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Event-mapping tasks: investigating the effects of prior information and event complexity on performance

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Abstract

Infants younger than 11.5 months typically fail in event-mapping tasks with complex event sequences, yet succeed when the event sequences are made very simple and brief. The present research explored whether younger infants might succeed at mapping complex event sequences if infants were given information to help them organize and structure the event. Three experiments were conducted with 7.5-month-olds. In all of the experiments, the infants were shown a two-phase test event. In the first phase, infants saw a box–ball occlusion sequence in which the objects emerged at least once to each side of the screen, reversing direction each time to return behind the screen. In the second phase, infants saw a one-ball display. Prior to the test trials, infants were shown an "outline" of the test event that contained the basic components of the event. The experiments varied in (a) the kind of information included in the event outline and (b) the complexity of the box–ball test sequence (i.e., the number of object reversals). The results revealed that the 7.5-month-olds benefitted from viewing an event outline, although the performance of the males was more robust than the females. These results add to a growing body of research indicating that young infants can succeed on event-mapping tasks under more supportive conditions and provide insight into why event mapping is such a difficult task for young infants.

Keywords: Object individuation; Object representation; Event mapping; Infant cognition

In the dynamic, three-dimensional world in which we live, objects frequently disappear and reappear as they pass behind nearer objects or surfaces. For example, a ball rolls behind one edge of a laundry basket and emerges at the other edge; a cup disappears and then reappears from behind a cereal box as the box is pushed about on the breakfast table; or a set of keys is

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dropped behind a counter and later retrieved. Perhaps one of the most basic cognitive processes in which we engage is that of object individuation: determining whether an object currently in view is the very same object as, or a different object than, the one that disappeared earlier. Recently, infant researchers have shown considerable interest in the origins and development of this ability (e.g., Aguiar & Baillargeon, 2002; Leslie, Xu, Tremoulet, & Scholl, 1998; Spelke, Kestenbaum, Simons, & Wein, 1995; Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b; Wilcox & Chapa, 2003; Wilcox & Schweinle, 2002, 2003; Xu & Carey, 1996).

Current research has generated some debate about whether infants, like adults, can use featural information as the basis for individuating objects. Some of the initial findings were conflicting: whereas some researchers (Xu & Carey, 1996) reported that infants 10 months and younger were unable to use featural information to individuate objects, other researchers (Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b) reported that infants as young as 4.5 months were capable of drawing on featural information. Subsequent research (e.g., Hespos, 2000; Leslie & Glanville, 2001; Wilcox & Baillargeon, 1998a; Wilcox & Chapa, 2002; Wilcox & Schweinle, 2002; for a review see Wilcox, Schweinle, & Chapa, 2003) suggested that the conflicting results could be explained, at least in part, by the information processing demands imposed by the method used. Although there now seems to be agreement that, at least under some conditions, young infants can use featural information to individuate objects in occlusion events, still at issue is why different experimental approaches elicit such different responses from infants (e.g., Needham & Baillargeon, 2000; Wilcox et al., 2003; Xu & Carey, 2000). More specifically, questions remain about the unique demands imposed by different methods and how these influence performance.

1. The distinction between event mapping and event monitoring

Wilcox and Baillargeon (1998a) proposed that two kinds of tasks, event mapping and event monitoring, have been used to assess object individuation in infancy and that these two tasks have different processing requirements. In a typical *event-mapping* task, infants see an event in which one or two objects emerge successively to each side of a screen, the screen is removed, and then infants see a display containing either one object or two objects. In order to succeed on an event-mapping task, infants must set up a representation of the first event and evaluate whether the event is internally consistent (i.e., judge whether the objects' movements and interactions are consistent with their existing knowledge). When the screen is removed, infants must set up a new representation for the second event and then determine whether it is internally consistent. Finally, in an attempt to make sense of these two independent situations infants must form a link between them. The linking together, or mapping, of event representations requires that infants (a) retrieve their representation of the first event; (b) compare it to their representation of the second event; and (c) judge whether the two events are consistent.

In contrast, in an *event-monitoring* task infants see only one event, usually an occlusion event, involving either one or two objects. As infants observe the event they must monitor whether successive portions of the event are consistent. In general, infants are more likely to demonstrate successful performance when they are tested with an event-monitoring than an event-mapping task (Aguiar & Baillargeon, 2002; Hespos, 2000; Spelke et al., 1995; Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b; Wilcox & Schweinle, 2002, 2003; Xu & Carey, 1996), presumably because it is easier for infants to monitor the internal consistency of a single event, than to map one event representation onto another.

The distinction between event mapping and event monitoring raises many interesting questions. Two questions fundamental to the concept of event mapping are: (1) What leads infants to view an event sequence as composed of two distinct events rather than as one continuous event? and (2) Why is it so difficult for infants to retrieve and compare event representations? In response to the first question, Wilcox, Baillargeon, and their coworkers have offered theoretical and empirical accounts of how infants segregate event sequences (e.g., Baillargeon & Wang, 2002; Wilcox & Baillargeon, 1998a; Wilcox & Chapa, 2002). This work supports the idea that infants group physical events into distinct categories, such as occlusion, containment, or support (Baillargeon, 1995; Baillargeon & Wang, 2002), and that it is this process that leads infants to parse event sequences into smaller and more meaningful units (Wilcox & Chapa, 2002). The second question motivates the present research.

2. Event complexity and event mapping

Although there are probably a number of factors that influence infants' performance on event-mapping tasks, one factor that has recently attracted a great deal of attention is event complexity. When events contain complex occlusion sequences (e.g., objects reverse direction as they move back and forth behind a screen) infants are less likely to succeed in event-mapping tasks than when events contain simple occlusion sequences (e.g., objects follow a single, non-reversing trajectory behind the screen). To illustrate, Wilcox and Baillargeon (1998a) examined 9.5- and 11.5-month-olds' ability to individuate objects on the basis of featural information using an event-mapping task with complex occlusion sequences. Infants were assigned to a ball–box or ball–ball condition. The infants in the ball–box condition saw a test event composed of an initial phase and a final phase. During the initial phase of the ball–box test event, the infants saw a ball move behind the left edge of a wide screen and a box appear at the right edge. The box then reversed direction and moved back behind the screen, and the ball reappeared and returned to its starting position. The entire ball–box sequence was then repeated. Finally, the ball moved behind the screen one last time and the screen was lowered to the apparatus floor, marking the end of the initial phase. The infants in the ball–ball condition saw a similar event in the initial phase except that a ball, rather than a box, emerged to the right of the screen. During the final phase of the test event, the infants saw the ball standing alone behind the lowered screen.

The 11.5-month-olds in the ball–box condition looked reliably longer at the final one-ball display than the 11.5-month-olds in the ball–ball condition. These and control data suggested that the infants had (a) used the featural information to conclude that the ball–box event involved two objects and the ball–ball event involved one object; (b) expected, in the ball–box condition, to see two objects when the screen was lowered; and (c) were surprised when this expectation was violated. In contrast, the 9.5-month-olds looked about equally during the final phase of the test event, as if they had failed to detect the discrepancy between the initial ball–box event and the final one-ball display. These results are consistent with those of Xu and Carey (1996), who reported that 12-month-olds, but not 10-month-olds, succeeded at using featural information to individuate objects when an event-mapping task with complex event sequences was used.

Wilcox and Baillargeon (1998a) obtained a different pattern of results, however, when the task was modified so that the initial event was extremely simple and brief. In this experiment, 9-month-olds saw a box (box–ball condition) or a ball (ball–ball condition) disappear behind the left edge of a wide screen and a ball appear at the right edge. The screen was then lowered to reveal only the ball to the right of the screen (the area behind the screen was empty). Hence, the objects moved left to right across the stage, without ever reversing direction, before the screen was lowered. The infants in the box–ball condition looked reliably longer at the one-ball display than the infants in the ball–ball condition. These and control data suggested that when the objects followed a single, non-reversing trajectory, the infants successfully mapped the box–ball event onto the one-ball display. Further data indicated just how fragile event-mapping performance is: if even a single reversal was added to one of the object's trajectories, infants failed to detect a discrepancy between the box–ball event and the one-ball display. Finally, the positive results obtained with the 9-month-olds when a simplified event-mapping task was used recently have been extended to 5.5-month-olds (Wilcox & Schweinle, 2002).

Why do infants younger than 11.5 months fail on event-mapping tasks when the objects move back and forth behind the screen, yet succeed when the objects follow a single, non-reversing trajectory? Wilcox and Baillargeon (1998a) argued that success on event-mapping tasks depends on infants' ability to retrieve a clear and coherent representation of the initial event. When the objects follow complex trajectories event representations become lengthy and unwieldy, making it difficult for infants to retrieve and scan the event to determine what objects were involved. Without a clear representation of the objects involved (e.g., a box moved to the right of the screen and a ball to the left), infants are unable to judge whether the initial and final phases of the test event are congruent. One question this analysis raises is whether there might be ways to facilitate the mapping process. Perhaps, infants would succeed at mapping more complex events if they were given information to help them organize and structure the event.

3. Facilitating infants' mapping of complex event sequences

One way to help infants make sense of lengthy and complex events would be to show them the basic components of the event, one piece at a time, prior to viewing the whole event. Seeing an "event outline," as it were, could serve as a structure with which to encode and/or retrieve events in an organized and meaningful way. What information would be important to include in an event outline? Implicit in Wilcox and Baillargeon's (1998a) argument is that infants are limited in their capacity to build representations of *occlusion* sequences. That is, event-mapping tasks of the kind described is this paper pose difficulties because they require infants to represent and reason about complex trajectories that are partially occluded. This view predicts that to be most effective, an event outline would need to make clear the trajectory of each object as it moves behind the screen. Alternatively, it is possible that infants fail to map more complex occlusion sequences, not because they are limited in their capacity to represent occluded trajectories, but because they are unable to keep track of the number of distinct objects involved in the event. In many event-mapping tasks, the objects are visible for only brief intervals during the initial phase of the test even (i.e., the objects are seen just briefly each time they emerge from behind the screen). Infants may have difficulty remembering, once the occlusion sequence is completed and the screen is lowered, how many distinct objects were involved in the event. On this view, an event outline that specifies the object to be seen to each side of the screen (e.g., the ball or the box), without specifying each object's trajectory, would be sufficient to facilitate event-mapping performance. One goal of the present research was to test these two hypotheses.

4. The present research

The present research assessed the extent to which viewing an event outline prior to the test event would facilitate young infants' mapping of complex occlusion sequences. Infants' aged 7.5 months were tested in three different experiments in which the following variables were manipulated: (a) the type of information included in the event outline (i.e., the objects or the objects *and* their occluded trajectories) and (b) the complexity of the box–ball sequence that infants were required to map (i.e., the number of reversing trajectories). Two predictions were made. First, infants would benefit most from event outlines that made explicit the trajectory of each object as it moved behind the screen. Second, the less complex the event sequence, the more likely it would be that infants would succeed in an event-mapping task. Finally, because there is recent evidence that, under some conditions, males are more likely than females to successfully map complex occlusion sequences (Schweinle & Wilcox, 2003; Wilcox, 2003), sex differences were explored.

5. Experiment 1

Experiment 1 assessed the extent to which 7.5-month-olds' mapping of complex event sequences would be facilitated by viewing an event outline prior to the event-mapping task. Two kinds of event outlines were used: one that specified the object that would be seen to each side of the screen and one that specified each object *and* its trajectory. Using this approach, infants were assigned to one of two conditions: full-view (i.e., the objects remained fully visible during the event outline) and move-behind (i.e., the objects moved behind the screen in the event outline).

The infants in both conditions saw a test event in which a box and a ball (box–ball event) or a ball (ball–ball event) emerged successively to opposite sides of a wide screen. Then the box–ball or ball–ball sequence was repeated once (Fig. 1). Finally, the screen was lowered to reveal a single ball behind the screen. Prior to viewing the test event, the infants in both conditions were presented with two pretest events that, together, composed an event outline. In the *move-behind* condition, the pretest events seen by the box–ball infants started with the box and the ball hidden behind the screen. In the first pretest trial, the box emerged to the left of the screen and returned (i.e., steps 1–2 in Fig. 1). Then these steps were repeated once. In

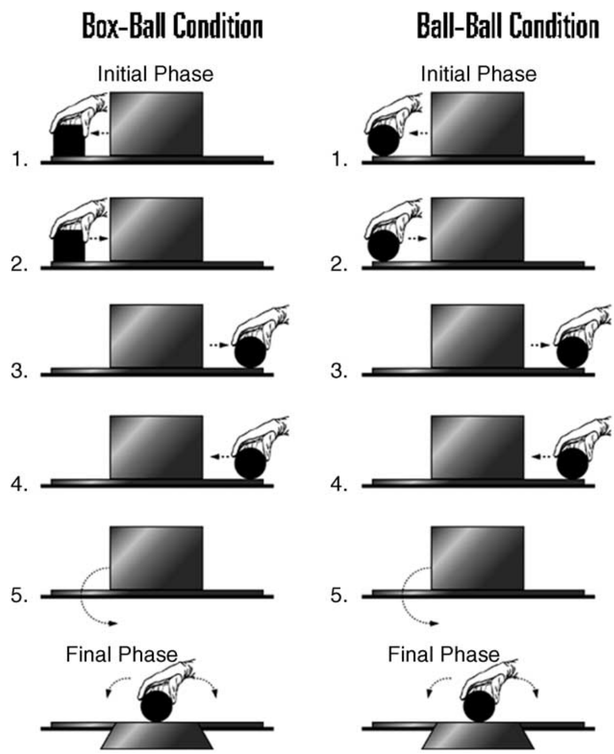

Fig. 1. Schematic representation of the test events shown to the infants in Experiments 1–3. The infants in Experiments 1 and 2 saw steps 1–5 repeat once before the screen was lowered.

the second pretest trial, the ball emerged to the right of the screen, and returned (i.e., steps 3–4 in Fig. 1). Then these steps were repeated once. Hence, each pretest trial contained one component of the test event—the box emerging to the left of the screen or the ball emerging to the right—and both pretest trials, together, formed a complete outline of the upcoming box–ball occlusion sequence. The infants in the ball–ball condition saw the same pretest events, except that the ball was seen in both pretest trials.

The infants in the *full-view* condition saw pretest trials that were identical to those presented to the infants in the move-behind condition with one exception: in each pretest trial the box/ball moved back and forth, in an oscillation pattern, next to the screen, but never moved behind the screen. Hence, in the full-view condition the objects were in view longer during the pretest trials than in the move-behind condition, but their trajectories remained unspecified.

If specifying the objects' trajectories prior to the test event facilitates infants' ability to map more complex event sequences, then positive results should be obtained in the move-behind condition. That is, the box–ball infants should look longer at the one-ball display than the ball–ball infants. In contrast, if additional exposure to the objects—but not their occluded trajectories—prior to the test event is sufficient to support infants' mapping of complex occlusion sequences, then positive results should be obtained with the infants in the full-view condition.

5.1. Method

5.1.1. Participants

Participants were 56 infants 7.5 months of age, 28 male and 28 female (mean age = 7 months, 26 days; range = 7 months, 0 days to 8 months, 20 days). In this and all subsequent experiments infants were healthy and born full-term. An additional 13 infants were eliminated from the analyses: 10 because of procedural problems, 2 because of fussiness, and 1 because of sleepiness. Fourteen infants, seven male and seven female, were randomly assigned (with the stipulation that an equal number of males and females were included in each group) to one of four groups formed by crossing pretest event (move-behind or full view) with test event (box–ball or ball–ball): move-behind, box–ball ($M = 7$ months, 28 days); move-behind, ball–ball ($M = 7$ months, 23 days); full-view, box–ball ($M = 7$ months, 27 days); full-view ball–ball ($M = 7$ months, 24 days).

5.1.2. Apparatus

The apparatus was a wooden cubicle 213 cm high, 105 cm wide, and 43.5 cm deep. The infant sat facing an opening 51 cm high and 93 cm wide in the front wall of the apparatus. The floor of the stage of the apparatus was covered with cream-colored contact paper and the side walls were painted off-white. The back wall was covered with lightly patterned contact paper. A platform, 1.5 cm high, 60 cm wide, and 17 cm deep, covered with cream contact paper lay centered between the left and right walls and flush with the back wall. A 12 cm deep strip of light blue flannel lay centered down the length of the platform.

The screen used in the pretest and test events was 30 cm wide and 20 cm high and was mounted on two metal clips positioned 24 cm apart and centered with the platform. The clips were attached to a wooden dowel 122 cm long and 1 cm in diameter that lay on the apparatus floor directly in front of the platform. The right end of the dowel was inserted through a hole in the right wall of the apparatus; its left end exited the apparatus through a hole in the left wall. By rotating the dowel's left end (out of the infants' view), an experimenter could lower the screen to the apparatus floor.

The infants who saw the box–ball event saw two test objects: a box and a ball. The ball was 10.25 cm in diameter, made of Styrofoam, and painted green with evenly spaced red, blue, and yellow dots. The box was 10.25 cm square, made of Styrofoam, covered with red felt, and decorated with evenly spaced silver thumbtacks. An experimenter's hand reached into the apparatus to move the box or the ball through a slit 6.5 cm high and 52.5 cm wide located 10 cm above the apparatus floor. Cream-colored fringe helped conceal the slit. To equate the events as much as possible, a second, identical ball was used in the ball–ball event. The box (box–ball conditions) or the second ball (ball–ball conditions) was removed from the apparatus through a concealed door, 14 cm wide, in the back wall of the apparatus located behind the screen.

A muslin-covered curtain was lowered after each trial to cover the opening in the front wall of the apparatus. Two muslin-covered frames, each 213 cm high and 68 cm wide, stood at an angle on either side of the apparatus; these frames isolated the infant from the experimental room. In addition to the room lighting, four 20-W fluorescent bulbs (60 cm long in front and back and 30 cm long on each side) were attached to the inside walls of the apparatus.

5.1.3. Events

Three experimenters worked together to produce the pretest and test events. The first wore a black glove and moved the box and the ball. The second lowered the screen. The third surreptitiously removed the box, or the second identical ball, from the apparatus before the screen was lowered. The numbers in parentheses indicate the time taken to produce the actions described. A metronome ticked softly once per second to help the experimenter's adhere to the events' scripts.

5.1.3.1. Move-behind, box–ball condition. At the start of the pretest events, the screen stood upright at the center of the platform. The box and the ball were hidden behind the left and right sides of the screen, respectively. In the first pretest trial, the hand moved the box to the left edge of the platform (2 s), paused (1 s), and then returned the box behind the screen (2 s). This 5 s sequence was then was repeated. In the second pretest trial, the hand moved the ball to the right edge of the platform (2 s), paused (1 s), and then returned the ball behind the screen (2 s). This 5 s sequence was then repeated. The ball and box moved at a rate of about 12 cm/s and remained in full contact with the platform.

The test events started like the pretest events: the screen stood upright at the center of the platform and the box and the ball were hidden behind the left and right sides of the screen, respectively. During the *initial phase* of the event, the hand moved the box to the left edge of the platform (2 s), paused (1 s), and then returned the box behind the screen (2 s). Next, the hand moved the ball to the right edge of the platform (2 s), paused (1 s), and then moved the ball back behind the screen (2 s). This 10 s sequence was then repeated. While the ball was in motion, the third experimenter surreptitiously removed the box from the apparatus through a concealed door in the back wall. After the ball was returned behind the screen the second time, the second experimenter lowered the screen to the apparatus floor (1 s), marking the end of the initial phase. During the *final phase*, the hand tilted the ball gently at the center of the platform until the trial ended.

5.1.3.2. Move-behind, ball–ball condition. The pretest and test events shown in the move-behind, ball–ball condition were similar to those in the move-behind, box–ball condition, except that the second, identical ball was substituted for the box.

5.1.3.3. Full-view, box–ball condition. At the start of the first pretest trial, the screen stood upright at the center of the platform and the box sat in full view at the left edge of the platform. The hand moved the box so that it was next to the screen (1 s) and then moved the box back to the left edge of the platform (1 s). This 2 s sequence repeated until the end of the trial. In the second pretest trial, the ball sat at the right edge of the platform. The hand moved the ball until it was next to the screen (1 s) and then moved it back to the right edge of the platform (1 s). This 2 s sequence repeated until the end of the trial. The test event shown in the full-view box–ball condition was identical to that in the move-behind box–ball condition.

5.1.3.4. Full-view, ball–ball condition. The pretest and test events shown in the full-view, ball–ball condition were similar to those in the full-view, box–ball condition, except that the second, identical ball was substituted for the box.

5.1.4. Procedure

The infant sat on a parent's lap centered in front of the apparatus. The infant's head was approximately 80 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 test events.

Each infant participated in a two-step procedure that consisted of a pretest period and a test period. During the *pretest* period, the infants saw the pretest events appropriate for their condition on two successive trials. The pretest trials ended with the infant either (a) looked away for 2 consecutive seconds after having looked for at least 5 cumulative seconds or (b) looked for 60 cumulative seconds without looking away for 2 consecutive seconds. During the *test* period, the infants saw the test event appropriate for their condition on two successive trials. Looking time during the initial and final phase of each trial was monitored separately. The final phase of each trial ended when the infant either (a) looked away for 1 consecutive second after having looked for at least 5 cumulative seconds or (b) looked for 60 cumulative seconds without looking away for 1 consecutive second.

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. Each observer held a button connected to a 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. Inter-observer agreement during the final phase of each test trial was calculated by dividing the number of intervals in which the computer registered agreement by the total number of intervals in the trial. Inter-observer agreement was measured for 49 infants (for 7 infants data from only one observer were available) and agreement averaged 95% per test trial per infant.

In this and the subsequent experiments, preliminary analyses of the mean looking times of the infants during the pretest and test trials revealed no reliable and consistent main effects of trial or interactions involving trial; the data were therefore collapsed across trial in all subsequent analyses.

5.2. Results

5.2.1. Pretest trials

The infants' looking times during the two pretest trials were averaged and then submitted to an ANOVA with pretest event (move-behind or full-view), test event (box–ball or ball–ball), and sex (male or female) as between-subjects factors. The main effect of pretest event, $F(1, 48) = 16.01$, MSE $= 92.32$, $p < .001$, was significant, indicating that the infants in the full-view condition ($M = 29.02$, SD $= 12.00$) looked reliably longer during the pretest trials than the infants in the move-behind condition ($M = 18.74$, SD $= 16.17$). In light of the fact that in the full-view condition the objects were moving and visible throughout the pretest trials, and in the move-behind condition the objects were moving and visible for less than 20 s, this result was expected. The main effects of pretest event and sex, $F(1, 48) < 1.00$, and the interactions involving this factors, all $F(1, 48) < 2.5$, were not significant (move-behind, box–ball condition, $M = 19.46$, SD $= 6.87$; move-behind, ball–ball condition, $M = 18.02$,

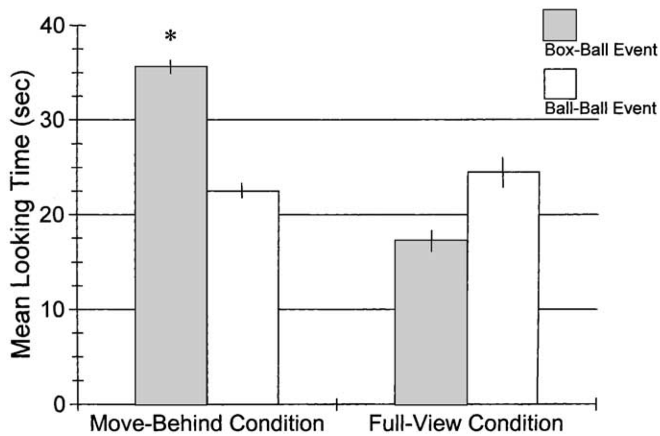

Fig. 2. Mean looking times (and standard errors) of the infants in the move-behind and the full-view conditions of Experiment 1.

SD = 5.54; full-view, box–ball condition, $M = 25.79$, SD = 8.55; full-view, ball–ball condition, $M = 32.24$, SD = 14.27).

5.2.2. Test trials

The infants' looking times during the final phases of the two test trials (see Fig. 2) were averaged and analyzed in the same manner as the pretest trials. The main effect of pretest event, $F(1, 48) = 5.91$, MSE = 159.44, $p < .025$, was significant. The main effects of test event and sex, $F(1, 48) < 1$, were not significant. The pretest event × test event interaction, $F(1, 48) = 9.10$, $p < .01$, was significant. No other interactions were significant, all $F(1, 48) < 1$. Planned comparisons indicated that the infants in the move-behind condition looked reliably longer at the one-ball display after having viewed the box–ball ($M = 35.56$, SD = 10.68) than ball–ball ($M = 22.50$, SD = 16.51) test event, $F(1, 48) = 7.49$, $p < .01$. In contrast, in the full-view condition the box–ball ($M = 17.18$, SD = 9.28) and ball–ball ($M = 24.48$, SD = 11.45) infants looked about equally at the one-ball display, $F(1, 48) = 2.34$, $p > .05$.

5.3. Discussion

In the move-behind condition, the infants who viewed the box–ball occlusion sequence looked reliably longer at the final one-ball display than those who viewed the ball–ball occlusion sequence. In contrast, in the full-view condition the infants who viewed the box–ball and ball–ball sequences looked about equally at the one-ball display. These results suggest two conclusions. The first is that it is possible to facilitate infants' mapping of complex occlusion sequences. When the 7.5-month-olds were shown an event outline that contained the basic components of the occlusion sequence that they would see in the upcoming test trials, they evidenced successful event-mapping performance. (Recall that infants younger than 11.5 months typically fail to map complex occlusion sequences.) The second is that, even though seeing an event outline can improve event-mapping performance, young infants do not benefit equally from all types of event outlines. In the present experiment, when the outline specified the objects and their spatiotemporal coordinates during the occlusion sequence (move-behind condition), infants succeeded at mapping the box–ball event. In contrast, when the outline specified the objects, but not their spatiotemporal coordinates during the occlusion sequence (full-view condition), the infants failed to map the box–ball event. These results highlight the importance of trajectory information to infants' representation of occlusion events. In both event outlines the infants were exposed to the objects that they would see in the test event. However, only when the outline specified the trajectory of each object as it moved behind the screen did infants evidence improved mapping performance.

One might be concerned, however, that the infants in the move-behind condition succeeded for other reasons. Perhaps, seeing moving objects prior to the test event increased the infants' sensitivity to the moving box–ball sequence, or exposure to objects prior to the test event improved infants' ability to recall which objects were involved in the box–ball sequence. Although possible, the negative results obtained in the full-view condition argue against these kinds of explanations. In the full-view condition, the infants also saw the objects moving prior to the test event, and they had longer to view the objects during that time (i.e., the objects were fully visible throughout the pretest trials). Yet, the infants in the full-view condition failed to detect the discrepancy between the box–ball event and the final one-ball display. Only when the infants saw each object move-behind the screen in the pretest trials did they demonstrate successful performance on the event-mapping task.

These results raise interesting questions about infants' capacity to make use of event outlines. For example, how much information must an event outline convey? Would infants benefit from an event outline that contained less information or that was more brief? The next experiment was designed to address this question.

6. Experiment 2

Experiment 2 explored whether infants would benefit from an event outline that was equally explicit, but more brief, than the event outline used in Experiment 1. Infants saw the same pretest and test events as the infants in the move-behind conditions (box–ball and ball–ball) of Experiment 1 with the following exception: in the pretest trials the objects emerged only once to the side of the screen. Hence, infants were given less exposure to the trajectory of each object prior to viewing the box–ball occlusion sequence. If 7.5-month-olds' success on this event-mapping task depends on their ability to identify the trajectory of the box and the ball, and this is difficult for infants to do with only one exposure to each trajectory prior to the test event, then viewing only one emergence of each object during the pretest trials should not support infants' mapping of the box–ball occlusion sequence.

6.1. Method

6.1.1. Participants

Participants were 32 infants 7.5 months of age, 16 male and 16 female (mean age = 7 months, 29 days; range = 7 months, 4 days to 8 months 19 days). An additional five infants were eliminated from the analyses: four because of procedural problems and one because of computer malfunction. Sixteen infants, 8 male and 8 female, were assigned to the box–ball ($M = 7$ months, 29 days) and the ball–ball ($M = 7$ months, 28 days) condition.

6.1.2. Apparatus

The apparatus used in Experiment 2 was identical to the apparatus of Experiment 1.

6.1.3. Events

6.1.3.1. Box–ball condition. The pretest and test events shown in the box–ball condition were identical to those of the move-behind, box–ball condition of Experiment 1 with one exception. In the pretest trials, the box (first pretest trial) and the ball (second pretest trial) emerged only once to each side of the screen (i.e., the 5 s cycle did not repeat).

6.1.3.2. Ball–ball condition. The pretest and test events in the ball–ball condition were identical to those in the move-behind, ball–ball condition of Experiment 1 with one exception. In the pretest trials, the ball emerged only once to each side of the screen.

6.1.4. Procedure

The procedure in Experiment 2 was identical to that of Experiment 1. Inter-observer agreement was measured for 27 infants and agreement averaged 95% per test trial per infant.

6.2. Results

6.2.1. Pretest trials

The infants' looking times during the two pretest trials were averaged and then submitted to an ANOVA with test event (box–ball or ball–ball) and sex (male or female) as between-subjects factors. The main effects of test event and sex, and their interaction, were not significant, all $F(1, 28) < 1.25$, $\text{MSE} = 84.59$. These results indicate that the infants in the box–ball ($M = 13.98$, $\text{SD} = 7.79$) and ball–ball ($M = 16.53$, $\text{SD} = 10.37$) conditions looked about equally at the pretest events.

6.2.2. Test trials

The infants' looking times during the final phases of the two test trials (see Fig. 3) were averaged and analyzed in the same manner as the pretest trials. The main effect of test event, $F(1, 28) = 2.30$, $p > .05$, $\text{MSE} = 168.47$, was not significant. The main effect of sex was significant, $F(1, 28) = 6.88$, $p < .025$, and the test event × sex interaction was significant, $F(1, 28) = 4.87$, $p < .05$. Follow-up comparisons revealed that the males who saw the box–ball event ($M = 48.74$, $\text{SD} = 9.01$) looked reliably longer at the one-ball display than the males who saw the ball–ball event ($M = 31.65$, $\text{SD} = 14.76$), $F(1, 28) = 6.93$, $p < .05$. In contrast, the females who saw the box–ball ($M = 26.58$, $\text{SD} = 11.09$) and ball–ball ($M = 29.74$, $\text{SD} = 15.87$) events looked about equally at the final display, $F(1, 28) < 1$.

When the objects emerged just once to the side of the screen in the pretest trials, the infants were afforded less opportunity to see the box/ball in motion than when the objects emerged

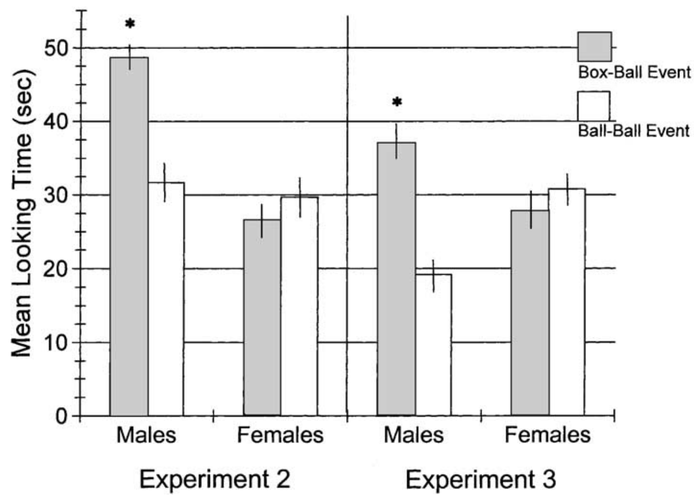

Fig. 3. Mean looking times (and standard errors) of the male and female infants in Experiments 2 and 3.

twice to the side of the screen. In fact, it is possible that if the infants were not attending during the first 5 s of the pretest trial—the only time the objects were in motion—they would fail to see the box or the ball. To explore the possibility that the females in Experiment 2 failed because they simply did not see the objects emerge from behind the screen, and not because of limited exposure to the objects' trajectories, the infants' mean looking times during the first 5 s of each pretest trial were examined. These looking times were compared by means of an ANOVA with pretest trial (trial 1 or 2) as a within-subjects variable and test event and sex as between-subjects variables. There were no significant main effects or interactions, all $F(1, 28) < 2$. The mean looking times of the females in the box–ball ($M = 4.54$, $SD = 0.67$) and ball–ball ($M = 3.86$, $SD = 1.58$) conditions did not differ reliably from those of the males in the box–ball ($M = 3.86$, $SD = 0.90$) and ball–ball ($M = 4.33$, $SD = 0.91$) conditions, suggesting that the negative results obtained with the females in Experiment 2 cannot be attributed to a failure to see the objects in the pretest events.

6.3. Discussion

Experiment 2 examined whether an event outline that was very brief would facilitate infants' performance on the event-mapping task. Positive results were obtained, but only with the males. The males in the box–ball condition looked reliably longer at the final one-ball display than the males in the ball–ball condition. In contrast, the females in the box–ball and ball–ball conditions looked about equally at the one-ball display. These results suggest that the ability to encode and retrieve complex event sequences is more fragile in 7.5-month-old females than males. When the event outline was pared down, so that the infants saw less of the objects and their trajectories, the females had difficulty judging whether the box–ball sequence seen in the initial phase of the test event was consistent with the one ball seen in the final phase. One might wonder, however, whether the females would be more likely to succeed on this task if the test event was pared down as well. Perhaps, if the box–ball event was shortened, making it easier to encode and retrieve, the females would find the abbreviated event outline sufficient to support event-mapping performance. The next experiment tested this hypothesis.

7. Experiment 3

Experiment 3 examined whether 7.5-month-old females would be more likely to succeed at mapping the box–ball test event if the occlusion sequence was shortened and made less complex (i.e., contained fewer reversing trajectories). Infants aged 7.5 months saw pretest and test events that were identical to those seen by the infants in the box–ball and ball–ball conditions of Experiment 2 with one exception: in the test trials the objects emerged just once to each side of the screen. Hence, the objects underwent fewer reversals than in Experiment 2, yet still performed at least one reversal to each side of the screen.

7.1. Method

7.1.1. Participants

Participants were 32 infants 7.5 months of age, 16 male and 16 female (mean age = 7 months, 17 days; range = 7 months, 1 day to 8 months, 10 days). An additional seven infants were eliminated from the analyses: five because of procedural problems, one because of computer malfunction, and one because the primary observer was unable to follow the infant's direction of gaze. Sixteen infants, eight male and eight female, were assigned to the box–ball ($M = 7$ months, 16 days) and the ball–ball ($M = 7$ months, 17 days) condition.

7.1.2. Apparatus

The apparatus used in Experiment 3 was identical to the apparatus of Experiment 1.

7.1.3. Events

7.1.3.1. Box–ball condition. The pretest and test events shown in the box–ball condition of Experiment 3 were identical to those of the box–ball condition of Experiment 2 with one exception. In the test trials, the box and the ball emerged only once to their respective sides of the screen (i.e., the 10 s box–ball occlusion sequence did not repeat before the screen was lowered).

7.1.3.2. Ball–ball condition. The pretest and test events in the ball–ball condition of Experiment 3 were identical to those of the ball–ball condition of Experiment 2 with one exception. In the test trials, the ball emerged only once to each side of the screen (i.e., the 10 s ball–ball occlusion sequence did not repeat before the screen was lowered).

7.1.4. Procedure

The procedure in Experiment 3 was identical to that of Experiment 1. Inter-observer agreement during the finals phases of the test trials was measured for 25 infants and averaged 25% per trial per infant.

7.2. Results

7.2.1. Pretest trials

The infants' looking times during the two pretest trials were averaged and then submitted to an ANOVA with test event (box–ball or ball–ball) and sex (male or female) as between-subjects factors. The main effects of test event and sex, and their interaction, were not significant, all $F(1, 28) < 1.25$, MSE $= 44.68$. These results indicate that the infants in the box–ball ($M = 11.49$, SD $= 7.22$) and ball–ball ($M = 11.17$, SD $= 6.04$) conditions looked about equally at the pretest events.

7.2.2. Test trials

The infants' looking times during the final phases of the two test trials (see Fig. 3) were averaged and analyzed in the same manner as the pretest trials. The main effects of test event, $F(1, 28) = 2.24$, $p > .05$, and sex $F(1, 28) < 1$, MSE $= 195.89$, were not significant. The test event × sex interaction was significant, $F(1, 28) = 4.40$, $p < .05$. Follow-up comparisons revealed that the males who saw the box–ball occlusion sequence ($M = 36.99$, SD $= 15.70$) looked reliably longer at the one-ball display than the males who saw the ball–ball occlusion sequence ($M = 19.20$, SD $= 11.84$), $F(1, 28) = 6.46$, $p < .05$. In contrast, the females who saw the box–ball ($M = 27.81$, SD $= 15.98$) and ball–ball ($M = 30.79$, SD $= 11.90$) sequences looked about equally, $F(1, 28) < 1$, at the one-ball display.

7.3. Discussion

The results obtained in Experiment 3 were identical to those obtained in Experiment 2. The males in the box–ball condition looked reliably longer at the final one-ball display than those in the ball–ball condition, whereas the females in the two conditions looked about equally at the one-ball display. These results provide converging evidence for the conclusion that (a) viewing an event outline prior to viewing the event itself can facilitate infants' performance on event-mapping tasks, but that (b) females are more limited than males in their capacity to benefit from this experience. Even when the occlusion sequence was pared down, so that each object performed only one reversal to the side of the screen, the females still failed to map the box–ball event. Possible explanations for this sex difference are explored in the following section.

7.4. General discussion

The present research explored whether infants' capacity to map complex occlusion sequences would be enhanced by first showing infants, in outline form, the basic components of the event. Three experiments were conducted with 7.5-month-olds using box–ball occlusion sequences. The experiments varied in (a) the type and amount of information that was conveyed prior to viewing the box–ball sequence (i.e., the objects or the objects *and* their occluded trajectories) and (b) the complexity of the box–ball sequence that infants were required to map (i.e., the number of reversing trajectories included in the event). The main results can be summarized in the following way. When the infants were given repeated exposure to the objects' trajectories prior to the test event, they successfully mapped a box–ball occlusion sequence onto a one-ball display (Experiment 1). However, when the infants were given more limited exposure to the objects' trajectories prior to the test event, the males but not the females, successfully mapped a box–ball occlusion sequence (Experiments 2 and 3).

These results add to a growing number of reports that the extent to which infants demonstrate the ability to use featural information to individuate objects often depends on the experimental context (e.g., Wilcox & Schweinle, 2003; Wilcox & Baillargeon, 1998a, 1998b; Wilcox & Schweinle, 2003), and provide converging evidence for the conclusion that infants younger than 11.5 months can succeed in event-mapping situations if the task is modified in a way that decreases the information processing demands (Wilcox & Baillargeon, 1998a; Wilcox & Chapa, 2002; Wilcox & Schweinle, 2002). Even more importantly, the present research reveals specific conditions that support infants' mapping of more complex event sequences. These findings offer insight into what makes event mapping so difficult for infants in the first place.

At the same time, the present results raise two questions. First, why does providing an event outline, that specifies the trajectory of each object as it moves behind the screen, lead to improved performance on a complex event-mapping task? Second, why are males more likely than females to benefit from viewing an event outline? The remainder of this section is dedicated to addressing these two questions.

7.4.1. Event outlines and event-mapping performance

How an event outline influences event-mapping performance depends, at least in part, on how event-mapping is accomplished. Wilcox and Baillargeon (1998a; see also Wilcox et al., 2003) proposed that there are at least two ways that event mapping can be accomplished. One way is for infants to retrieve a literal representation of the first event, scan this representation to determine what objects are involved, and then align those objects with the objects in the second event. This requires that infants retrieve and manipulate a "whole event" representation, a process that is difficult for infants when the event is long and complex. A second way is to compose a summary representation of the first event that contains only the basic elements of the event (e.g., the number of distinct objects and their paths of motion) and store the summary representation. When faced with an event-mapping situation, infants retrieve the summary representation, rather than the whole event, to compare to the final display. In the present context—young infants' representation of moving occlusion sequences—it is likely that summary representations would be a dynamic images. However, there are probably a number of different kinds of summary representations that would support event-mapping performance in infants (e.g., dynamic images, static images, labels). The kind of summary representation used by infants would depend on the nature of the task, the age of the infant, and infants' information processing and linguistic capacities. The important point is that summary representations, regardless of their format, capture the important components of the events.

The distinction drawn here between whole event representations and summary representations bears close resemblance to the distinction that has been made between analogical and propositional codes of mental representation in adults (e.g., Anderson & Bower, 1973; Paivio, 1969; Pylyshyn, 1973, 1981). The first suggests that mental representations are veridical and remain true to what is observed (i.e., the main perceptual features of what is being represented are preserved), whereas the second suggests that mental representations are more abstract and symbolic in form.

This analysis suggests several ways that exposure to an event outline could lead to improved performance on an event-mapping task. One possibility is that viewing the event outline helps infants to encode the upcoming occlusion sequence. Seeing the pretest trials provides a structure, or a scaffolding, with which to organize, or hang, the occlusion sequence as it unfolds before them. Having this structure increases the probability that infants will be able to form a coherent representation of the entire event that can later be retrieved. A second possibility also focuses on improving memory for the whole event, but proposes that the event outline acts as a memory aid at retrieval rather than at encoding. According to this view, when infants attempt to retrieve the whole event representation they also retrieve the event outline, and then use the event outline as a way to remember the components of the whole event. This process is more complicated, involving multiple processing steps and comparison of many events over time, and hence less likely as a potential explanation. A third possibility is that viewing the event outline helps infant to form a summary representation of the occlusion sequence. Seeing the basic components of the events, one piece at a time, helps infants to identify the simple structure of the occlusion sequence (e.g. a box moves from behind the left side of the screen and a ball moves from behind the right). Once the simple structure has been identified, infants can use this to compose a summary representation.

Which of the three possible explanations outlined above is the most likely? The second possibility has already been deemed as improbable, because of the complexity of the processing involved. Of the remaining two possibilities, there are some reasons to favor an explanation that focuses on infants' use of summary representations rather than whole event representations. In Experiment 1, where positive results were obtained with the males and the females, the pretest trials were not, literally, pieces of the test event that were seen independently and in sequence. To illustrate, in each pretest trial, the object (i.e., the box or the ball) emerged twice to each side of the screen. Combining the two pretest trials, in their literal form, would create an event in which the box emerged twice to each side of the screen and then the ball emerged twice to each side of the screen. This was not what infants saw in the test event. In the test event, the box and the ball emerged once to each side of the screen, and then this entire sequence was repeated. Hence, it is more likely that the pretest trials served as a aid for extracting the simple structure of the box–ball event—the box to the left of the screen and the ball to the right—rather than as an aid to remembering the whole event—the emergence of a box, a ball, a box, and, finally, a ball.

7.4.2. Why males are more likely than females to benefit from an event outline

How can the sex difference in infants' ability to make use of the event outline, observed in Experiments 2 and 3, be explained? The above discussion raises two possibilities: (1) with support, males are better able to remember lengthy and complex event sequences or (2) with support, males are more skilled at composing summary representations. Unfortunately, the present data do not distinguish between these two possibilities. However, if one favors the idea that, in Experiment 1, the event outline facilitated infants' ability to extract the simple structure of the box–ball sequence, then one way to explain the sex differences observed in Experiments 2 and 3 is that the males were more skilled at composing a summary representation of the test event than the females.

Why would males be more skilled at composing a summary representation than females? This process depends, critically, on infants' ability to identify, as the event unfolds before them, the simple structure of the event. Once the simple structure has been identified, infants must then encode this information in a way that can be accessed and used at later point in time. Wilcox and coworkers (Wilcox & Schweinle, 2002; Wilcox et al., 2003) have suggested that, at least within the context of occlusion events, the simple structure is primarily spatiotemporal in nature. That is, to interpret occlusion sequences infants must first, and foremost, identify the trajectory (i.e., the spatiotemporal coordinates) of each object as it moves back and forth behind the screen. More detailed information can be added to this structure in a hierarchical fashion. For example, infants might next include information about the functional properties of the objects involved, or information about what the objects look like (i.e., their featural characteristics).

The proposal that males are more likely than females to identify the simple structure of occlusion sequences is consistent with other sex differences that have been reported in the infant literature. For example, there is evidence that human and monkey male infants out perform female infants on tasks that require them to keep track of specific objects, and their spatiotemporal coordinates, over time (Clark & Goldman-Rakic, 1989; Goldman, Crawford, Stokes, Galkin, & Rosvold, 1974; Overman, Bachevalier, Schuhmann, & McDonough-Ryan, 1997; Overman, Bachevalier, Schuhmann, & Ryan, 1996). These differences have been linked to different rates of cortical maturation in the orbital prefrontal cortex, favoring males, that appear to be induced by the presence of steroid gonadal hormones (Clark & Goldman-Rakic, 1989; Goldman & Brown, 1975; Goldman et al., 1974; Hagger & Bachevalier, 1991; Hagger, Bachavelier, & Bercu, 1987). In addition, there is evidence obtained with children and adults that males out perform females on tasks that require the extraction and manipulation of the spatial structure of visual displays (e.g., Kerns & Berenbaum, 1991; Linn & Peterson, 1985). Together, these findings suggest that there may be biologically based sex differences in cognitive functioning that set the stage for later sex differences in visuospatial abilities.

Of course, the link between the sex difference observed in the present experiments and sexually dimorphic cognitive behaviors observed in children and adults is speculative, at best. In addition, it is not clear whether these early sex differences are triggered by biological events or select environmental experiences (or a combination of the two). At the same time, the fact that sex differences have been observed in different tasks that appear to tap similar cognitive processes suggests that further investigation in warranted.

Finally, one might wonder when males and females would first map complex box–ball sequences. The present research, along with results obtained in other event-mapping experiments using complex occlusion sequences (Schweinle & Wilcox, 2003), predicts that males would succeed before females. To test this hypothesis, Wilcox (2003) assessed 9.5- to 11.5-month-olds' capacity to map the box–ball event used in Experiment 3 (i.e., in the test event the box and ball emerged once to each side of the screen). The results revealed a clear developmental progression favoring males: at 9.5 months males and females failed to map the box–ball occlusion sequence, at 10.5 months only males succeeded at mapping the box–ball sequence, and at 11.5 months both males and females succeeded. Additional results revealed that the 10.5-month-old females evidenced successful performance, however, if they were first shown a brief event outline, identical to the one used in Experiment 3 (e.g., the box and ball emerged just once during the pretest trials), prior to the test event. These findings provide converging evidence for the idea that males are more likely than females to extract the simple structure of complex occlusion sequences, and reveal that older females can benefit from viewing an event outline.

7.4.3. Concluding comments

Event-mapping tasks, which have been used extensively to assess infants' capacity to individuate objects, pose unique information processing demands not associated with other types of individuation tasks. The present research gives weight to the idea that young infants often fail on event-mapping tasks because they have difficulty building representations of events involving occluded trajectories, and demonstrates that event-mapping tasks can be made easier by providing infants with a structure with which to encode and retrieve complicated occlusion sequences. Continued research along these lines will lead to a better understanding of the complex set of processes involved in event mapping and the factors that influence mapping performance.

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