Short communication

Infants' reasoning about opaque and transparent occluders in an individuation task

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Abstract

There has been some debate about whether infants 10 months and younger can use featural information to individuate objects. The present research tested the hypothesis that negative results obtained with younger infants reflect limitations in information processing capacities rather than the inability to individuate objects based on featural differences. Infants aged 9.5 months saw one object (i.e. a ball) or two objects (i.e. a box and a ball) emerge successively to opposite sides of an opaque occluder. Infants then saw a single ball either behind a transparent occluder or without an occluder. Only the infants who saw the ball behind the transparent occluder correctly judged that the one-ball display was inconsistent with the box–ball sequence. These results suggest that: (a) infants categorize events involving opaque and transparent occluders as the same kind of physical situation (i.e. occlusion) and (b) support the notion that infants are more likely to give evidence of object individuation when they need to reason about one kind of event (i.e. occlusion) than when they must retrieve and compare categorically distinct events (i.e. occlusion and no-occlusion). © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

The problem of object individuation – determining whether an object currently in view is the same object or a different object than seen previously – has recently received a great deal of attention from infant researchers. Most of this research has focused on infants' ability to use featural information to individuate objects in occlusion events and the results

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have been somewhat controversial (e.g. Carey & Xu, 2001; Needham & Baillargeon, 2000; Wilcox & Baillargeon, 1998a,b; Wilcox, Schweinle, & Chapa, 2002; Xu & Carey, 1996, 2000).

For example, Xu and Carey (1996) showed 10- and 12-month-olds a test event in which two featurally distinct objects (e.g. a duck and a ball) emerged successively and repeatedly to opposite sides of a wide screen. The screen was then removed and infants saw a display containing one object (e.g. a duck) or two objects (e.g. a duck and a ball). The 12-month-olds, but not the 10-month-olds, responded as if they found the one-object display unexpected. Xu and Carey (1996) concluded that the ability to individuate objects using featural information develops between 10 and 12 months of age. They hypothesized that the capacity to draw on featural information to represent numerically distinct individuals is linked to the development of specific object concepts, that these concepts are acquired only at the end of the first year, and that language acquisition (e.g. noun comprehension) plays an important role in the process.

An alternative interpretation, proposed by Wilcox and Baillargeon (1998a), argued that the 10-month-olds in Xu and Carey (1996) had failed, not because they could not individuate the objects, but because of the information processing demands entailed in the task Xu and Carey used. This interpretation drew on the notion that infants group physical events into distinct categories (e.g. occlusion, support, containment, etc.) and then reason about the world in terms of these categories (Baillargeon, 1995, 1998). In Xu and Carey (1996), the infants saw two separate categories of events: an occlusion event (in which objects moved back and forth behind a screen) and a no-occlusion event (in which objects rested on a platform). Wilcox and Baillargeon (1998a) contended that tasks involving categorically distinct events place relatively high information processing demands on infants. First, when presented with two different physical situations infants must set up separate event representations (i.e. the change in event category leads infants to establish a new event representation). Second, in the interest of making sense of these two independent situations, infants must form a link between them. This linking, or mapping, process 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 are consistent. This process is particularly difficult when infants must map complex event sequences (e.g. featurally distinct objects that follow complicated trajectories), as they were required to do in Xu and Carey.

Two general approaches have been used to test Wilcox and Baillargeon's (1998a) interpretation. One approach has been to create a new procedure in which infants see only one event, rather than two events, so that infants do not need to engage in event mapping. Instead, they only need to monitor the internal consistency of a single event. When an event-monitoring task is used infants aged 4.5–11.5 months demonstrate the ability to use featural information to individuate objects (Wilcox, 1999b; Wilcox & Baillargeon, 1998a,b; Wilcox & Chapa, 2002). A second approach has been to use a task similar to that of Xu and Carey (1996), but to alter it in ways that make it simpler or more tractable. There is evidence that when the objects follow a single uncomplicated trajectory, so that it is easier to retrieve and scan the event, 5.5- to 9.5-month-olds successfully individuate objects (Wilcox & Baillargeon, 1998a; Wilcox & Schweinle, 2002). Alternatively, when the simple structure of a complex event is made more explicit (e.g.

infants are given spatiotemporal information about the number of objects present), 5.5- to 10-month-olds again successfully individuate objects (Wilcox, 1999a; Wilcox & Schweinle, 2002; Xu & Carey, 1996).

The present research took a third and different approach. Infants were, again, tested using a task like that of Xu and Carey (1996) except that the initial and final phases of the test event were either from the same physical category (i.e. occlusion) or two different physical categories (i.e. occlusion and no-occlusion). In the former this was accomplished by the use of transparent occluders in the final phase of the test event.[1] This manipulation allowed us to test directly the hypothesis that infants are more likely to succeed on tasks that involve two distinct physical situations than those that involve only a single physical situation. At the same time, we could explore what infants include in their occlusion category.

In Experiment 1, 9.5-month-olds saw a two-phase test event (Fig. 1). During the initial phase, a box (box–ball event) or a ball (ball–ball event) emerged from behind the left side of the screen and returned; next a ball emerged from behind the right side of the screen and returned. Then the center portion of screen was lowered to leave a narrow frame standing. During the final phase, a single ball was seen behind the frame. For half of the infants, the frame held a transparent pane affixed with dots (dotted-pane condition); for the other infants, the frame remained empty (no-pane condition). If the infants in the dotted-pane condition view the test event as one continuous event, an occlusion event with first an opaque and then a transparent occluder, and are able to monitor the internal consistency of the event as it unfolds before them, then the infants who see the box–ball sequence should find the one-ball display unexpected. Because infants typically look longer at events they find novel or unexpected (Bornstein, 1985; Spelke, 1985), the box–ball infants should look reliably longer during the final phase of the test event. In contrast, if the infants in the no-pane condition view the test event as composed of two distinct physical situations, an occlusion event followed by a no-occlusion event, and have difficulty mapping the objects from the box–ball event onto the one-ball display, then the infants in the two conditions should look about equally during the final phase.

In Experiment 2, a transparent pane without dots was used instead of the dotted pane.

2. Experiment 1

2.1. Method

2.1.1. Participants

Participants were 24 healthy term infants, 10 males and 14 females ($M = 9$ months, 17 days; range = 9 months, 6 days to 10 months, 2 days). Two additional infants were eliminated from the experiment because of procedural problems. Six infants were randomly assigned to each of four groups formed by crossing screen (dotted pane or no pane) and test event (box–ball or ball–ball).

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[1] Although this is a novel use of transparent occluders, they have been previously used in a number of different ways to investigate infants' object knowledge. For examples, see Johnson and Aslin (2000), Lockman (1984), Luo (2001), Neilson (1982), and Shinskey and Munakata (2001).
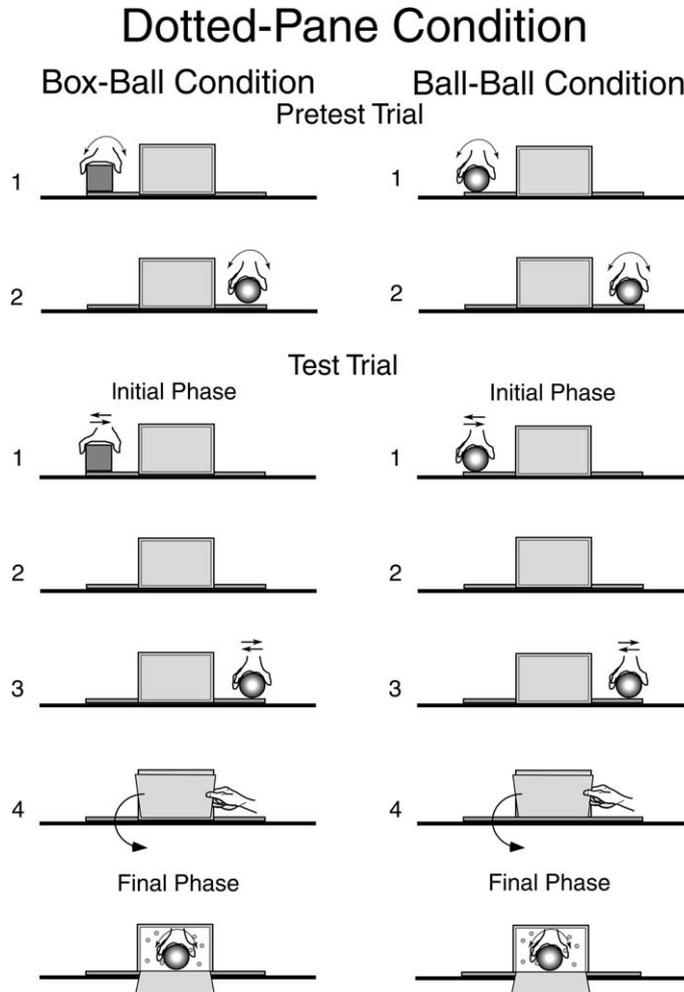
Dotted-Pane Condition

Fig. 1. Pretest and test events in the dotted-pane condition of Experiment 1. In the first pretest trial of the box–ball condition, a hand held the box to the left of the screen and tilted it gently to the left and to the right (once to each side per second) until the end of the trial. In the second trial, the ball underwent the same motion to the right of the screen. At the start of the test trial, the box and the ball were hidden behind the left and right sides of the screen, respectively. During the initial phase of the event, a 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). The ball and box moved at a rate of 12 cm/s. While the ball was in motion, a second experimenter surreptitiously removed the box from the apparatus through a hidden opening in the back wall. After the ball returned behind the screen, a third experimenter lowered the center portion of 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. The pretest and test events in the ball–ball condition were identical to those of the box–ball condition except that a ball was seen to both sides of the screen. The test events in the no-pane box–ball and ball–ball conditions were identical to those of the dotted-pane box–ball and ball–ball conditions except that the frame was empty.

2.1.2. Apparatus

The apparatus consisted of a wooden cubicle 213 cm high, 105 cm wide, and 43.5 cm deep. The infant sat on a parent's lap and faced an opening 51 cm high and 93 cm wide. A platform 1.5 cm high, 60 cm wide, and 19 cm deep lay flush against the back wall, centered between the left and right walls. The experimenter's hand moved the objects along the platform through a slit, concealed with cream-colored fringe, 7 cm high and 53 cm wide located 12 cm above the apparatus floor. Objects could be moved in or out of the apparatus through an opening, concealed by a removable door, 10 cm high and 14 cm wide, behind the screen.

The screen was 30 cm wide and 20 cm high. The center portion of the screen could be lowered, from the top, to leave a 2.5 cm frame standing. In the dotted-pane condition a clear plastic transparency affixed with blue dots, 2 cm in diameter and spaced approximately 3–6 cm apart, was placed in the frame. The box was 10.25 cm square, made of Styrofoam, covered in red felt, and adorned with silver thumbtacks. The ball was 10.25 cm in diameter, made of Styrofoam, and painted green with evenly spaced red, blue, and yellow dots. To equate the box–ball and ball–ball events as much as possible, the latter was produced using two identical balls.

2.1.3. Procedure

The infants received two pretest trials followed by one test trial. The pretest trials ended when the infant either (a) looked at the display for 30 cumulative seconds or (b) looked away for 2 consecutive seconds after looking for 5 cumulative seconds. Looking times to the initial and final phases of the test trial were recorded separately; only looking times to the final phase were analyzed. The final phase of the test trial ended when the infant either (a) looked at the display for 30 cumulative seconds or (b) looked away for 1 s after looking for 5 cumulative seconds.

Each infant's looking behavior was monitored by two observers who watched the infant through peepholes in cloth-covered frames on either side of the apparatus. Trial terminations were determined by the primary observer. Interobserver agreement in this and the following experiment averaged 96% or more per trial per infant.

2.2. Results and discussion

2.2.1. Pretest trials

The infants' looking times during the two pretest trials were averaged and analyzed by means of an analysis of variance (ANOVA) with screen (dotted pane or no pane) and test event (box–ball or ball–ball) as between-subjects factors. The main effects of screen and test event, and the interaction between these two factors, were not significant, all $F(1, 20)$s < 1.75, indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (dotted pane, box–ball, $M = 20.8$, SD $= 10.5$, and ball–ball, $M = 28.0$, SD $= 4.1$; no pane box–ball, $M = 24.8$, SD $= 7.9$, and ball–ball, $M = 24.2$, SD $= 8.1$).

2.2.2. Test trial

The infants' looking times during the final phase of the test trial (Fig. 2) were analyzed
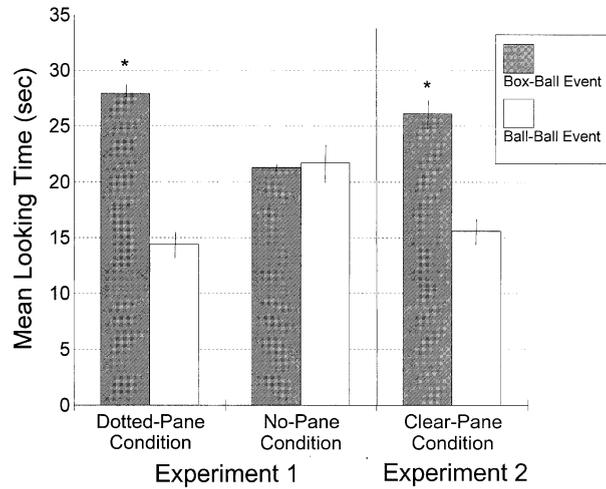
Fig. 2. Mean looking times (and standard errors) to the one-ball display in Experiment 1 (dotted-pane and no-pane condition) and Experiment 2 (clear-pane condition). Significant differences in looking times between the box–ball and ball–ball conditions are marked by an asterisk (see text).

in the same manner as in the pretest trials. The main effect of screen was not significant, $F(1, 20) < 1$. The main effect of test event, $F(1, 20) = 7.81$, $P < 0.025$, and the interaction between screen and test event, $F(1, 20) = 8.66$, $P < 0.01$, were significant. Planned contrasts indicated that in the dotted-pane condition, the infants who saw the box–ball event ($M = 27.9$, SD $= 4.5$) looked reliably longer at the one-ball display than the infants who saw the ball–ball event ($M = 14.4$, SD $= 7.0$), $F(1, 20) = 16.38$, $P < 0.001$. In contrast, in the no-pane condition, the box–ball ($M = 21.3$, SD $= 1.9$) and ball–ball ($M = 21.7$, SD $= 7.8$) infants looked about equally during the final phase, $F(1, 20) < 1$.

When the frame contained a transparent occluder, so that infants saw only one event, an occlusion event, the infants successfully judged that the one-ball display was inconsistent with the box–ball sequence. In contrast, when the frame was empty, so that infants saw two categorically distinct events – an occlusion event followed by a no-occlusion event – the infants were unable to detect the discrepancy between the box–ball sequence and the one-ball display.[2]

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[2] This interpretation argues that the infants in the dotted-pane condition constructed only one event representation because the initial and final phases of the test trial belonged to the same category of event (occlusion). Only when event categories change must another event representation be constructed. Thus in our parlance, the dotted-pane condition constitutes an event-monitoring rather than an event-mapping situation for the infants. An alternative interpretation is that the infants in the dotted-pane condition, like those in the no-pane condition, constructed two event representations. However, the infants in the dotted-pane condition, unlike those in the no-pane condition, constructed two event representations from the same category. By this interpretation, the infants in both conditions were faced with an event-mapping task, but the information processing demands for the dotted-pane infants were less because the events were of the same category.

Clearly, the heightened looking times in the dotted-pane box–ball condition were not attributable to infants' attraction to the dotted pane, otherwise looking times in the dotted-pane ball–ball condition would also be elevated. However, one might be concerned that the infants in the dotted-pane condition succeeded, not because they viewed the transparent pane as a type of occluder, but because the dots on the pane facilitated processing of the one-ball display. Experiment 2 tested this possibility.

3. Experiment 2

Infants aged 9.5 months saw box–ball and ball–ball test events identical to those in the dotted-pane condition of Experiment 1 with one exception: a clear pane was used instead of a dotted pane.

3.1. Method

3.1.1. Participants

Participants were 12 infants, four males and eight females ($M = 9$ months, 19 days; range $= 9$ months, 10 days to 10 months, 1 day). Two additional infants were eliminated because of procedural error and one because the primary observer was unable to follow the infants' direction of gaze. Six infants saw the box–ball or ball–ball test event.

3.1.2. Apparatus and procedure

The apparatus and procedure were identical to that of Experiment 1 (dotted-pane condition) with the following exception: the transparency was without dots. To ensure that the infants detected the presence of the transparency, they were shown the screen for 60 s prior to the test trial. The first experimenter held the screen within the infants' reach and infants were encouraged to touch the screen; all infants touched the transparent screen at least once.

The data from Experiment 2 and the no-pane condition of Experiment 1 were analyzed together.

3.2. Results and discussion

3.2.1. Pretest trials

The infants' looking times during the two pretest trials were averaged and analyzed by means of an ANOVA with screen (clear pane or no pane) and test event (box–ball or ball–ball) as between-subjects factors. The main effects of screen and test event, and the interaction between these two factors, were not significant, all $F(1, 20)$s < 1, indicating that the infants in the four conditions did not differ reliably in their mean looking times during the pretest trials (clear pane, box–ball, $M = 22.9$, SD $= 6.4$, and ball–ball, $M = 23.6$, SD $= 9.2$).

3.2.2. Test trial

The infants' looking times during the final phase of the test trial (Fig. 2) were analyzed in the same manner as in the pretest trials. The main effects of screen, $F(1, 20) < 1$, and

test event, $F(1, 20) = 4.04$, $P > 0.05$, were not significant. The interaction between screen and test event, $F(1, 20) = 4.62$, $P < 0.05$, was significant. Planned contrasts indicated that in the clear-pane condition, the infants who saw the box–ball event ($M = 26.1$, SD $= 6.2$) looked reliably longer at the one-ball display than the infants who saw the ball–ball event ($M = 15.6$, SD $= 7.0$), $F(1, 20) = 8.73$, $P < 0.01$. In contrast, in the no-pane condition, the box–ball and ball–ball infants looked about equally, $F(1, 20) < 1$.

These results provide converging evidence for the conclusion that (a) infants categorize an event involving a transparent occluder (whether or not it contains dots) as the same sort of event as an event involving an opaque occluder and (b) infants are more likely to demonstrate successful performance when they need reason only about a single situation than when they are required to map categorically distinct situations.

4. General discussion

The present results join an increasing number of reports (Hespos, 2000; Leslie & Glanville, 2001; Wilcox, 1999a,b; Wilcox & Baillargeon, 1998a,b; Wilcox & Schweinle, 2002) that infants 10 months and younger can use featural information to individuate objects in occlusion events. The finding that preverbal infants demonstrate sensitivity to featural information, along with evidence that rhesus macaques, who lack language skills, do the same (Munakata, Santos, Spelke, Hauser, & O'Reilly, 2001; Uller, Carey, Hauser, & Xu, 1997), calls into question the hypothesis that young infants fail on Xu and Carey's task because of limited language and conceptual capacities (Xu & Carey, 1996, 2000). A more viable explanation for the negative results obtained with younger infants is one that focuses on the information processing demands of the task used (Wilcox & Baillargeon, 1998a,b; Wilcox et al., 2002). Tasks that require infants to retrieve and map categorically distinct events are more taxing than tasks that require only the monitoring of a single event.

The present results also provide insight into what infants include in their "occlusion" category. Some investigators have suggested that infants generate event categories based on the nature of the relation between objects (Hespos & Baillargeon, 2001; Wilcox et al., 2002). Apparently, when infants are faced with categorizing an event as occlusion or no occlusion, the relation 'behind something', or the inference 'cannot be reached directly', is as important as the relation 'out of view'. The consequence is that infants treat transparent occluders like opaque occluders. Further investigation is needed to determine how infants' notion of occlusion might change during the first year of life.

with data collection; and the parents who kindly agreed to have their infants participate in the research.

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