Infancy

Sex Differences in Infants' Mapping of Complex Occlusion Sequences: Further Evidence

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Recently, infant researchers have reported sex differences in infants' capacity to map their representation of an occlusion sequence onto a subsequent no-occlusion display. The research reported here sought to identify the extent to which these sex differences are observed in event-mapping tasks and to identify the underlying basis for these differences. Two experiments were conducted with 9.5-, 10.5-, and 11.5-month-olds using the following task. First, infants were shown an occlusion event in which a box and a ball emerged successively to opposite sides of a screen. Then, the screen was lowered and infants saw a single ball on the platform. Boys first showed prolonged looking to the 1-ball display at 10.5 months, suggesting that at 10.5 months, boys detected the inconsistency between the box–ball occlusion sequence and the final 1-ball display. In contrast, girls first showed prolonged looking to the 1-ball display at 11.5 months. However, girls did show prolonged looking at 10.5 months if they were shown an outline of the box–ball occlusion sequence prior to the test trials. These results provide converging evidence for the conclusion that boys are more likely than girls to successfully map complex occlusion sequences onto no-occlusion displays. These results also suggest that boys perform better on event-mapping tasks because they are more adept at extracting the simple structure of complex occlusion sequences that they can then retrieve and compare to the final display, but that girls can extract the simple structure under more supportive conditions. Possible reasons for these robust, albeit transient, sex differences are suggested.

One of the most pervasive and controversial characteristics of cognitive and social functioning in humans is that of sex differences. Over the years, the identification of sex differences in adults has generated a great deal of debate about the extent to

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which these differences can be observed reliably, where these differences originate, and what they mean in terms of everyday functioning. In an attempt to identify the origins of sex differences, some investigators have turned to infancy research. The rationale for this approach is to determine the extent to which differences between the sexes exist prior to extensive language, social, and educational experiences. Investigations with infants have revealed a number of sex differences on cognitive and perceptual tasks, some favoring females and others favoring males (e.g., Alexander, 2003; Antell & Keating, 1983; Bauer, Shimojo, Gwiazda, & Held, 1986; Benenson, Duggan, & Markovits, 2004; Creighton, 1984; Held, Bauer, & Gwiazda, 1988; Held, Shimojo, & Gwiazda, 1984; Kavšek, 2004; Lutchmaya & Baron-Cohen, 2002; Moore & Cocas, 2006; Serbin, Poulin-Dubois, Colburne, Sen, & Eichstedt, 2001). Some of the most prominent and well-documented sex differences in infancy have been observed in object processing tasks. For example, at 13 months girls demonstrate better recognition memory in object discrimination tasks, which require infants to discriminate between familiar and novel objects (Overman, Bachevalier, Schuhmann, & McDonough-Ryan, 1997; Overman, Bachevalier, Schuhmann, & Ryan, 1996). In contrast, at 15 months boys outperform girls on object retrieval tasks, which require keeping track of baited objects that change location across trials. These differences typically abate within a year. For example, by 35 months boys and girls perform similarly on object discrimination tasks and by 30 months perform similarly on object retrieval tasks (Overman et al., 1997; Overman et al., 1997). Similar results (e.g., females perform better on object discrimination tasks whereas males perform better on object retrieval tasks) have been observed in infant monkeys (Bachevalier, Brickson, Haggar, & Mishkin, 1990; Bachevalier, Hagger, & Bercu, 1989; Clark & Goldman-Rakic, 1989; Goldman, Crawford, Stokes, Galkin, & Rosvold, 1974; Overman et al., 1997; Overman et al., 1996) and are associated with different rates of neural maturation. For example, males' better performance on object retrieval and related tasks has been associated with faster rates of cortical maturation in the orbital prefrontal cortex that appear to be induced by the presence of gonadal hormones (Clark & Goldman-Rakic, 1989; Goldman & Brown, 1975; Goldman et al., 1974; Hagger & Bachevalier, 1991; Hagger, Bachevelier, & Bercu, 1987; see also Held et al., 1988).

Recently, Wilcox and her colleagues (Schweinle & Wilcox, 2004; Wilcox, 2003) reported sex differences in infants' performance on one type of object individuation task: an event-mapping task. In an event-mapping task, infants see an event in which one or two objects emerge successively to opposite sides of an occluder, the occluder is removed, and then infants see a display containing either one or two objects. To illustrate, Schweinle and Wilcox (2004) presented 9.5-month-olds with an occlusion sequence (see Figure 1) in which an object disappeared behind one edge of a screen and an identical object appeared immediately at the other edge, too quickly to have traversed a path behind the screen. The object

Speed-Discontinuity Event

Initial Phase

Final Phase
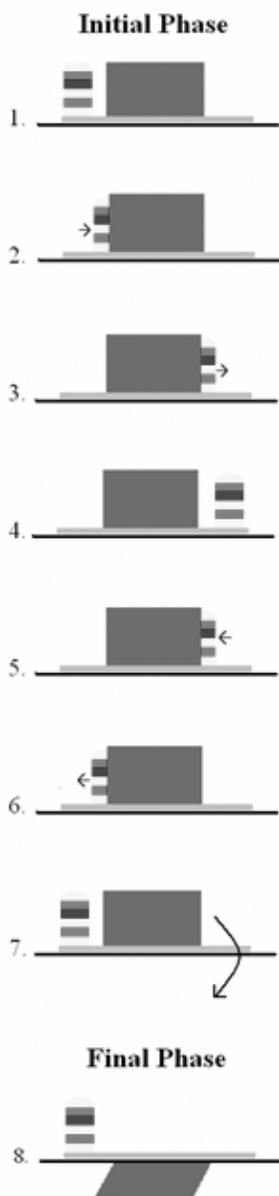
FIGURE 1   Schematic representation of the speed-discontinuity event. A hand (not pictured)
moved the objects.

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then reversed direction and the event was seen in reverse. Finally, the screen was lowered and infants saw one object on the platform. The infants demonstrated prolonged looking to the one-object display as compared to those tested in control conditions (e.g., the object was occluded for an interval appropriate for its rate of motion), suggesting that they interpreted the speed-discontinuity event as involving two objects and, when the screen was lowered, found the presence of only a single object on the platform inconsistent with their representation of the speed-discontinuity event. Additional studies revealed that boys and girls exhibit different developmental trajectories in their performance on this task. Boys first showed prolonged looking to the one-object display at 7.5 months, whereas girls first showed prolonged looking at 9.5 months, indicating that boys precede girls in their capacity to detect the discrepancy between the speed-discontinuity event and the final one-object display.

How can one explain group differences in infants' performance on event-mapping tasks? In what cognitive processes do infants engage during such tasks? There is evidence that infants organize physical events into categories, and then segregate event sequences on the basis of the physical category to which they belong, such as occlusion, containment, or collision (Baillargeon, 1998; Baillargeon & Wang, 2002; Wang, Baillargeon, & Paterson, 2005). Wilcox and Baillargeon (1998a) proposed that when infants see an occlusion event followed by a no-occlusion display, the change in event category leads them to parse the sequence into two separate and distinct events. The result is that infants form two event representations: one for the occlusion event and another for the no-occlusion display. In the interest of making sense of the world as it unfolds, rather than dealing with only independent snapshots of the world, infants are compelled to link the two events. It is when infants attempt to retrieve their representation of the first (occlusion) event and compare it to the final (no-occlusion) display, to determine whether the two events are consistent, that infants experience difficulty. According to this analysis, infants' failure on event-mapping tasks reflects their inability to form a clear representation of the initial occlusion event that they can then retrieve and compare to the final one-object display. This is particularly difficult when the objects reverse direction and undergo multiple occlusion sequences. Under these conditions, the event is too long and unwieldy for infants to retrieve from beginning to end. The only opportunity infants have for success is to form a summary representation of the event and retrieve the summary representation. A summary representation describes the simple structure of the event—the number of distinct number objects and their spatiotemporal coordinates—and is much easier to manipulate than a lengthy and complex event sequence. If the summary representation does not map onto the final display—if the number of objects involved in the occlusion event is inconsistent with the number of objects present in the final display—infants find the events incongruent and show prolonged looking. In short, event-mapping requires infants to align and compare the structure of one event with that of another event and judge

whether the two are consistent. If infants do not have a clear representation of one of the event's structures because the event was too complex to retrieve from beginning to end, and infants were unable to extract the simple structure of the event to use in its place, the process fails.

There are three lines of evidence that support this hypothesis. First, if the initial and final phases of the test event are of the same event category (i.e., both events are occlusion events), so that mapping of one event onto another is not required, infants succeed at interpreting the final display. For example, if a transparent occluder is positioned behind the opaque occluder, so that when the opaque screen is lowered the event category does not change (the transparent occluder remains standing), infants successfully monitor the internal consistency of this one event and find the presence of a single object on the stage at the end of the event unexpected. That is, they show prolonged looking when the number of objects present behind the transparent occluder is inconsistent with the number of objects that had emerged from behind the opaque occluder (Wilcox & Chapa, 2002). Second, when infants are given help in identifying the simple structure of a complex event, either by labeling the objects (Xu, 2002; Xu, Cote, & Baker, 2005) or by showing them the basic components of the occlusion sequence prior to the test trials (Wilcox, 2003), they are more likely to succeed on event-mapping tasks. Third, if the objects follow a single trajectory across the platform, never changing direction, so that the occlusion sequence is very simple and easy to retrieve, infants demonstrate improved performance on event-mapping tasks (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002). For example, if infants are presented with just one trajectory of the speed-discontinuity event (i.e., an object disappears behind one edge of a screen and immediately appears at the right edge), and then the screen is lowered, 4.5-month-olds (girls and boys) show prolonged looking to a one-object display (Wilcox & Schweinle, 2002).

The concept of mapping one event representation onto another is not entirely new, and precursors can be found in a long-standing and prominent model of adult cognition. According to structure mapping theory (Gentner, 1983, 1989; Markman & Gentner, 1993), cognitive representations are structured, and many cognitive processes in which adults engage (e.g., analogy, similarity) require comparison of these structured representations. The comparison process involves aligning two representations and then determining whether the elements of one representation (i.e., the objects, the attributes of the objects, or the relations between the objects) are consistent with those of a second representation. Mapping can be simple one-to-one mapping (i.e., do the objects in Event 1 map onto the objects in Event 2) or relational mapping (i.e., does the relation between the objects in Event 1 map onto the relation between the objects in Event 2). In event-mapping tasks like those already described, successful performance requires only one-to-one mapping: determining whether the number of objects involved in the first event is consistent with the number of objects seen in the second event. However, event-mapping

tasks have been adapted to assess the extent to which infants can map object attributes as well as the relation between those attributes and individual objects (e.g., Káldy & Leslie, 2003, 2005; Leslie, Xu, Tremoulet, & Scholl, 1998; Tremoulet, Leslie, & Hall, 2001, Wilcox & Schweinle, 2002). Finally, and perhaps most important to this research, is that structural comparison has not only been implicated in adults (Bowdle & Gentner, 2005; Gentner & Gunn, 2001; Gentner & Kurtz, 2006; Gentner & Markman, 1994; Markman & Gentner, 1997), but has also been observed in children in a wide range of cognitive tasks, including category learning (Gentner & Namy, 1999), analogical reasoning (A. L. Brown, 1989; A. L. Brown, Kane, & Echols, 1986; Crisafi & Brown, 1986; Gentner & Toupin, 1986; Goswami & Brown, 1990), language learning (Gentner & Namy, 2006), and spatial mapping (Loewenstein & Gentner, 2001). Generally speaking, the more explicit or better understood the structure of a representation, the more likely children are to map that representation onto a new problem context.

Finally, although the sex differences reported by Schweinle and Wilcox (2004) are provocative, the extent to which these differences are observed in event-mapping tasks more generally is unknown. One area in which event-mapping tasks have been used extensively is that of infants' sensitivity to featural information. To illustrate, Wilcox and Baillargeon (1998a) presented 9.5- and 11.5-month-olds with a test event in which a ball started at the left edge of a platform and moved behind the left edge of a screen. After an interval appropriate for the ball's rate of motion, a ball (ball–ball event) or a box (ball–box event) emerged at the right edge of the screen; this sequence was next seen in reverse. The entire event cycle just described was repeated once, and then the ball moved one last time to disappear behind the left edge of the screen. Finally, the screen was lowered to reveal a single ball on the platform. Prior to the test events, infants were presented with familiarization events designed to acquaint them with the objects and the occlusion sequence. The familiarization events were identical to the test events except that a second, shorter screen stood behind the first screen, so that when the first screen was lowered the center of the platform remained occluded. At 9.5 months, the infants in ball–box and ball–ball conditions looked about equally at the one-ball test display, suggesting that they failed to detect the inconsistency between the ball–box occlusion sequence and the final one-ball display. In contrast, at 11.5 months the infants in the ball–box condition looked reliably longer at the one-ball display, suggesting that they found the one-ball display unexpected after viewing the ball–box event. Most important for this discussion, the performance of the boys and girls did not differ at either age. Whereas both the boys and the girls at 11.5 months detected the inconsistency between the ball–box event and the one-ball display, neither the boys nor the girls successfully completed this task at 9.5 months. If the sex difference observed in the speed-discontinuity event-mapping task of Schweinle and Wilcox (2004) reflects underlying differences in infants' ability to form and use representations of occlusion sequences, then boys should

succeed at mapping different-features events prior to girls. The first experiment tests this hypothesis.

EXPERIMENT 1

Experiment 1 assessed 9.5-, 10.5-, and 11.5-month-olds' performance on a different-features event-mapping task. Although Wilcox and Baillargeon (1998a) reported that boys and girls do not differ in their capacity to map a different-features event at 9.5 months (both fail) and at 11.5 months (both succeed), there are several differences between the experimental procedure of Wilcox and Baillargeon (1998a) and that of this experiment. To systematically explore the development of infants' capacity to map different-features events, all three age groups were assessed using the test events of Figure 2. If boys and girls differ in their capacity to
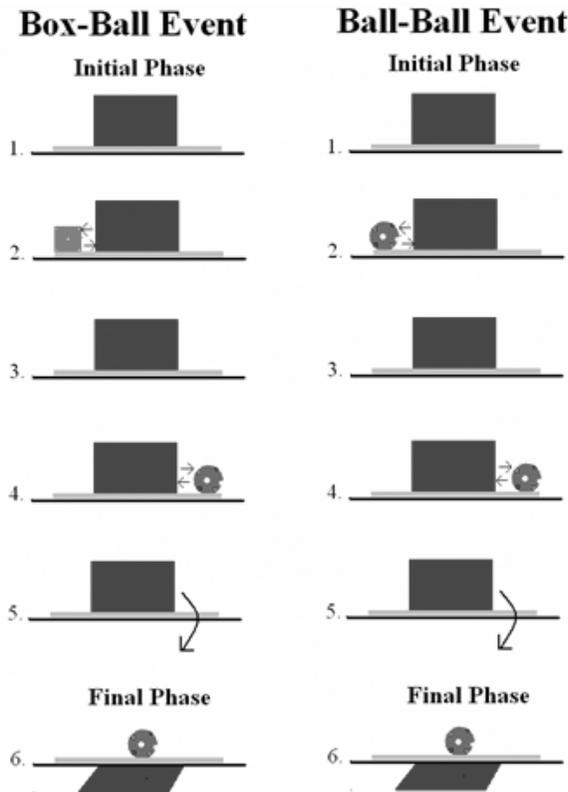
FIGURE 2   Schematic representation of the box–ball and ball–ball test events of Experiment 1. A hand (not pictured) moved the objects.

map a different-features event, like they differ in their capacity to map a speed-discontinuity event, boys should detect an inconsistency between the box–ball occlusion sequence and the final one-ball display prior to girls. More specifically, 9.5-month-old boys and girls should not show prolonged looking to the one-ball display after viewing the box–ball event (i.e., the infants in the box–ball and ball–ball condition should look equally at the one-ball display). At 10.5 months only boys should show prolonged looking after viewing the box–ball event and, finally, at 11.5 months, both boys and girls in the box–ball condition should show prolonged looking to the one-ball display.

Method

Participants

An equal number of boys and girls were tested at 9.5 months ($n = 32$; *M* age = 9 months, 15 days; range = 9, 3 to 9, 28), 10.5 months ($n = 40$; *M* age = 10 months, 11 days; range = 10, 2–10, 28), and 11.5 months ($n = 32$; *M* age = 11 months, 13 days; range = 11, 1 to 12, 1). Infants were healthy and born full-term. An additional 11 infants were tested but eliminated from the analyses: 7 because of procedural problems, 2 because of crying, and 2 because the primary observer was unable to determine the infants' direction of gaze. At each age infants were randomly assigned (with the stipulation that an equal number of boys and girls were included in each group) to one of two conditions: box–ball or ball–ball.

Apparatus and Stimuli

The apparatus was a wooden cubicle 213 cm high, 105 cm wide, and 43.5 cm deep. Infants faced an opening 51 cm high and 93 cm wide in the front wall of the apparatus. The floor and walls of the stage were cream-colored and the back wall was covered with lightly patterned contact paper. A cream-colored platform 1.5 cm high, 60 cm wide, and 17 cm deep, 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.

Two test objects were used in the box–ball event. The ball was 10.25 cm in diameter and painted green with evenly spaced red, blue, and yellow dots. The box

was 10.25 cm square, covered with red felt, and decorated with evenly spaced sil-ver 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. The slit was covered with cream-colored fringe. To equate the events as much as possible, a second identical ball was used in the ball–ball event. The box (box–ball condition) or the second ball (ball–ball condition) 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-watt fluorescent bulbs were attached to the inside walls of the apparatus.

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 in-dicate the time taken to produce the actions described. A metronome ticked softly once per second to help the experimenters adhere to the events' scripts.

Box–ball condition.   At the start of each familiarization trial, the screen stood upright at the center of the platform. In the first familiarization trial, the ex-perimenter's hand gently tilted the box, left to right, at the left edge of the platform. In the second familiarization trial, the hand tilted the ball at the right edge of the platform. At the start of each test trial 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 test event, the hand moved the box to the left edge of the platform (2 sec), paused (1 sec), and then returned the box behind the screen (2 sec). Next, the hand moved the ball to the right edge of the platform (2 sec), paused (1 sec), and then moved the ball back behind the screen (2 sec). 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 experimenter lowered the screen to the apparatus floor (1 sec), 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.

Ball–ball condition.   The familiarization and test events of the ball–ball con-dition were similar to those of the box–ball condition, except that the second iden-tical ball was substituted for the box.

Procedure

The infant sat on a parent's lap centered in front of the apparatus, with his or her head approximately 80 cm from the objects on the platform. The parent was asked not to interact with the infant during the experiment and to close his or her eyes during the test events.

The infants first saw the familiarization events appropriate for their condition. The familiarization trials ended when the infant either (a) looked away for 2 consecutive sec after having looked for at least 5 cumulative sec or (b) looked for 60 cumulative sec without looking away for 2 consecutive sec. Next, 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. Trial termination criteria for the final phase of the test trials were identical to those of the familiarization trials.

The infant's looking behavior was monitored by two naive observers[1] 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 pressed the button when the infant attended to the events. The looking times recorded by the primary observer determined when a trial had ended and were used in the data analyses. Each trial was divided into 100-msec intervals, and the computer determined in each interval whether the two observers agreed on the direction of the infant's gaze. Interobserver agreement was calculated for the test trials for 99 infants (only one observed was available for 5 infants) and averaged 95% per test trial per infant.

Results

Familiarization Trials

The infants' looking times during the two familiarization trials were submitted to a mixed-model analysis of variance (ANOVA) with age (9.5, 10.5, or 11.5 months), condition (box–ball or ball–ball), and sex (male or female) as between-subject factors and trial (first or second) as the within-subjects' factor. The main effect of trial, $F(1, 92) = 8.21$, $p < .01$, was significant, as was the Trial × Condition interaction, $F(1, 92) = 7.86$, $p < .01$. The infants in the box–ball condition looked about equally during the first ($M = 31.9$, $SD = 16.1$) and the second ($M = 31.9$, $SD = 17.4$) familiarization trial. In contrast, the infants in the ball–ball condition looked longer during the first ($M = 36.9$, $SD = 16.3$) than the second ($M =$

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[1]In Experiments 1 and 2 infants saw a box–ball or a ball–ball test event. Observers were asked to guess at the end of each test session whether the infant saw a box–ball or ball–ball event. Of the 124 infants tested, primary observers responded for 121. Of these, 61 guessed correctly, a performance not significantly different from chance (cumulative binomial probability, $p > .05$).

26.1, SD = 17.8) familiarization trial. However, looking times averaged over the two familiarization trials were similar for the two conditions (box–ball M = 31.9, SD = 14.3 and ball–ball M = 31.5, SD = 13.9), indicating that the infants in the box–ball and ball–ball conditions did not differ in their overall attention to the familiarization displays. No other main effects or interactions were significant, $Fs(1, 92) < 1.5$.

Test Trials

Preliminary analyses revealed no reliable main effects or interactions involving trial. Hence, infants' looking times during the final phase of the two test trials (Table 1) were averaged and analyzed by means of an ANOVA with age (9.5, 10.5, or 11.5 months), condition (box–ball or ball–ball), and sex (male or female) as between-subject factors. The Age × Condition × Sex interaction was significant, $F(1, 92) = 9.39$, $p < .001$, $\eta_p^2 = .17$. To specify the nature of the three-way interaction, a 2 (condition) × 2 (sex) ANOVA was computed for each age separately.

For the 9.5-month-olds, there were no significant main effects or interactions, $Fs(1, 28) < 2.7$, indicating that the infants in the box–ball and ball–ball conditions looked about equally at the final one-ball display and that looking times did not vary reliably by sex.

For the 10.5-month-olds, the Condition × Sex interaction was significant, $F(1, 36) = 22.17$, $p < .001$, $\eta_p^2 = .33$. Planned comparisons revealed that the boys in the box–ball than the ball–ball condition looked longer at the final display, $F(1, 36) =$

TABLE 1
Looking Times (in Seconds) to the One-Ball Display of the Infants
in the Box–Ball and the Ball–Ball Conditions of Experiment 1

Age in Months	Sex	Box–Ball Condition		Ball–Ball Condition	
		M	SD	M	SD
9.5	Male	20.9	9.7	30.7	14.2
	Female	24.3	5.0	28.0	15.3
	Total	22.6	7.7	29.4	14.3
10.5	Male	43.9	15.6	19.9	8.6
	Female	20.1	3.9	32.2	16.0
	Total	32.0	16.5	26.0	14.0
11.5	Male	28.0	10.0	16.4	9.2
	Female	32.3	10.8	21.2	6.6
	Total	30.2	10.3	18.8	8.1

Note. Statistical analyses (see text) revealed sex differences at 10.5 months (boys but not girls in the box–ball condition showed prolonged looking) but not at 9.5 months (neither sex in the box–ball condition showed prolonged looking) and 11.5 months (both boys and girls in the box–ball condition showed prolonged looking).

19.58, $p < .001$. A Mann–Whitney U test confirmed that the distributions of these two groups differed reliably, $Z = 3.03$, $p < .01$ (two-tailed). In contrast, the girls in the ball–ball than box–ball condition looked reliably longer at the final display, $F(1, 36) = 4.98$, $p < .05$. A Mann–Whitney U test confirmed that the distributions of these two groups also differed reliably, $Z = -2.12$, $p < .05$ (two-tailed). Although we did not predict this outcome with the girls (we expected equal looking times for the two conditions), a similar trend was observed with the 9.5-month-olds (boys and girls). Perhaps when infants are unable to successfully engage in the mapping process, they become interested in other aspects of the event, leading to unpredictable patterns of looking.

For the 11.5-month-olds, the main effect of condition was significant, $F(1, 28) = 12.03$, $p = .002$, $\eta_p^2 = .30$. The main effect of sex and the Sex × Condition interaction were not significant, all Fs$(1, 28) < 2.0$. These results indicate that the infants in the box–ball condition looked longer at the one-ball display than the infants in the ball–ball condition and that looking times did not vary reliably by sex. Planned comparison confirmed that the boys, $F(1, 28) = 6.33$, $p < .025$, and the girls, $F(1, 28) = 5.71$, $p < .025$, looked reliably longer at the one-object display after viewing the box–ball than the ball–ball event. Finally, Mann–Whitney U tests confirmed that the distributions of the box–ball and the ball–ball infants differed reliably for the boys, $Z = -2.42$, $p < .025$ (two-tailed), and the girls, $Z = -2.00$, $p < .05$ (two-tailed).

Discussion

The results of Experiment 1 revealed a sex difference in the age at which infants first successfully mapped a different-features (box–ball) event onto a one-ball display. Whereas boys first succeeded at 10.5 months, girls first succeeded at 11.5 months. These results are consistent with those of other event-mapping experiments in which sex differences have been obtained (Schweinle & Wilcox, 2004; Wilcox, 2003) and provide converging evidence for the conclusion that male and female infants differ in their capacity to map occlusion sequences.

Why did the girls have difficulty mapping the box–ball event? Like Wilcox and Baillargeon (1998a; see also Wilcox, Schweinle, & Chapa, 2002; Wilcox & Woods, in press), we would argue that failure to succeed on an event-mapping task reflects infants' difficulty with extracting the simple structure of the occlusion event—which includes the number of distinct objects and their spatiotemporal coordinates—that they can then retrieve and compare to the final display. According to this hypothesis, infants should demonstrate improved performance when given experiences that facilitate extraction of the simple structure. For example, if presented with the basic components of the occlusion sequence, one piece at a time, prior to viewing a test event, infants should demonstrate improved performance. The hypothesis, then, is that if 10.5-month-old girls are shown an outline of the

box–ball event prior to the test trials, they should be more likely to map the box–ball event onto the one-object display. Experiment 2 tests this hypothesis.

EXPERIMENT 2

One way to conceptualize an outline is to think of it as a précis that captures the basic structure of the event. To illustrate, consider attending a lecture on biomechanical engineering, a topic of which you have limited knowledge. Before the lecture begins, the professor provides an outline of the talk that organizes the talk into three sections and clearly identifies the main points to be covered in each section. This organization provides a structure with which to integrate material as it is presented, helping you to condense a lengthy lecture into several main points. When you are later asked by your colleagues what the lecture was about, you can easily retrieve these main points. Similarly, we propose that providing infants with an outline of the box–ball event, prior to viewing the event itself, facilitates the formation of a summary representation that infants can then retrieve and compare to the final display.

What would be an outline of the box–ball event? What is the simple structure of the event? The box–ball event contains two basic components: a box that moves to the left of the screen and a ball that moves to the right. Using this analysis as the basis for designing an event outline, 10.5-month-old girls were tested using the procedure of Experiment 1 except that in the familiarization trials, the trajectories of the objects were specified. In the first familiarization trial, infants saw a box (box–ball condition) or a ball (ball–ball condition) move on a trajectory to the left of the screen and then return. In the second familiarization trial the ball moved on a trajectory to the right of the screen and returned. Previous studies suggest that this type of outline can facilitate infants' mapping of different-features events (Wilcox, 2003).

Method

Participants

Participants were 20 girls aged 10.5 months (*M* age = 10 months, 15 days; range = 10, 2–10, 29). Infants were randomly assigned to one of two conditions: box–ball or ball–ball.

Apparatus, Stimuli, Events, and Procedure

The apparatus, stimuli, events, and procedure were identical to those of Experiment 1 with one exception: In the familiarization trials the trajectory of each object was specified.
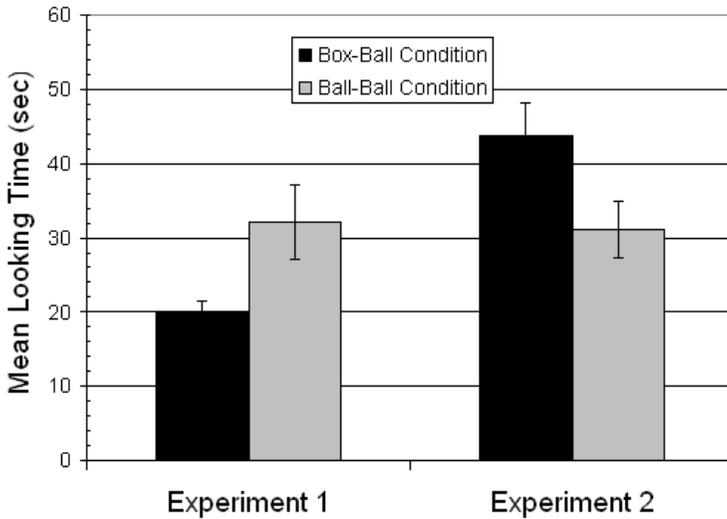
FIGURE 3   Mean looking times (with *SE* bars) of the 10.5-month-old girls of Experiment 1, who did not see an event outline, and the 10.5-month-old girls of Experiment 2, who did see an event outline.

Box–ball condition.   At the start of each familiarization trial, the box and the ball were hidden behind the left and right sides of the screen, respectively. In the first familiarization trial (Steps 1–3 of the box–ball event of Figure 2), the hand moved the box to the left edge of the platform (2 sec), paused (1 sec), and then returned the box behind the screen (2 sec). No other action was taken. In the second familiarization trial (Steps 3–5 of the box–ball event of Figure 2), the hand moved the ball to the right edge of the platform (2 sec), paused (1 sec), and then returned the ball behind the screen (2 sec). No other action was taken. Infants were then presented with the test event of the box–ball condition of Experiment 1.

Ball–ball condition.   The familiarization events of the ball–ball condition were identical to those of the box–ball condition except that the second identical ball was substituted for the box. That is, the first familiarization trial consisted of Steps 1 to 3 of the ball–ball event of Figure 2 and the second familiarization trial consisted of Steps 3 to 5 of the same event. Infants were then presented with the test event of the ball–ball condition of Experiment 1.

Interobserver agreement was measured for 17 of the 20 infants and agreement averaged 97%.

Results

Familiarization Trials

Preliminary analysis of familiarization data revealed no significant main effects or interactions involving trial; data were therefore collapsed across trials in subsequent analysis. The infants' mean looking times were averaged across the two familiarization trials and submitted to a one-way ANOVA with condition as the between-subject factor. The main effect of condition was not significant, $F(1, 18) < 1$, indicating that the infants in the box–ball ($M = 16.1$, $SD = 9.0$) and ball–ball ($M = 17.5$, $SD = 4.1$) condition looked about equally during the familiarization trials.

Test Trials

Preliminary analysis of test data revealed no significant main effects or interactions involving trial; data were therefore collapsed across trial in subsequent analysis. The infants' mean looking times were averaged across the two test trials and analyzed in the same manner as the familiarization trials. The main effect of condition was significant, $F(1, 18) = 4.52$, $p < .05$. $\eta_p^2 = .20$, indicating that the infants in the box–ball condition ($M = 43.8$, $SD = 13.8$) looked reliably longer at the final one-object display than the infants in the ball–ball condition ($M = 31.3$, $SD = 12.0$).

To compare the performance of the 10.5-month-old girls across the two experiments, an analysis was performed with experiment (Experiment 1 or Experiment 2) and condition (box–ball or ball–ball) as between-subject factors. The Experiment × Condition interaction was significant, $F(1, 36) = 9.87$, $p < .01$, $\eta_p^2 = .22$, indicating that the girls of Experiment 2 responded reliably differently to the final one-object display than those of Experiment 1. Whereas the girls of Experiment 2 looked longer at the final display after viewing the box–ball than the ball–ball event, the girls of Experiment 1 looked longer at the final display after viewing the ball–ball than the box–ball event.

To compare the performance of the 10.5-month-old girls of Experiment 2 with the 9.5-month-old boys of Experiment 1, an analysis was performed with age and sex (10.5-month-old girls or 9.5-month-old boys) and condition (box–ball or ball–ball) as between-subject factors. The main effect of condition was significant, $F(1, 36)$, $= 20.14$, $p < .001$, $\eta_p^2 = .36$, indicating the infants in the box–ball condition looked reliably longer at the final display than the infants in the ball–ball condition. The main effect of age and sex and the Age and Sex × Condition interaction were not significant, $Fs(1, 36) < 2.5$, indicating that the 10.5-month-old girls of Experiment 2 responded like the 9.5-month-olds of Experiment 1. Both groups looked longer at the final display after viewing the box–ball than the ball–ball event.

Discussion

After seeing an outline of the box–ball event prior to the test trials, 10.5-month-old girls successfully mapped the box–ball occlusion sequence onto the final one-ball display. Additional analyses revealed that the 10.5-month-old girls of Experiment 2, who saw an outline of the box–ball event prior to the test trials, performed reliably better on the event-mapping task than the 10.5-month-old girls of Experiment 1, who did not see an event outline. One interpretation of these results is that seeing each object and the trajectory it would follow prior to viewing the occlusion sequence helped the infants to form a summary representation of the test event—a box moves to the left of the screen and a ball to the right—that they could then compare to the final one-ball display. This interpretation is consistent with the outcome of other event-mapping studies (Wilcox, 2003).

However, there is an alternative explanation for these results that should be considered. Perhaps viewing the objects on a motion path during the familiarization trials is more likely to capture infants' attention than viewing the objects tilting left to right at one location. Once attention is captured by the familiarization event, this leads to better encoding of the test event. However, the familiarization data argue against this interpretation. In Experiment 2 the objects were in view for a much shorter period of time in each familiarization trial than in Experiment 1 (5 sec vs. 60 sec) and infants' familiarization looking times were much shorter for Experiment 2 (box–ball $M = 16.1$, $SD = 9.0$; ball–ball $M = 17.5$, $SD = 4.1$) than Experiment 1 (box–ball $M = 31.9$, $SD = 14.3$; ball–ball $M = 31.5$, $SD = 13.9$). Yet infants evidenced better event-mapping performance in Experiment 2 than Experiment 1. This outcome suggests that viewing each object and its trajectory, even for a brief period of time, is more likely to facilitate event-mapping performance than having a lengthy period of time during which to encode the objects. That is, identifying the number of distinct objects present and their paths of motion is more important to the mapping of occlusion sequences than remembering the featural properties of the objects involved, at least in this experimental context.

GENERAL DISCUSSION

In these experiments, boys and girls demonstrated different developmental trajectories in their capacity to map their representation of a different-features (i.e., box–ball) event onto a one-ball display. Whereas boys first mapped a box–ball event at 10.5 months, girls first mapped the same event at 11.5 months. The better performance of the boys, although short-lived (boys and girls both failed at 9.5 months and both succeeded at 11.5 months), mirrors that observed in other event-mapping tasks (Schweinle & Wilcox, 2004; Wilcox, 2003). For example, Schweinle and Wilcox (2004) reported a sex difference in infants' capacity to map

a speed-discontinuity event. Whereas boys first evidenced event-mapping success at 7.5 months, girls first evidenced success at 9.5 months. Hence, there is now converging evidence, with two different event-mapping tasks, that boys precede girls in their capacity to map complex occlusion sequences onto no-occlusion displays.

It is important to note that sex differences have not been observed in tasks that simply assess infants' capacity to interpret an occlusion sequence. A number of experiments have revealed that infants interpret an ongoing box–ball event as involving two separate and distinct objects (McCurry, Wilcox, & Woods, 2006; Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b; Wilcox & Chapa, 2002). For example, infants 4.5 months to 11.5 months old are surprised to see the ball and the box out of view behind a screen too narrow to occlude both objects simultaneously (Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b) and infants 5.5 months to 7.5 months old search behind the screen for the box after viewing the box–ball occlusion sequence (McCurry et al., 2006), and sex differences have not been observed in any of these tasks. Similarly, experiments have revealed that infants as young as 3.5 months old interpret an ongoing speed-discontinuity event as involving two objects and, again, sex differences were not observed (Wilcox & Schwienle, 2003). The fact that sex differences have been observed in tasks that require infants to map occlusion sequences, but not in tasks that require infants to simply interpret those occlusion sequences, suggests that the sex difference observed in this research is better ascribed to the cognitive demands associated with event-mapping tasks than to the capacity to individuate objects. This begs the question, however, of why males and females demonstrate robust, albeit transient, differences in event-mapping abilities.

Explaining Sex Differences in Event-Mapping Performance

We suggested earlier that the difference in performance between males and females obtained in event-mapping tasks is best explained by differences in the capacity to identify the simple structure of an event sequence. The outcome of Experiment 2, which demonstrated that girls performed better when they were given experiences that helped them to extract the simple structure of the box–ball event, supports this hypothesis. Why are males more skilled than females at composing summary representations of occlusion sequences? What is the underlying basis for this difference?

There have been a number of sex differences reported in infants' perception of visual stimuli and events, some favoring boys (Overman et al., 1997; Overman et al., 1996) and others favoring girls (Bauer et al., 1986; Creighton, 1984; Held et al., 1988; Held et al., 1984; Kavšek, 2004; Moore & Cocas, 2006; Overman et al., 1997; Overman et al., 1996; Tighe & Powlison, 1978). Most pertinent to this discussion are findings that human (Overman et al., 1997; Overman et al., 1996) and monkey (Clark & Goldman-Rakic, 1989; Goldman et al., 1974) male infants ma-

ture more quickly than female infants in their ability to perform on tasks that require them to relate information over space and time and to retrieve and act on stored information. For example, male infants are more likely than female infants to succeed on an object retrieval task. In an object retrieval task, participants must learn to choose a new or unrewarded object over a previously rewarded object. That is, infants must use featural information to discriminate between objects, keep track of the identity of the objects across trials, and retrieve and use information about the outcome of previous trials. Furthermore, these differences are associated with different rates of cortical maturation that are hormonally induced (Clark & Goldman-Rakic, 1989; Goldman & Brown, 1975; Hagger & Bachevalier, 1991; Hagger et al., 1987). For example, research with monkeys suggests that the orbital frontal lobe mediates tasks that require spatiotemporal integration of information, that the orbital frontal lobe matures more quickly in males, and that altering the level of plasma testosterone alters performance on tasks that tap orbital frontal functions (Clark & Goldman-Rakic, 1989; Goldman & Brown, 1975; Goldman et al., 1974).

Together, these results suggest a possible biological basis for the sex difference obtained in these experiments. The processing demands associated with event-mapping tasks are similar, in many respects, to the processing required for object reversal and other tasks known to be mediated by the orbital frontal cortex. For example, success on the different-features event-mapping task is dependent on infants' ability, first, to integrate featural and motion-carried information through an occlusion sequence and, second, to track information about the identity of objects across successive, and categorically distinct, events. Both of these processes require updating and integration of information over space and time, suggesting that performance on event-mapping tasks, like performance on object reversal tasks, may be mediated by the orbital frontal cortex.

Admittedly, this account is only speculative. Although parallels can be drawn between object reversal (and related) tasks and event-mapping tasks, these tasks also differ in many respects. These differences make it difficult to draw firm conclusions about the extent to which sex differences observed in event-mapping tasks can be explained by different rates of neural maturation. Of course, in human infants we are unable to directly assess the relation between hormonally induced changes in brain maturation and performance on perceptual and cognitive tasks. However, there are experimental approaches that have been used to explore the relation among hormones, brain, and behavior in human children and adults. These same approaches could be used to examine the extent to which gonadal hormones influence perceptual and cognitive processing in infancy. For example, there are infants who endogenously produce, or are exposed to, atypical levels of testosterone during the prenatal and early postnatal period. This is a period of time during which the brain undergoes substantial maturation and during which neural development is particularly sensitive to the organizational effects of hormones. One

group that has been well studied is that composed of individuals with congenital adrenal hyperplasia (CAH), an autosomal recessive disorder. Individuals with CAH have a deficiency in cortisol synthesis that triggers the overproduction of cortisol precursors, most notably androgens (i.e., testosterone). This overproduction of testosterone begins prenatally and continues postnatally. Researchers have compared girls and boys with CAH with unaffected girls and boys on a number of physical attributes (W. M. Brown, Hines, Fane, & Breedlove, 2002) and behavioral measures (Berenbaum & Hines, 1992; Hines & Kaufman, 1994; Pasterski et al., 2005). The outcome of these studies has revealed that girls with CAH often show a masculinization of sex-typed behaviors (i.e., they display characteristics more like unaffected boys than unaffected girls), even when environment influences have been accounted for (e.g., Pasterski et al., 2005).

One possible strategy, then, is to assess the extent to which girls with CAH perform like unaffected boys and unaffected girls on event-mapping tasks. If the sex differences in event-mapping performance observed here and in other recent papers (Schweinle & Wilcox, 2004; Wilcox, 2003) are linked to high levels of testosterone (which leads to different rates of neural maturation) then girls with CAH, like unaffected boys, should mature more quickly than unaffected girls in their capacity to succeed on event-mapping tasks. More specifically, girls with CAH should successfully map different-features events at 10.5 months and speed-discontinuity events at 7.5 months. If this outcome were obtained, follow-up research could be conducted to identify the extent to which other neural markers of increased levels of testosterone (e.g., W. M. Brown et al., 2002) are correlated with event-mapping performance and to explore, using brain-mapping techniques, the neural structures involved.

In sum, there are approaches that allow researchers to test specific hypotheses about the relation between gonadal hormones and perceptual and cognitive development in infancy and, more generally, to assess the extent to which biological mechanisms can account for early sexually dimorphic behaviors. Although these approaches require access to special populations, which is sometimes difficult to obtain, the outcome of such studies would significantly advance our understanding of the relation between hormones and behavior during the first year of life.

Finally, the analysis of sex differences outlined in this section leads to predictions about other tasks in which sex differences should be observed. One straightforward prediction is that males should outperform females on any task that requires them to extract the simple structure of an event sequence and then map that structure onto the structure of another categorically distinct event. For example, consider the following task. First, infants are presented with an event in which an object is placed into one of several containers. This is repeated with several different objects; each object is placed into a different container. Next, the containers are replaced by occluders and the same sequence is observed; one object is placed behind each of several occluders. Boys should be more likely than girls to detect

when the number and the location of the objects involved in the containment event are inconsistent with the number and the location of the objects involved in the occlusion event. One word of caution is warranted, however. If the sex difference is subtle, the task will need to be made sufficiently taxing (e.g., by increasing the number of containers and occluders or by making the spatial arrangements more complicated) for the sex difference to be revealed. Another prediction is that boys will precede girls in their capacity to succeed on tasks that are mediated by the orbital frontal cortex. Although developmental neuroscientists have yet to identify specific tasks that tap orbital frontal function in young infants, there is evidence that boys outperform girls on orbital frontally mediated tasks in early childhood (Overman et al., 1997; Overman et al., 1996).

Infants' Mapping of Different Features Versus Speed-Discontinuity Events

In addition to illuminating early sex differences in event-mapping capacities, the outcomes of Experiments 1 and 2 also shed light on infants' processing of different-features and spatiotemporally discontinuous events. These results, when compared to other recent event-mapping results, reveal that infants succeed at mapping a speed-discontinuity event prior to a box–ball event. To illustrate, boys and girls first map a speed-discontinuity event at 7.5 months and 9.5 months, respectively (Schweinle & Wilcox, 2004). In contrast, as revealed by these experiments, boys and girls first map a different-features event at 10.5 months and 11.5 months, respectively. So even though boys precede girls in their event-mapping abilities, both boys and girls map a speed-discontinuity event prior to a different-features event. The most likely explanation for this phenomenon has to do with the ease with which infants can access and use these two types of information—spatiotemporal and featural—to interpret occlusion events. Most investigators agree that from the early months of life, infants are sensitive to spatiotemporal information (e.g., Aguiar & Baillargeon, 2002, Arterberry, 1997; Arterberry, Craton, & Yonas, 1993; Spelke, Kestenbaum, Simons, & Wein, 1995) and are more likely to rely on motion-carried than featural information to interpret occlusion sequences. When featural information is ambiguous or difficult to interpret, even older infants draw on spatiotemporal information to parse visual displays into objects and track those objects through space and time. In light of infants' greater sensitivity to spatiotemporal than featural information, it is not surprising that infants are better equipped to interpret and form a representation of the speed-discontinuity event than the box–ball event. This developmental progression may reflect, at least in part, rates of cortical maturation. Generally speaking, there are two main pathways that mediate visual object processing. The dorsal pathway, which projects from the visual cortex to the parietal cortex, is important to the analysis of the spatiotemporal properties of objects (e.g., location, depth, path of motion), whereas the

ventral pathway, which projects from the visual cortex to the temporal cortex, is important to the analysis of the featural properties of objects (i.e., color, pattern). It may be that the processing required by individuation-by-spatiotemporal tasks, which involve moving occluded objects, is mediated by the dorsal pathway. In contrast, the processing required by individuation-by-feature tasks, which involve moving occluded objects that differ in their featural properties, is mediated by the ventral pathway and perhaps even requires interaction between the two pathways (Johnson, Mareschal, & Csibra, 2001; Mareschal, Plunkett, & Harris, 1999; Stiles, 2001). Recent neuroimaging data collected with infants support the idea that the analysis of featural information is mediated by different neural structures than the analysis of spatiotemporal information (Wilcox, Bortfeld, Woods, & Armstrong, 2006; Wilcox, Bortfeld, Woods, Wruck, & Boas, 2005, 2007). Furthermore, some researchers have suggested that the dorsal pathway matures prior to the ventral pathway, and that the neural connections that support the interaction between the two pathways may be particularly late in developing (Johnson et al., 2001; Mareschal et al., 1999). The fact that infants succeed on individuation-by-spatiotemporal tasks prior to individuation-by-feature tasks is consistent with this view of neural maturation.

Concluding Comments

The sex differences reported here join a growing number of papers reporting sex differences in perceptual and cognitive tasks in infancy and, more specifically, sex differences in infants' capacity to map occlusion sequences. Given the robust nature of these findings, it is unlikely that they are spurious and, hence, cannot be easily dismissed. The charge of future research will be to identify (a) the underlying basis for the differences observed, and (b) the extent to which these differences are related to other early emerging sex differences in behavioral and cognitive functioning. For example, infants who evidence behavioral traits early in infancy associated with higher levels of testosterone may also evidence better performance on event-mapping tasks. Finally, careful examination of sex differences observed in infancy may shed light on the origins of sex differences that have been reported in adults with selected cognitive tasks.

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