelke *et al.* (1995) examined 4-month-olds' responses to a same-object occlusion event using an event-mapping task. The infants were first habituated to a cylinder that moved back and forth along a track whose center was occluded by a wide screen. Next, the screen was removed, and the infants saw a one- and a two-cylinder test event. In the one-cylinder event, a single cylinder moved back and forth along the track. In the two-cylinder event, two identical cylinders moved sequentially along the track, one to the left and one to the right of the area formerly occluded by the habituation screen. The infants tended to look equally at the one- and two-cylinder test events. This negative result was confirmed in a second experiment conducted with a similar procedure (Spelke *et al.*, 1995). The authors concluded that 4-month-olds make no assumption, when they see an object move back and forth behind a screen, as to whether one or two objects are involved in the event.

This conclusion is inconsistent with the results of experiments conducted with infants aged 2.5 to 5.5 months using event-monitoring tasks (e.g., Aguiar and Baillargeon, 1997a, b; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987). In one experiment, for example, 3-month-olds were habituated to a toy mouse that moved back and forth behind a wide screen (Aguiar and Baillargeon, 1997a). Following habituation, the infants saw a possible and an impossible test event. These events were similar to the habituation event except that a portion of the screen's midsection was removed to create a large window. In the possible event, the window was located in the screen's upper half; the mouse was shorter than the window's lower edge and so did not appear in the window when passing behind the screen. In the impossible event, the window was located in the screen's lower half; in this event, the mouse should have appeared in the window but did not in fact do so. The infants looked reliably longer at the impossible than at the possible event. These and control results indicated that the infants (a) believed that a single mouse was involved in the habituation and test events; (b) expected the mouse to appear in the low but not the high window; and hence (c) were surprised in the impossible event when this expectation was violated. Had the infants been unsure about the number of mice involved in the habituation and test events, they would have had no reason to be surprised when no mouse appeared in the low window in the impossible event; the fact that they did show surprise at this event indicates that they assumed that a single mouse was present in the apparatus (see Aguiar and Baillargeon, 1997a).

The discrepancy between the results of Spelke *et al.* (1995) and Aguiar and Baillargeon (1997a) is not entirely surprising when one considers the requirements associated with their respective tasks. To be successful, the infants tested by Spelke *et al.* had to compare the one- or two-cylinder test event before them to the habituation event they had seen earlier. The infants thus had to retrieve a representation of the habituation event, map it onto the test event before them, and determine whether the two were consistent. The situation was very different for the infants tested by Aguiar and Baillargeon. To correctly respond to the possible and impossible test events, the infants did not need to compare them to the earlier habituation event;[2] the infants had only to focus on the test event before them and judge whether successive portions of the event were consistent (see also Aguiar and Baillargeon, 1997b; Baillargeon and DeVos, 1991; and Baillargeon and Graber, 1987).

Taken together, the findings presented above suggest two conclusions. First, infants as young as 2.5 or 3 months of age are able to individuate objects in same-object occlusion events. Second, whether infants give evidence of this ability depends on the task that is used to assess it: tasks that require infants to engage in event mapping are less likely to yield positive results than are tasks that require only event monitoring.

Different-objects occlusion events

Xu and Carey (1996) examined 10-month-olds' responses to different-objects occlusion events using an event-mapping task. The infants first received introductory trials in which they saw one or two objects (e.g., a rabbit; a rabbit and a basket). Next, the infants received test trials. At the start of each trial, one object (e.g., a ball) emerged from behind the left edge of a wide screen and then returned behind the screen; after a pause, a different object (e.g., a bottle) moved from behind the right edge of the screen and then returned behind the screen. The process was repeated until the infants had observed multiple emergences of each object. At that point, the screen was turned aside to reveal either one object (e.g., a ball) or two distinct objects (e.g., a ball and a bottle). The infants looked reliably longer at the two- than at the one-object display during both the introductory and the test trials. Xu and Carey took their results to suggest that the infants (a) did not realize that the featural differences between the objects that emerged on either side of the screen signaled the presence of two distinct objects and hence (b) found neither the one- nor the two-object test display surprising. The infants' test responses thus reflected only their intrinsic preference for the two- over the one-object test display (a preference suggested by the infants' introductory data). Similar results were obtained in additional experiments conducted with related event-mapping procedures (Xu and Carey, 1996; see also Leslie *et al.*, 1996, and Wilcox and Baillargeon, in press).

The negative findings of Xu and Carey (1996) contrast with positive results we obtained with 9.5- and 7.5-month-olds in experiments conducted with event-monitoring tasks (Wilcox and Baillargeon, in press). In one experiment, the infants first received familiarization trials in which a ball moved behind the left edge of a very wide screen that occluded the center and right portions of the apparatus; after a long pause, the ball reappeared at the screen's left edge and returned to its

[2] This is not to say that the habituation event was of no use to the infants; being familiar with the mouse and the habituation screen no doubt made it easier for the infants to focus on and reason about the opening in the test screen.

starting position. Following the familiarization trials, the very wide screen was replaced with a narrower test screen that occluded only the center portion of the apparatus. As before, the ball moved behind the left edge of the screen; after a pause, a box emerged at the screen's right edge and moved to the right. The entire sequence was then repeated in reverse. For half of the infants (wide-screen condition), the test screen was sufficiently wide to occlude the ball and box simultaneously; for the other infants (narrow-screen condition), the test screen was too narrow to occlude the two objects at once. The infants in the narrow-screen condition looked reliably longer during the test trials than did those in the wide-screen condition. These and control results indicated that the infants (a) were led by the featural differences between the ball and box to view them as distinct objects; (b) realized that the ball and box could both be occluded by the wide but not the narrow screen; and hence (c) were surprised in the narrow-screen condition when this judgment was contradicted.

The discrepancy between the results of Xu and Carey (1996) and our own results (Wilcox and Baillargeon, in press) can again be understood in terms of the different requirements associated with event-mapping and event-monitoring tasks. In order to be successful, the infants tested by Xu and Carey had to compare the one- or two-object test display before them to the preceding occlusion event. According to the present analysis, this comparison required the infants to retrieve a representation of the occlusion event, map it onto the test display before them, and determine whether the two were consistent. The infants we tested, on the other hand, had only to monitor the narrow- or wide-screen test event before them and judge whether successive portions of the event were consistent.

The research reviewed in this section suggests two conclusions. First, infants as young as 7.5 months of age are able to use featural information to individuate objects in different-objects occlusion events. Second, whether infants reveal this ability depends on the task that is used to assess it: event-mapping tasks yield less successful performances than do event-monitoring tasks.

The present research

The present research examined the responses of 7.5-month-olds (Experiment 1) and 4.5-month-olds (Experiment 2) to different-objects and same-object occlusion events. The infants were tested with an event-monitoring task adapted from that in our initial experiments (Wilcox and Baillargeon, in press).

There were two main reasons to carry out this research. The first was to confirm and extend our previous results with 9.5- and 7.5-month-olds (Wilcox and Baillargeon, in press). Recall that in these experiments infants were shown only different-object events; in the present research, however, as was noted above, infants were presented with both different-objects and same-object events. The second reason to conduct the present research was to ascertain whether younger, 4.5-month-old infants are also able to use featural information to individuate objects in occlusion events. The experiments reviewed above on same-object occlusion events suggest that, when tested with an event-monitoring task, young infants give evidence that they view such events as involving a single object (e.g., Aguiar and Baillargeon, 1997a, b; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987). However, the findings do not make clear what is the basis of infants' responses. Do infants compare the featural properties of the objects that appear on either side of the occluder and conclude that a single object is present when the properties are similar? Or do infants bypass any featural analysis of the objects and reach their conclusion on an entirely different basis, such as a comparison of the objects' motions? We reasoned that evidence that 4.5-month-olds respond differentially to different-objects and same-object occlusion events, even when they involve similar object motions, would help resolve this issue. Such results would indicate that, in the absence of unambiguous spatiotemporal information, infants as young as 4.5 months of age are capable of using featural information to determine how many objects are involved in an occlusion event.

Experiment 1

In a recent series of experiments, we found that, when tested with an event-monitoring task, 7.5-month-olds give evidence that they can use featural information to individuate the objects in a different-objects occlusion event (Wilcox and Baillargeon, in press). Experiment 1 was designed to confirm and extend these results. The infants were assigned to a ball-box or a ball-ball condition. The infants in the *ball-box* condition (see Figure 1) were first familiarized with the following event: a green ball resting at the left end of a platform moved to the right until it disappeared behind the left edge of a wide yellow screen; after a pause, a red box appeared at the screen's right edge and moved to the right end of the platform. The entire sequence was then repeated in reverse: the box returned behind the screen, and then the ball returned to its starting position at the left end of the

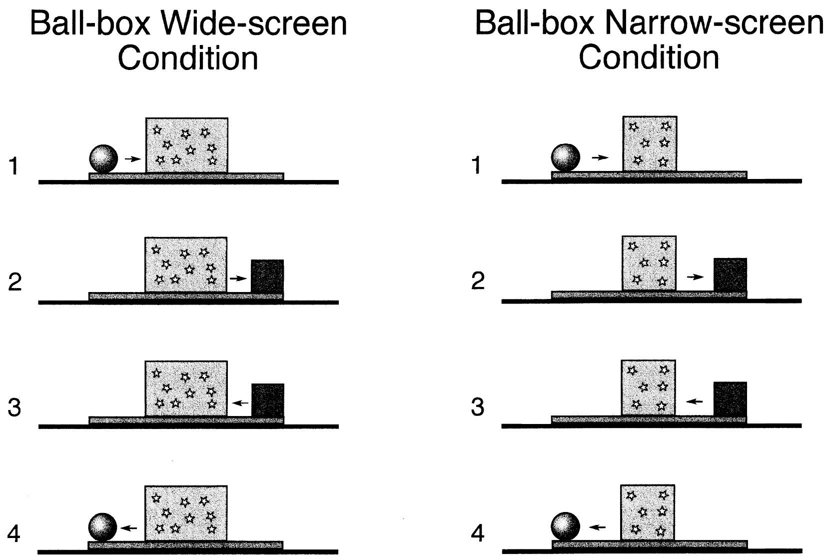

Figure 1. *Schematic drawing of the test events in the ball-box narrow- and wide-screen conditions in Experiment 1.*

platform. Following the familiarization trials, the infants saw a test event identical to the familiarization event, with one exception: the screen was replaced with one of two novel test screens. Both test screens were blue, decorated with stars, and shorter in height than the familiarization screen (these changes were intended to help the infants notice the introduction of the novel test screens). The only difference between the two test screens had to do with their widths. One screen (wide-screen condition) was of the same width as the familiarization screen and was sufficiently large to occlude the ball and box at the same time. The other test screen (narrow-screen condition) was narrower than the familiarization and wide test screens; the width of the narrow test screen was in fact smaller than the combined width of the ball and box, so that it should have been impossible for the narrow screen to simultaneously occlude the two objects. The infants in the *ball-ball condition* (see Figure 2) saw the same familiarization and test events as the infants in the ball-box condition, except that the ball appeared on both sides of the screen.

Our reasoning was as follows. If the infants in the ball-box condition (a) were led by the featural differences between the ball and box to view them as distinct objects; (b) realized that the combined width of the ball and box relative to that of the screen determined

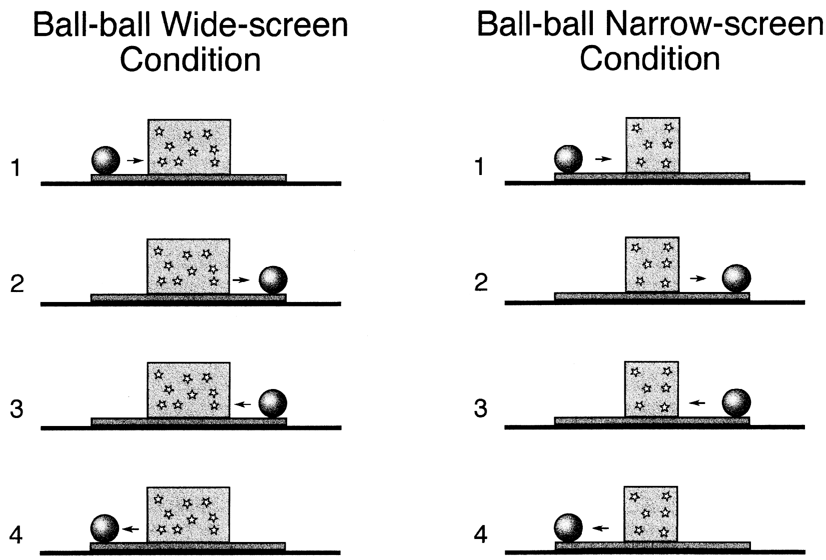

Figure 2. *Schematic drawing of the test events in the ball-ball narrow- and wide-screen conditions in Experiment 1.*

whether the two objects could be simultaneously occluded by the screen; and (c) judged that the ball and box could both be occluded by the wide but not the narrow screen, then the infants in the narrow-screen condition should be surprised when this judgment was violated. Because infants' surprise or puzzlement at an event typically manifests itself by prolonged looking at the event (Bornstein, 1985; Spelke, 1985), the infants in the narrow-screen condition should look reliably longer during the test trials than those in the wide-screen condition. Furthermore, if the infants in the ball-ball condition (a) assumed, based on the featural similarities between the balls that appeared on either side of the screen, that they were one and the same ball, and (b) recognized that the ball could be occluded by either the wide or the narrow screen, then the infants in the narrow- and wide-screen conditions should look about equally during the test trials.

Method

Participants

Participants were 26 healthy fullterm infants, 12 male and 14 female ($M = 7$ months, 18 days; range = 7 months, 2 days to 8 months, 4 days). Five additional infants were tested but eliminated; they failed to complete three valid test trials, three because of procedural problems, one because of fussiness, and one because the infant looked the maximum number of seconds allowed (60 s) on all familiarization and test trials. The infants were randomly assigned to the four experimental groups formed by crossing the two object conditions (ball-box versus ball-ball) and the two screen conditions (narrow versus wide): ball-box narrow-screen ($n = 6$, $M = 7$ months, 19 days); ball-box wide-screen ($n = 7$, $M = 7$ months, 26 days); ball-ball narrow-screen ($n = 6$, $M = 7$ months, 13 days); and ball-ball wide-screen ($n = 7$, $M = 7$ months, 13 days). In this and the next experiment, the infants' names were obtained from birth announcements in the local newspaper. Parents were contacted by letter and follow-up phone calls. Parents in Experiment 1 were offered reimbursement for their travel expenses but were not compensated for their participation.

Apparatus and stimuli

The apparatus consisted of a wooden cubicle 182 cm high, 100 cm wide, and 42 cm deep. The infant sat facing an opening 41 cm high and 94 cm wide in the front wall of the apparatus. The floor of the apparatus was covered with cream colored contact paper, and the side and back walls were covered with patterned contact paper. A platform 1.5 cm tall, 60 cm wide, and 19 cm deep and covered with patterned contact paper lay 4.5 cm from the back wall, centered between the left and right walls; a 6 cm wide piece of light blue flannel lay length-wise down the center of the platform.

The screen used in the familiarization trials was 30 cm wide and 29 cm high; it was made of yellow cardboard and covered with clear contact paper. The wide test screen was 30 cm wide and the narrow test screen 21 cm wide; both screens were 21.5 cm high, were made of blue cardboard decorated with small gold and silver stars, and were covered with clear contact paper. The familiarization and test screens were all mounted on metal legs.

The ball was 10.25 cm in diameter, made from styrofoam, and painted green with evenly spaced red, blue, and yellow dots. The ball had a thin wooden stick (not visible from the infants' viewpoint) attached to its back that protruded through a slit in the back wall. This slit was 2 cm high and 48 cm wide, was located 7 cm above the apparatus floor, and was partly concealed by a cream-colored fringe. By moving the ball's stick along the slit, an experimenter could move the ball left and right along the platform. The experimenter's hand holding the stick was concealed from the infants' view by the ball, the back wall, and the fringe covering the slit; as an added precaution, the hand also wore a cream-colored glove that blended with the fringe.

The box was 11.75 cm square, made of cardboard, and covered with red felt decorated with evenly spaced silver thumbtacks.[3] The box was open on its left side and also had an open channel in its back. After it moved behind the screen, the ball entered the box through its left open side; the ball's stick protruded through the channel at the back of the box and was used to move the box. The box was first rotated clockwise so that its open

[3] Since the ball was 10.25 cm wide and the box 11.75 cm wide, the narrow screen, which was 21 cm wide, was only 1 cm narrower than the ball and box combined. It might be thought that such a small violation would have been impossible even for adults to detect reliably. Nevertheless, our positive results with 9.5- and 7.5-olds (Wilcox and Baillargeon, in press) were obtained using a 1-cm violation similar to the one used here. In addition, data collected with adult subjects (Wilcox and Baillargeon, in press) indicated that they not only readily perceived the narrow-screen violation, but believed it was several times greater than it actually was (see Figure 1). Subjects apparently assumed that the ball, rather than stopping abruptly as soon as it was out of sight, pursued its trajectory for some distance behind the screen; this of course contributed to the perception that the screen was too narrow to simultaneously hide the ball and box. In Experiment 2, a different process was used to produce the events that made it possible to present the infants in the ball-box narrow-screen violation with a larger, 5-cm violation.

side faced down; the box could then be moved to the right of the screen. Because the box's open side faced down, the opening was not visible to the infants when the box was in view. After it returned behind the screen, the box was rotated counter-clockwise and the ball was free to emerge from the box's open side.

To equate as much as possible the procedures used in the ball-box and ball-ball conditions, a 'fake' box was placed behind the screen in the ball-ball condition. This box was 11.75 cm square, made of light weight metal, and covered with red felt. The fake box had two open sides (right and left) and an open channel in the back so that the ball and its attached stick could move through the box.

A muslin-covered frame 61 cm high and 100 cm wide was lowered in front of the opening in the front wall of the apparatus at the end of each trial. Two wooden frames, each 182 cm high and 69 cm wide and covered with yellow cloth, stood at an angle on either side of the apparatus. These frames isolated the infants from the experimental room. In addition to the room lighting, two 20-watt fluorescent bulbs 59 cm long were affixed to the inside front wall of the apparatus.

Events

One experimenter produced the events. The numbers in parentheses indicate the time taken to produce the actions described. A metronome ticked softly once per second to help the experimenter adhere to the events' scripts.

Ball-box narrow-screen condition

Familiarization event At the start of each familiarization trial, the ball sat with its center 6 cm from the left end of the platform. The familiarization screen stood upright and centered in front of the platform, and the box sat behind the screen.

Each familiarization trial began with a brief pretrial during which the observers monitored the infant's looking at the ball until the computer signaled that the infant had looked for 1 cumulative second. After a 1-s pause, the ball moved behind the screen and entered the box, which was quickly rotated (2 s). The box then emerged from behind the screen and moved to the right until its center was 6 cm from the right end of the platform (2 s). After a 1-s pause, the box returned to its original position behind the screen and was again quickly rotated (2 s). The ball then emerged from the box and returned to its starting position at the left end of the platform (2 s). When in view, the ball and box moved at a speed of about 12 cm per s; when out of view, the objects were moved slightly faster to allow time for the box's rotation. The 10-s event sequence just described was repeated continuously until the trial ended.

Test event The test event was identical to the familiarization event except that the familiarization screen was replaced with the narrow test screen.

Ball-box wide-screen condition

The familiarization and test events in the ball-box wide-screen condition were identical to those in the ball-box narrow-screen condition except that the narrow test screen was replaced with the wide test screen.

Ball-ball narrow- and wide-screen conditions

The familiarization and test events in the ball-ball narrow- and wide-screen conditions were identical to those in the ball-box narrow- and wide-screen conditions, respectively, with two exceptions. First, the ball, rather than the box, emerged to the right of the screen. Second, to prevent infants and observers from distinguishing between the ball-box and ball-ball conditions on the basis of faint noise cues associated with the lifting and lowering of the box (when rotated) in the ball-box condition, the fake box was used. After moving behind the screen, the ball entered the fake box, which was then quickly lifted and lowered; the ball then exited the fake box through its other open side.

Procedure

The infant sat on a parent's lap centered in front of the apparatus. The infant's head was approximately 78 cm from the objects on the platform. The parent was asked not to interact with the infant while the experiment was in progress and to close his or her eyes during the familiarization and test trials.

Each infant participated in a two-phase procedure that consisted of a familiarization and a test phase. During the *familiarization* phase, the infants saw the familiarization event appropriate for their condition on six successive trials. Each trial ended when the infant (a) looked away for 2 consecutive seconds after having looked at the event for at least 5 cumulative seconds (beginning at the end of the pretrial) or (b) looked for 60 cumulative seconds without looking away for 2 consecutive seconds. During the *test* phase, the infants saw the test event appropriate for their condition on three successive trials. The criteria used to terminate the test trials were the same as for the familiarization trials. The 5-s minimum value was chosen to ensure that the infants had the opportunity to observe the box or ball emerge to the right of the screen.

The infant's looking behavior was monitored by two observers who watched the infant through peepholes in the cloth-covered frames on either side of the apparatus. The observers were not told, and could not determine, to which condition each infant was assigned.[4] Each observer held a button connected to a DELL computer and depressed the button when the infant attended to the events. The looking times recorded by the primary observer were used to determine when a trial had ended. 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. Interobserver agreement was measured for 25 of the infants (only one observer was present for one of the infants) and was calculated for each test 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 94% per test trial per infant.

Preliminary analysis of the infants' mean looking times during the test trials did not yield a significant Sex × Object Condition (ball-box versus ball-ball) × Screen Condition (narrow versus wide) interaction, $F(1, 18) = 0.05$; the data were therefore collapsed across sex in subsequent analyses.[5]

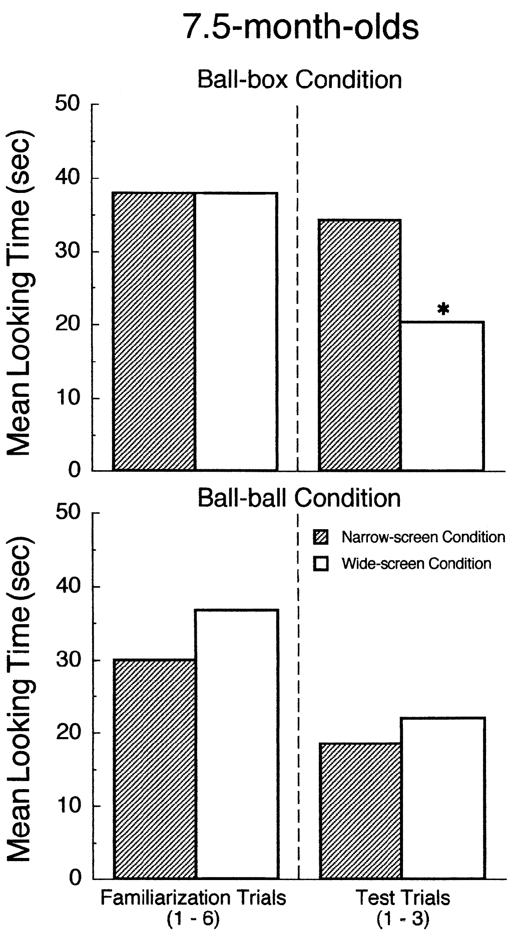

Figure 3. *Mean looking times of the infants in Experiment 1 during the familiarization and test trials.*

Results

Familiarization trials

The infants' looking times during the six familiarization trials (see Figure 3) were averaged, as in Wilcox and Baillargeon (in press), and compared by means of a 2×2 analysis of variance (ANOVA), with Object Condition (ball-box versus ball-ball) and Screen Condition (narrow versus wide) as between-subjects factors. The main effects of object condition, $F(1, 22) = 1.38$, and screen condition, $F(1, 22) = 0.77$, were not significant, both p's > 0.05. In addition, the Object Condition × Screen Condition interaction was not significant, $F(1, 22) = 0.72$, indicating that the infants in the four different conditions did not differ reliably in their mean looking times during the familiarization trials (ball-box narrow-screen, $M = 37.8$, $SD = 6.8$; ball-box wide-screen, $M = 38.0$, $SD = 10.9$; ball-ball narrow-screen, $M = 30.0$, $SD = 10.9$; and ball-ball wide-screen, $M = 36.7$, $SD = 10.1$).

Test trials

The infants' mean looking times during the three test trials (see Figure 3) were averaged and analyzed in the same fashion as the familiarization trials. The main effects of object condition, $F(1, 22) = 3.52$, and screen condition, $F(1, 22) = 1.90$, were not significant, both p's > 0.05. However, the Object Condition × Screen

[4] The infants in Experiments 1 and 2 were presented with test events in which a ball or a ball and box appeared on either side of a screen. For all 54 infants in these experiments, the primary experimenter was asked at the end of each test session whether the infant had seen the same object or different objects on the two sides of the screen. The primary observer guessed correctly for only 30/54 infants, a performance not significantly different from chance (cumulative binomial probability, $p > 0.05$).

[5] Because of the small number of infants in each Sex × Object Condition × Screen Condition cell, this analysis needs to be interpreted with caution. The same caveat applies to the sex analysis in Experiment 2, which also yielded negative results.

Condition interaction was significant, $F(1, 22) = 5.30$, $p < 0.05$. Planned comparisons indicated that, in the ball-box condition, the infants who saw the narrow-screen event ($M = 34.2$, $SD = 8.6$) looked reliably longer than those who saw the wide-screen event ($M = 20.4$, $SD = 8.2$), $F(1, 22) = 6.76$, $p < 0.025$; in the ball-ball condition, in contrast, no reliable difference was found between the looking times of the infants who saw the narrow- ($M = 18.5$, $SD = 11.0$) or the wide-screen ($M = 22.0$, $SD = 10.3$) event, $F(1, 22) = 0.43$.[6]

Discussion

In the ball-box condition, the infants looked reliably longer when tested with the narrow as opposed to the wide screen; in the ball-ball condition, in contrast, the infants tended to look equally whether they were tested with the narrow or the wide screen. Together, these results suggest that the infants (a) were led by the available featural information to view the objects that emerged on either side of the screen as two distinct objects in the ball-box condition and as the same object in the ball-ball condition; (b) judged that the ball and box could both be occluded by the wide but not the narrow screen, whereas the ball alone could be occluded by either screen; and hence (c) were surprised in the ball-box narrow-screen condition when the ball and box were out of view at the same time.[7] These findings confirm our earlier results (Wilcox and Baillargeon, in press) and provide further evidence that 7.5-month-old infants can use featural information to individuate objects in occlusion events. The present findings also extend our previous results in that they indicate that infants are sensitive to both featural similarities and differences. Recall that the infants in our initial experiments were shown only different-objects occlusion events; the infants in Experiment 1 were shown same-object as well as different-objects events, and they interpreted both in a manner consistent with their featural content.

It might be objected that other, less interesting explanations could be offered for the results of Experiment 1. For example, one could argue that the infants in the ball-box condition looked reliably longer at the narrow- than at the wide-screen event because they found the narrow screen more attractive than the wide screen, or because they could see the objects for a longer time on the left and right of the narrow screen. These explanations are unlikely, however, for two reasons. First, the infants in the ball-ball condition did not show a reliable preference for the narrow- over the wide-screen event (recall that the analysis of the test trials did not reveal a significant main effect of screen condition). Second, data from two previous experiments with 7.5-month-olds support the interpretation offered here (Wilcox and Baillargeon, in press). The infants in one experiment were tested with a narrow and a wide screen similar to those in Experiment 1; half of the infants saw a ball and box identical to the ones used here, and half saw a smaller ball and box that could be simultaneously occluded by the narrow screen. Only the infants tested with the larger ball and box showed a reliable preference for the narrow-screen event. In another experiment, the small ball and the large box from the preceding experiment were used in conjunction with a screen that was either too narrow (narrow-screen event) or sufficiently large (wide-screen event) to occlude them simultaneously. The infants again looked reliably longer at the narrow- than at the wide-screen event. Although it would be possible to attribute the results of these various experiments to an arbitrary baseline preference for the narrow-screen event involving the large ball and large box or small ball and large box over all of the other narrow- and wide-screen events used in the experiments, such an explanation seems, at best, unparsimonious.

[6] Although the analysis of the familiarization data did not yield a significant main effect of object condition ($p = 0.25$), there was nevertheless a tendency for the ball-box infants to look longer than the ball-ball infants during the familiarization trials (see Figure 3). In light of this tendency, the test data were also subjected to an analysis of covariance (ANCOVA); the factors were the same as in the ANOVA, and the covariate was the infants' mean familiarization looking times. The purpose of this analysis was to examine whether the same test results would obtain after adjusting for the differences in looking times between the infants in the ball-box and ball-ball conditions. The results of the ANCOVA replicated those of the ANOVA: the Object Condition × Screen Condition interaction was significant, $F(1, 21) = 4.54$, $p < 0.05$, and planned comparisons confirmed that the ball-box infants looked reliably longer at the narrow- than at the wide-screen event, $F(1, 21) = 6.59$, $p < 0.025$, whereas the ball-ball infants looked about equally at the events, $F(1, 21) = 0.23$.

[7] It might be suggested that the infants in the ball-box narrow-screen condition were surprised for a different reason than the one just outlined: perhaps the infants, upon realizing that the ball and box could not stand side by side behind the narrow screen, concluded that the objects abruptly changed course when out of view so as to rest one in front of the other, between the screen and the apparatus's back wall. Although this alternative interpretation is logically possible, it is less parsimonious than the one given in the text. Both interpretations assume that the infants in the narrow-box condition recognized that (a) the ball and box were distinct objects and (b) the two objects could not be fully occluded when standing side by side behind the narrow screen. However, the alternative interpretation makes a further assumption, which is that the infants generated an explanation for the violation they observed – an abrupt trajectory change behind the screen – which in turn led to their prolonged looking.

Experiment 2

Experiment 2 examined whether younger, 4.5-month-old infants would succeed when tested with the same task as in Experiment 1. There were two reasons to expect positive results in this experiment. First, recent findings by Needham and her colleagues (e.g., Needham, in press; Needham and Baillargeon, 1997; Needham, Baillargeon, and Kaufman, 1997) indicate that, contrary to earlier claims (e.g., Kellman and Spelke, 1983; Spelke, 1990; Spelke, Breinlinger, Jacobson, and Phillips, 1993), infants as young as 4.5 months of age use featural information to organize stationary adjacent and partly occluded displays. In the experiments in which infants were presented with a partly occluded display, similar or dissimilar surfaces were visible on either side of a screen; only featural information could be used to determine whether the surfaces belonged to the same object or to distinct objects. The infants' interpretation of the display was assessed by means of an event-monitoring task. To illustrate, in one experiment, 4.5-month-olds received familiarization trials in which they saw a stationary dissimilar partly occluded display (Needham, in press). This display consisted of a yellow cylinder and a tall blue box that protruded from behind the left and right edges, respectively, of a tall narrow screen. Next, the infants received test trials in which a hand grasped the cylinder and moved it back and forth toward and away from the screen. For half of the infants (move-together condition), the box moved with the cylinder; for the other infants (move-apart condition), the box remained stationary. The infants in the move-together condition looked reliably longer than did those in the move-apart condition. These and control results indicated that the infants (a) were led by the featural differences between the cylinder and box to view them as two distinct objects and (b) expected the cylinder to move alone and were surprised that it did not. These and related findings (see Needham *et al.*, 1997, for a review), suggest that, when tested with an event-monitoring task, infants as young as 4.5 months of age give evidence that they can use featural information to judge how many objects are included in a similar or a dissimilar partly occluded display.

The evidence just reviewed suggested that the 4.5-month-olds in Experiment 2 might be able to use the available featural information to individuate the objects in the ball-ball and ball-box events. But would the infants be able to give evidence of this ability? Consider, for example, the infants in the ball-box narrow-screen condition, who had to compare the combined width of the ball and box to that of the narrow screen. How likely were the infants to succeed at this task? The second reason to expect positive results in Experiment 2 had to do with this question. There have been several reports over the past few years of infants aged 3.5 months and older attending to objects' width or height when reasoning about various physical events (e.g., Aguiar and Baillargeon, in press; Baillargeon, 1987, 1991; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987; Sitskoorn and Smitsman, 1995; Spelke *et al.*, 1992). Of particular relevance here is the experiment by Spelke *et al.* (1992) that was described in the introduction; recall that 4-month-old infants successfully compared the width of a ball to that of a gap to determine whether the one could pass through the other behind a screen. In light of such results, it seemed possible that the 4.5-month-olds in Experiment 2 would also succeed at the width comparison task they were given.

Method

Participants

Participants were 28 healthy fullterm infants, 14 male and 14 female ($M = 4$ months, 23 days; range = 4 months, 3 days to 5 months, 15 days). Seven additional infants were tested but eliminated; they failed to complete six valid test trials, one because of procedural problems, two because of fussiness, and four because the primary observer was unable to follow the direction of the infant's gaze. Seven infants were randomly assigned to each of the four experimental conditions: ball-box narrow-screen ($M = 4$ months, 22 days); ball-box wide-screen ($M = 4$ months, 26 days); ball-ball narrow-screen ($M = 4$ months, 22 days); and ball-ball wide-screen ($M = 4$ months, 23 days).

Apparatus and stimuli

The apparatus and stimuli used in Experiment 2 were similar to those in Experiment 1, except that a different system was used to change the objects behind the screen. As was noted earlier, this new system made it possible to present the infants in the ball-box narrow-screen condition with a 5-cm instead of a 1-cm violation. The modifications introduced were as follows. First, a new box was used that was closed on all sides and was 10.25 cm square, rather than 11.75 cm square; thus, the box was now of the same width as the ball. Second, the ball and box each rested on a Plexiglas base 10 cm wide, 6.5 cm deep, and 0.3 cm thick. Each base had a handle 16 cm long that protruded through an opening 3.25 cm high between the back wall and floor of the apparatus; the opening was partly concealed by cream-colored fringe. By moving the Plexiglas handle, an experimenter could move the ball and box left and right along the platform. Third, two identical balls were used in the ball-ball condition; one appeared to the left and one to the right of the screen. Fourth, embedded in the center of the platform was a metal bi-level composed of an upper and a lower shelf 16 cm apart; each shelf was 12.7 cm wide, 13 cm deep, and 0.2 cm thick. The upper shelf was level with the top of the platform and the bottom shelf extended underneath the platform. The bi-level could be lifted by means of a handle 19 cm long that protruded through an opening 19.5 cm high and 7 cm wide in the apparatus's back wall; when the bi-level was lifted, its lower shelf became level with the platform. Finally, the screen used in the familiarization trials was 30 cm wide and 41 cm high; it was made of yellow cardboard and covered with clear contact paper. The wide test screen was 30 cm wide and 33 cm high and the narrow test screen was 15.5 cm wide and 41 cm high; the wide test screen thus differed from the familiarization screen in height and the narrow test screen in width. Both test screens were made of blue cardboard, were decorated with small gold and silver stars, and were covered with clear contact paper. The screens were mounted on a wooden stand that was centered in front of the platform.

Events

Ball-box narrow-screen condition

Familiarization event At the start of each familiarization trial, the ball sat with its center 6 cm from the left end of the platform. The familiarization screen stood upright and centered in front of the platform, and the box sat on the lower shelf of the bi-level.

Each familiarization trial began with a brief pretrial during which the observers monitored the infant's looking at the ball until the computer signaled that the infant had looked for 1 cumulative second. After a 1-s pause, the ball moved to the right until it reached the upper shelf of the bi-level behind the screen (2 s). Next, the bi-level was lifted until its lower shelf was level with the platform (1 s); the box then emerged from behind the screen and moved to the right until its center was 6 cm from the right end of the platform (2 s). After a 1-s pause, the box returned to the bi-level (2 s) which was lowered (1 s) until its top shelf was once again level with the platform; the ball then returned to its starting position at the left end of the platform (2 s). The ball and box moved at a speed of about 12 cm per s. The 12-s event sequence just described was repeated continuously until the trial ended.

Test event The test event was identical to the familiarization event except that the familiarization screen was replaced with the narrow test screen.

Ball-box wide-screen condition

The familiarization and test events in the ball-box wide-screen condition were identical to those in the ball-box narrow-screen condition except that the narrow test screen was replaced with the wide test screen.

Ball-ball narrow- and wide-screen conditions

The familiarization and test events in the ball-ball narrow- and wide-screen conditions were identical to those in the ball-box narrow- and wide-screen conditions, respectively, with one exception: the box was replaced with a second, identical ball.

Procedure

The procedure used in Experiment 2 was identical to that in Experiment 1, with two exceptions. First, the infants saw six, rather than three, successive test trials. Pilot data suggested that the infants enjoyed the task and rarely became fussy, making it possible to give them more test trials (in our earlier research with infants aged 7.5 to 11.5 months, infants tended to become less attentive as the experiment progressed and so were typically given fewer trials; see Wilcox and Baillargeon, in press). Second, because each event cycle now lasted 12 s, instead of 10 s, the criteria used for terminating the familiarization and test trials were modified slightly. Each trial now ended when the infant either (a) looked away for 2 consecutive seconds after having looked at the event for at least 6 cumulative s (beginning at the end of the pretrial) or (b) looked for 60 cumulative seconds without looking away for 2 consecutive seconds.

Interobserver agreement averaged 90% per test trial per infant. Preliminary analysis of the infants' mean looking times during the test trials did not yield a significant Sex × Object Condition (ball-box or ball-ball) × Screen Condition (narrow or wide) interaction, $F(1, 20) = 0.77$; the data were therefore collapsed across sex in subsequent analyses.

Results

Familiarization trials

The infants' looking times during the six familiarization trials (see Figure 4) were averaged and analyzed as in Experiment 1. The main effects of object condition, $F(1,24) = 3.41$, and screen condition, $F(1,24) = 1.22$, were not significant, both p's > 0.05. In addition, the Object Condition × Screen Condition interaction was not significant, $F(1,24) = 0.01$, indicating that the infants in the four different conditions did not differ reliably in their mean looking times during the familiarization trials (ball-box narrow-screen, $M = 37.1$, $SD = 9.3$; ball-box wide-screen, $M = 42.1$, $SD = 9.1$; ball-ball narrow-screen, $M = 27.8$, $SD = 15.1$; ball-ball wide-screen, $M = 33.5$, $SD = 16.1$).

Test trials

The infants' mean looking times during the six test trials (see Figure 4) were averaged and analyzed in the same fashion as the familiarization trials. The main effects of object condition, $F(1,24) = 3.33$, and screen condition, $F(1,24) = 1.38$, were not significant, both p's > 0.05. However, the analysis yielded a significant Object Condition × Screen Condition interaction, $F(1,24) = 4.49$, $p < 0.05$. Planned comparisons indicated that, in the ball-box condition, the infants who saw the narrow-screen event ($M = 40.2$, $SD = 10.5$) looked reliably longer than those who saw the wide-screen event ($M = 25.8$, $SD = 13.7$), $F(1,24) = 5.43$, $p < 0.05$; in the ball-ball condition, in contrast, no reliable difference was found between the looking times of the infants who saw the narrow- ($M = 22.9$, $SD = 9.2$) or the wide-screen ($M = 27.1$, $SD = 12.5$) event, $F(1,24) = 0.44$.[8]

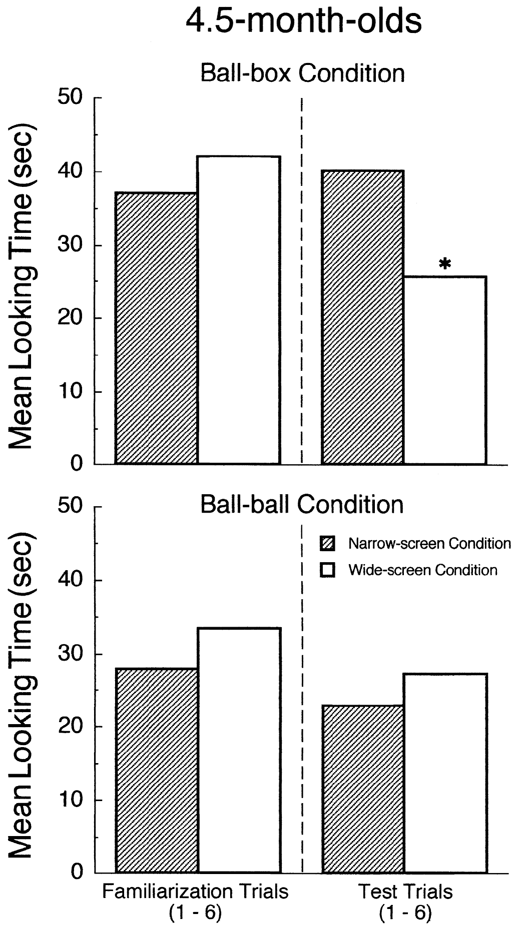

Figure 4. *Mean looking times of the infants in Experiment 2 during the familiarization and test trials.*

Discussion

The 4.5-month-olds in Experiment 2 produced the same test looking pattern as the 7.5-month-olds in Experiment 1. In the ball-box condition, the infants looked reliably longer when tested with the narrow as opposed to the wide screen; in the ball-ball condition, in contrast, the infants tended to look equally whether they were tested with the narrow or the wide screen. These results suggest that the ball-box infants (a) were led by the featural differences between the ball and box to view them as distinct objects; (b) realized that the combined width of the ball and box relative to that of the screen determined whether the two objects could be simultaneously occluded behind the screen; (c) judged that the ball and box could both be occluded by the wide but not the narrow screen; and hence (d) were surprised in the narrow-screen event when this last judgment was violated. On the other hand, the ball-ball infants (a) assumed, based on the featural similarities of the balls that appeared on either side of the screen, that they were one and the same ball; (b) recognized that the ball could be occluded by either the narrow or the wide screen; and

[8] Although the analysis of the familiarization data did not yield a significant main effect of object condition ($p = 0.077$), there was nevertheless a tendency for the ball-box infants to look longer than the ball-ball infants during the familiarization trials (see Figure 4). In light of this tendency, the test data were subjected, as in Experiment 1, to an ANCOVA using the infants' mean familiarization looking times as the covariate. The results of the ANCOVA replicated those of the ANOVA: the Object Condition × Screen Condition interaction was again significant, $F(1,23) = 4.46$, $p < 0.05$, and planned comparisons confirmed that the ball-box infants looked reliably longer at the narrow- than at the wide-screen event, $F(1,23) = 6.14$, $p < 0.025$, whereas the ball-ball infants looked about equally at the events, $F(1,23) = 0.23$.

hence (c) found neither the narrow- nor the wide-screen event surprising.

These results indicate that, by 4.5 months of age, infants are sensitive to featural differences and similarities between objects and use this information to individuate objects in occlusion events. As such, the present results confirm previous positive findings obtained with different-objects (Wilcox and Baillargeon, in press) and same-object (Aguiar and Baillargeon, 1997a, 1997b; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987) occlusion events. The present results also extend these previous reports by making clear that infants' responses to same-object occlusion events are based on a comparison of the featural properties, rather than the motions, of the objects that emerge on either side of the occluder. The 4.5-month-olds in Experiment 2 responded differently when the object that emerged to the right of the screen was a ball as opposed to a box, even though the ball and box underwent similar motions.

The results of Experiment 2 are also consistent with those obtained by Needham and her colleagues in object segregation tasks (e.g., Needham, in press; Needham *et al.*, 1997). Recall that 4.5-month-old infants were found to organize partly occluded displays in accordance with their featural content, grouping together similar but not dissimilar surfaces.

Finally, the present results are consistent with reports in the physical reasoning literature that infants aged 3.5 months and older can use information about the width or height of objects to predict the outcome of events involving the objects (e.g., Baillargeon, 1991; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987; Sitskoorn and Smitsman, 1995; Spelke *et al.*, 1992). The present findings also extend these prior results in two ways. First, they indicate that, by 4.5 months of age, infants recognize that the width of an object relative to that of an occluder determines whether the object will be fully or only partly concealed when behind the occluder. Second, the present research reveals that, when reasoning about an occlusion event, 4.5-month-olds can take into account not only the width of an individual object, but also about the combined width of two distinct objects: the infants in the ball-box condition in Experiment 2 appreciated that, although the ball or box *alone* could be fully occluded by the narrow screen, the two objects *together* could not.

Conclusion

The present research indicates that 7.5- and 4.5-month-old infants can use featural information to determine how many objects are involved in an occlusion event. When the objects that emerge on either side of a screen possess similar featural properties, infants assume that a single object is involved in the event (even though two identical objects may actually be used to produce the event, as in Experiment 2). In contrast, when the objects that emerge on either side of the screen differ in shape, color, and pattern, infants conclude that two distinct objects are present. These results confirm positive findings that have been obtained in similar tasks with same-object (Aguiar and Baillargeon, 1997a, 1997b; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987) and different-objects (Wilcox and Baillargeon, in press) occlusion events. The present results are also consistent with recent reports by Needham and her colleagues (e.g., Needham, in press; Needham *et al.*, 1997) that 4.5-month-old infants attend to featural similarities and differences when segregating stationary adjacent and partly occluded displays. Finally, the present findings bear on previous research on infants' expectations about occlusion events. As was noted in the introduction, a typical approach in many investigations has been to first present infants with one or more objects in an otherwise empty apparatus, and then occlude the objects (e.g., Baillargeon, 1986; Baillargeon *et al.*, 1985, 1990; Peterson, 1997; Spelke *et al.*, 1992; Wilcox *et al.*, 1996). The present results extend this research by showing that infants aged 4.5 months and older can represent and reason about occlusion events even when they are *not* given unambiguous spatiotemporal information about the number of objects in the events and must use featural information to individuate the objects. The infants in Experiments 1 and 2 succeeded in both (a) determining how many objects were present in each test event, based on the available featural information, and (b) judging whether the object(s) could be fully occluded when behind the screen.

At the same time that it confirms and extends positive reports on young infants' ability to use featural information to individuate objects, the present research also makes even more marked the discrepancy between these positive findings and the negative results reported by Spelke *et al.* (1995) and Xu and Carey (1996; see also Leslie *et al.*, 1996, and Wilcox and Baillargeon, in press). Recall that Spelke *et al.* found that 4-month-old infants made no assumption, when shown a same-object occlusion event, as to the number of objects involved in the event. Similarly, Xu and Carey reported that 10-month-old infants were unable to determine, when shown a different-objects occlusion event, whether the event involved one or two objects. How can we account for these discrepant results?

As was discussed in the introduction, we believe that the most likely explanation for this discrepancy has to do with the nature of the tasks used to assess infants' capacity for individuation. All of the tasks that have produced negative results (e.g., Leslie *et al.*, 1996; Spelke *et al.*, 1995; Wilcox and Baillargeon, in press; Xu and Carey, 1996) have made use of *event-mapping* tasks: infants are shown a same-object or a different-objects occlusion event, and then the screen is removed to reveal a test display composed of one or two objects. In contrast, all of the tasks that have produced positive findings (Aguiar and Baillargeon, 1997a, b; Baillargeon and DeVos, 1991; Baillargeon and Graber, 1987; Wilcox and Baillargeon, in press) have used *event-monitoring* tasks: infants are again shown a same-object or a different-objects occlusion event, but the screen is never removed; infants simply monitor the event as it unfolds.

Why are event-mapping tasks more difficult for infants than are event-monitoring tasks? Our explanation for this difference (see Wilcox and Baillargeon, in press, for a fuller account) rests on four assumptions. The first is that, when shown an occlusion event, infants categorize the physical situation before them as one of occlusion. When the screen is later removed, infants assign the situation to a novel category which, for lack of a better term, we will describe as a no-occlusion situation. This re-categorization in turn compels infants to set up a new representation. What is being argued, then, is that instead of viewing the screen's removal simply as a change within an ongoing situation, infants are prompted by the screen's removal to initiate a new and distinct representation.

Our second assumption is that, just as infants are motivated to monitor changes *within* any one physical situation, to determine whether they are consistent with their physical knowledge, infants also seek to keep track of changes *across* situations, to make sense of the world as it unfolds around them. It should be obvious that most of our experimental tools would fail if infants were content to observe the world without reacting to it and evaluating, comparing, and learning from past and present situations.

Our third assumption is that the attempt to link up two successive representations requires, at the very least, mapping or aligning the objects involved in the two representations. Thus, after setting up the new representation, infants attempt to retrieve information about the objects in the previous representation, to align them with those in the present representation.

Our fourth and last assumption is that infants have little difficulty retrieving object information from a prior representation when this information was based on unambiguous spatiotemporal information (e.g., the infants saw the ball and box simultaneously prior to the test trials; see Wilcox and Baillargeon, in press, and Xu and Carey, 1996). When the object information was based on featural information, however, a more complex process seems to be required: infants apparently attempt to retrieve and scan the previous event to determine what objects were involved in it.

The explanation just outlined makes several testable predictions. One is that infants might succeed at an event-mapping task if the occlusion situation were made extremely simple and brief so as to reduce the burden associated with retrieving and scanning the situation. We have recently obtained data confirming this prediction (Wilcox and Baillargeon, in press). In one experiment, 9-month-old infants received a single test trial in which they saw the following event sequence: a box moved a short distance to the right until it disappeared behind the left edge of a wide screen; next, a ball emerged from behind the screen's right edge and moved a short distance to the right; finally, the screen was lowered to the apparatus floor to reveal an empty area (only the ball was visible to the right of the screen). Infants in control conditions saw the same test event except that (a) a ball was shown on either side of the screen or (b) when the screen was lowered, a half-screen was revealed that was sufficiently tall to hide the box. The infants in the experimental condition looked reliably longer than those in the control conditions, suggesting that they expected the box to be revealed when the screen was removed and were surprised when this expectation was violated. Further data indicated that the positive result obtained in this event-mapping task was extremely fragile. When the event sequence shown to the experimental infants was made slightly longer – the box sat behind the screen at the start of the trial and first moved to the left, into view, before proceeding to the right as before – the infants no longer responded with prolonged looking. Adding a single reversal to the box's motion at the start of the event sequence was thus sufficient to confound the infants: they no longer succeeded in judging whether the objects involved in the occlusion situation correctly mapped onto those revealed in the no-occlusion situation.

We are currently testing additional predictions suggested by our explanation for infants' difficulties with tasks involving mappings based on featural information. For example, we are exploring whether the same patterns of results arise when infants are presented with a different pair of physical situations, such as an occlusion and a containment situation. Whatever the outcome of these experiments and the final status of our explanation, however, two broad conclusions have been achieved. First, the view that infants' difficulties with event-mapping tasks stem from an inability to use featural information to individuate objects (e.g., Spelke *et al.*, 1995; Xu and Carey, 1996) seems highly unlikely. The 7.5- and 4.5-month-olds in the present experiments could not have detected the violation embedded in the ball-box narrow-screen event if they had not realized that the ball and box were two distinct objects. Second, the present research and the explanatory framework within which we interpret it underscore the need for a theory that spells out precisely how infants form and use representations of physical events. Within the field of infancy research, several debates have cropped up over the past few years as to the nature and content of infants' representations (e.g., Haith, 1997; Munakata, 1997; Thelen and Smith, 1994). Regardless of their particular perspectives, however, all participants in these debates are coming to the realization that developmental science will not be able to fully explain infants' responses across cognitive tasks and across ages without an explicit account of how infants form and manipulate representations.

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