4.5-month-old infants’ learning, retention and use of object boundary information

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Abstract

4.5-month-old infants can use information learned from prior experience with objects to help determine the boundaries of objects in a complex visual scene (Needham, 1998; Needham, Dueker, & Lockheed, 2002). The present studies investigate the effect of delay (between prior experience and test) on infant use of such experiential knowledge. Results indicate that infants can use experience with an object to help them to parse a scene containing that object 24 (Experiment 1). Experiment 2 suggests that after 24 h infants have begun to forget some object attributes, and that this forgetting promotes generalization from one similar object to another. After a 72-h delay, infants did not show any beneficial effect of prior experience with one of the objects in the scene (Experiments 3A and B). However, prior experience with multiple objects, similar to an object in the scene, facilitated infant segregation of the scene 72 h later, suggesting that category information remains available in infant memory longer than experience with a single object. The results are discussed in terms of optimal infant benefit from prior experiences with objects.

Keywords: Learning; Memory; Generalization; Object segregation and infants

1. Introduction

More than 100 years ago, James (1899) suggested that adults’ prior experience with objects exerted an important influence on the interpretation of visual displays. For example, if an adult sees a black bag leaning up against a yellow throw pillow on the couch, she will most likely
assume that although the bag and pillow are adjacent and touching, they are in fact two objects. This decision could be based on a number of factors, including: differences in shape between the two objects, differences in color and/or texture, past experience with the exact bag and/or pillow as separate objects, or past experience with similar bags and/or pillows applied to this particular bag and pillow. All of these information sources, featural, physical and experiential, help adults parse visual information.

Young infants also use a variety of sources of information to make sense of the visual world. Early research established the important roles of cues such as common motion (Kellman & Spelke, 1983), spatial separation (Kestenbaum, Termine, & Spelke, 1987; Needham & Kaufman, 1997) and attribute (featural) information (e.g., Johnson, 1997; Needham, 1997; Needham & Baillargeon, 1998) in helping infants organize a visual scene. Recently, researchers have begun to investigate the role of prior experience in infants’ interpretation of visual information. Are infants able to use information learned from prior experience with an object or objects to help them understand a novel visual scene containing that object or a similar object? If so, how long does this type of information remain available to young infants?

In order for infants’ prior experiences with objects to facilitate their parsing of a novel visual scene, infants must be able to do several things. First, they must remember their prior experiences. Second, they must realize that what they learned previously could apply to this new situation. Third, they must then use the knowledge learned from previous encounters to draw conclusions about the novel visual scene. Prior research suggests that infants are capable of all three steps. Infants can retain information for long periods of time (Perris, Meyers, & Clifton, 1990; Rovee-Collier & Gulya, 2000). Infants can recognize that they know something about a novel situation based on prior experience, and they can use that knowledge to help them reason about a novel situation (Bahrick, 2002; Needham, 2001; Needham & Baillargeon, 1998; Needham, Dueker, & Lockhead, 2003; Vishton, Stulac, & Calhoun, 1998; see Needham & Modi, 1999 for a review). Although there is evidence to suggest that infants can successfully remember information for long periods of time and can use information gained in one context in another novel context, the interaction of the two factors is less well studied. It is on this interaction that the current studies focus.

1.1. Object segregation and prior experience

Prior experience with a particular object or kind of object could facilitate object segregation and inform expectations about how an object will behave in the future. Remember the bag and pillow example. If the adult tried to pick up the bag and found that it was connected securely to the pillow, she would probably be surprised. This adult experience is similar to the object segregation task presented to infants in the experiments reported here. Infants’ segregation of a novel visual display was assessed by giving infants physical evidence about how many objects were part of the display and observing infant responses. The interpretation is that if the physical evidence of the number of objects in the display (one or two) contradicts the infant’s interpretation of that display, the infant will look longer at this surprising event.

Prior research with this particular display, which is composed of two objects, a tall thin blue box and a curved yellow cylinder (see Fig. 1), established that for 4- to 6-month-old infants, the
composition of the display was ambiguous. That is, after seeing the stationary display, infants showed no clear expectation about whether there were one or two objects present (Needham, 1997; Needham & Baillargeon, 1998). However, a short, prior exposure to either individual piece of the display facilitated infant segregation of the test display. Thus, prior experience allowed infants to add information to their memory store, in this case what the boundaries of a particular object were, and to use that information later when they were apprehending the test display (Needham & Baillargeon, 1998; Needham & Modi, 1999).

1.2. Current studies

Prior research using this particular object segregation task has demonstrated that experience with one piece of the display (the test box) 24 h before test facilitated later infant segregation of the display (Needham & Baillargeon, 1998). However, the effect of delay on experience with another piece of the display or with an object or objects similar to those in the test display is unknown. The following studies will utilize the same presentation methodology and testing situation as the Needham and Baillargeon (1998) study so that the current studies can be compared to this earlier result, and the set of results can be interpreted together.

The experiments in this paper will examine the effect of delays on infants’ use of prior experiences with objects in an object segregation task. Experiments 1 and 3 will explore how long prior experience with one of the objects present in the novel test display will remain available to guide infant segregation of that display. Experiments 2 and 4 involve manipulating infants’ prior experience with an object or set of objects that is similar to, but noticeably different from one of the objects in the segregation task, and assessing how delays affect the benefit infants receive from experiences with similar objects.
2. Experiment 1

Our first question was whether a delayed prior exposure involving the cylinder would be as effective a cue to the composition of the test display as the delayed prior exposure to the box had been in the Needham and Baillargeon (1998) study. Therefore, infants were presented with the cylinder approximately 24 h prior to assessing the infants’ segregation of the test display.

2.1. Method

2.1.1. Participants

Participants were 12 healthy, full-term infants (6 females, 6 males), ranging in age from 4 months, 12 days to 5 months, 12 days (\(M = 4\) months, 23 days; SD = 8.7). Half of the infants saw the move-apart test event (\(M = 4\) months, 20 days; SD = 7.4) and half saw the move-together test event (\(M = 4\) months, 26 days; SD = 9.6). Data from one additional infant were collected and eliminated due to distraction in the testing chamber.

Infants’ names in this experiment and the following experiments were obtained from the Durham County (North Carolina) vital records office. Approximately 75% of the infants were Caucasian, with the remaining infants being Asian, African-American, Hispanic, or other. Parents were contacted via letter and follow-up phone call to schedule an appointment. Parents were reimbursed for their travel but not compensated for their participation.

2.1.2. Procedure and apparatus

2.1.2.1. Home visit.

Procedure. Infants were visited in their homes approximately 24 h prior to coming to the lab (\(M = 23\) h, 55 min) and were given 2 min of visual experience with the yellow cylinder. The caretaker was asked to hold or seat the infant in a comfortable position facing the experimenter. The experimenter presented the yellow cylinder approximately 50 cm in front of the infant. The cylinder was moved from side to side as necessary to maintain infant interest until the infant had accumulated 2 min of looking (as measured by a stopwatch). The cylinder was then removed from the infants’ view, ending the familiarization trial. At test, the experimenter who visited the home was not present, so as not to provide extra memory cues for the infant.

2.1.2.2. Lab visit.

Apparatus. The apparatus consisted of a wooden cubicle 200 cm high, 106 cm wide, and 49.5 cm deep. The infant faced an opening 56 cm high and 95 cm wide in the front wall of the apparatus. The floor of the apparatus was covered with pale blue cardboard with a clear Plexiglas cover (this allowed the felt-bottomed objects to move smoothly and silently across the apparatus floor). The side walls were painted white and the back wall was covered with brightly patterned white contact paper.

At the start of the test event, a zigzag-edged cylinder and a rectangular box stood side by side on the floor of the apparatus. The cylinder was 22 cm long and 10 cm in diameter. It consisted
of a section of clothes dryer vent hose that was stuffed with Styrofoam so that it was rigid and formed a modified ‘C’ shape with its ends curved slightly forward. The left end of the cylinder was covered with cardboard; the right end was covered with a thin metal disc. The entire cylinder was painted bright yellow. The box was 35 cm high, 13 cm wide, and 13 cm deep. It was made of foam core and was covered with bright blue contact paper decorated with small (approximately 1.5 cm on a side) white squares. One of the box’s corners faced the infants. The left rear wall of the box (not visible to the infants) had a magnet inset 3.5 cm from the bottom. The cylinder lay on the floor of the apparatus with its right, metallic end set against the box’s bottom magnet (the magnet made it possible for the box to move with the cylinder when the latter was pulled by the experimenter’s hand). The bottom surfaces of the cylinder and the box were covered with felt so they both slid smoothly and silently across the Plexiglas on the apparatus floor. The front 2.5 cm of the cylinder’s right end protruded from the box’s left corner; this protrusion was designed to make clear to the infants that the cylinder and box were adjacent. In its starting position, the box was 17.5 cm from the front edge of the apparatus and 31.5 cm from the right wall; the cylinder was 28 cm from the front edge of the apparatus and 33.5 cm from the left wall. Together, the cylinder and box subtended about 30° (horizontal) and 27° (vertical) of visual angle from the infants’ viewpoint.

In each test event, the cylinder was pulled to the side by an experimenter’s right hand wearing a 59 cm long lavender spandex glove. The hand entered the apparatus through an opening 55.5 cm high and 37.5 cm wide in the left wall. This opening was partially hidden by a white muslin curtain; the curtain and the experimenter were positioned in such a way that the infant could not see the experimenter’s face through this opening.

The infants were tested in a brightly lit room. Four clip-on lights (each with a 40-W light bulb) were attached to the back and side walls of the apparatus to provide additional light. Two wooden frames, each 200 cm high and 69 cm wide and covered with blue cloth, stood at an angle on either side of the apparatus. These frames served to isolate the infants from the experimental room. At the end of each trial, a curtain consisting of a white muslin-covered frame 57 cm high and 98 cm wide was lowered in front of the opening in the front wall of the apparatus.

2.1.3. Events

Numbers in parentheses refer to the amount of time taken by each action. See Fig. 1 for a depiction of these events.

2.1.3.1. Move-together event. At the start of each test trial, the experimenter’s right hand rested on the floor of the apparatus about halfway between the cylinder and the opening in the left wall. After a 1-s pause, the hand grasped the cylinder (1 s) and pulled it 14 cm to the left at the approximate rate of 7 cm/s (2 s). The cylinder and box moved as a single, rigid unit with no slight movements of one object relative to the other. The hand paused for 1 s and then pushed the cylinder and the box back to their starting positions at the same rate as before (2 s). The hand then resumed its initial position on the apparatus floor (1 s). Each event cycle thus lasted about 8 s. Cycles were repeated without stop until the computer signaled that the trial had ended (see below). When this occurred, a second experimenter lowered the curtain in front of the apparatus.
2.1.3.2. Move-apart event. The move-apart event was identical to that just described except that only the cylinder moved: the box remained stationary throughout the trial.

2.1.4. Procedure
During the experiment, each infant sat on his or her parent’s lap in front of the apparatus. The infant’s head was approximately 63.5 cm from the box. The infant’s looking behavior was monitored by two observers who viewed the infant through peepholes in the cloth-covered frames on either side of the apparatus. Although the observers knew that the infants had received prior exposure to either a portion of the test display or to an object or objects similar to those in the test display, they were not told whether the delay between initial exposure and testing was that used in Experiments 1 and 3 (24 h) or Experiments 2 and 4 (72 h), nor what object/s the infant had seen during the home visit. Each observer held a joystick connected to a Gateway 2000 4DX2-66 computer and depressed the trigger when the infant attended to the events. 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 was calculated for each trial on the basis of the number of intervals in which the computer registered agreement, out of the total number of intervals in the trial. Agreement in this experiment and the next averaged 92% per trial. The input from the primary (more experienced) observer was used to determine the end of the trials.

Each infant saw either the move-apart or the move-together test event on six successive trials. Each test trial ended when the infant (a) looked away from the event for 2 consecutive seconds after having looked at it for at least 8 cumulative seconds or (b) looked at the event for 60 cumulative seconds without looking away for 2 consecutive seconds.

2.2. Results and discussion

2.2.1. Preliminary analyses
Preliminary analyses explored effects of Trial and Sex on infants’ looking times at the two test events. A 2 × 6 mixed model ANOVA was conducted on the infants’ looking times, with trial (trials 1–6) as a within-subjects variable and event (move-apart or move-together) as a between-subjects variable. This analysis produced a significant effect of Trial (\(F(5, 50) = 10.85, p < .001\)), indicating that the infants looked reliably less as the experiment progressed. The Trial × Event interaction was not significant (\(F = 1.34, p > .05\)). As a result, the data were collapsed across trial for further analyses. A 2 × 2 between-subjects ANOVA was conducted to examine effects of sex on infants’ looking times at the two test events, and this analysis showed no significant interaction between sex and event (\(F(1, 8) = 2.94, p > .05\)). Thus, data were collapsed across both trial and sex for further analysis.

2.2.2. Main analysis
The main analysis was a 1-factor ANOVA exploring infants’ looking times at the two test events. This analysis yielded a significant effect of event: the infants who saw the move-together event (\(M = 49.11, SD = 8.4\)) looked reliably longer than the infants who saw the move-apart event (\(M = 33.42, SD = 14.4\)), \(F(1, 10) = 5.30, p < .05\) (see Fig. 2).
These results show that the infants who had seen the cylinder in their homes 24 h prior to testing looked reliably longer at the move-together than at the move-apart event. This finding suggests that the infants who saw the cylinder in their homes the day before testing (like the infants in prior research who saw the box in their homes the day before testing) expected the cylinder to be separate from the box and were surprised when it was not. Prior research (Needham & B illargeon, 1998) indicates that this preference could not be an inherent preference for one event over another, as infants who had no prior experience with any portion of the display looked about equally at these two test events. The present work, together with prior research, indicates that seeing either the box alone or the cylinder alone about 24 h prior to testing allows infants to see the adjacent cylinder and box as separate objects when they would not do so otherwise.

3. Experiment 2

Together with existing research, the results of Experiment 1 showed that infants were able to use prior experience with either of the objects in the display 24 h prior to seeing the test display to decide its composition. We wanted to know what attributes if any might have been forgotten during the 24-h delay. Prior research suggests that infant memory for all types of information about an object or stimulus is not equivalent. For example, after seeing an image of an arrow that could vary along four dimensions—form, color, orientation or size, 5-month-old infants remembered the color of what they had seen longer than the size or orientation, and the form was remembered even longer than the color (Strauss & Cohen, 1978, in Siegler, 1998).

Later work with 6-month-old infants found that changing contextual cues between training and test disrupted performance over shorter delays, however after longer delays, context shifts appeared to have no impact on performance (Borovsky & Rovee-Collier, 1990). This result suggests that infants lose information from memory at different rates, and that peripheral attributes (in this study, the physical context) appear to be lost first. Once lost, these details no longer constrain performance. Thus, infants were more likely to generalize a learned response to a novel situation after a longer delay. Findings like these suggest that infants begin to lose details from memory first, leaving infants with a general representation of what they have seen before.

We were interested to learn if the details of infants’ memory for object attributes would also disappear soon after their encounter with the first object in our task. We investigated
this question by altering features between the object seen at home and the objects seen in the test display. Because the box had more discrete attributes than the cylinder, we decided to manipulate the attributes of the box. We were drawing on the results of prior work with infants of this age that showed that immediate prior experience with a box similar to the test box did not facilitate infant segregation of the test display (Needham, 2001). After immediate prior exposure to a box of identical size, shape and overall color as the test box, but with differently colored texture elements (red vs. white), 4.5-month-old infants showed no expectation about the composition of the test display. Needham interpreted this and similar results as evidence of the specificity of infants’ use of prior experience. If these young infants noticed a change in attributes between the test box (blue with white squares) and the box seen previously, they did not generalize their knowledge of object boundaries from one object to the next.

In an effort to learn what information infants might be forgetting during a 24-h delay, infants were familiarized with a box (blue with red squares) similar to the test box (recall that the test box used in these studies is blue with white squares) 24 h prior to seeing the test display. If infants are retaining a detailed memory of the box seen 24 h prior, we would expect that they would not show facilitated segregation of the test display, since they do not show facilitated segregation when shown the same patterned box immediately before seeing the test display. However, if infants do begin to forget some of the attributes during the 24-h delay, we might expect them to generalize object boundary information from one box to the next because they have forgotten the differing attributes that would have limited an immediate generalization.

3.1. Method

3.1.1. Participants

The participants were 12 healthy, full-term infants (6 females, 6 males) ranging in age from 4 months, 11 days to 6 months, 0 days ($M = 5$ months, 2 days; $SD = 14.6$). Half of the infants saw the move-apart test event ($M = 5$ months, 3 days; $SD = 15.1$) and half saw the move-together test event ($M = 5$ months, 1 day; $SD = 15.4$). Data from two additional infants were collected and excluded, one due to distracting noise during testing and one as a statistical outlier ($Z = 4.35$).

3.1.2. Apparatus, events and procedures

The apparatus, events and procedures were identical to those described in Experiment 1 with two exceptions. First, during the home visit, infants were familiarized with a box that was an exact replica of the test box in every dimension except that the squares on the box were red rather than white.

Second, immediately prior to starting the test event in the lab, infants were given a brief familiarization trial featuring the stationary test display. This trial ended when the infant (a) looked away from the display for 2 consecutive seconds after having looked at it for at least 10 cumulative seconds or (b) looked at the display for 30 cumulative seconds without looking away for 2 consecutive seconds.¹

All infants visited the lab approximately 24 h ($M = 24.1$ h, $SD = 0.80$) after being visited in their home. Eleven infants contributed a full set of six trials. One infant contributed only five trials because of low observer visibility during the last trial. There was no reliable difference
in the delay between home visit and test for the infants who would see the move-apart test event \((M = 24.1\, \text{h}, \ SD = 0.73)\) vs. the move-together test event \((M = 24.1; \ SD = 0.97), F(1, 10) = 0.007\). There were also no reliable differences in the looking times during the stationary familiarization trial for the infants who would see the move-apart test event \((M = 21.7, \ SD = 9.6)\) vs. the move-together test event \((M = 20.7, \ SD = 10.2), F(1, 10) = 0.03\).

3.2. Results

3.2.1. Preliminary analyses

The data were analyzed as in Experiment 1. Infants looked reliably less as the experiment progressed \(F(1, 5) = 8.04, p < .0001\). There was no differential effect of Trial on the infants’ looking times at the two test events, \(F(1, 5) = 1.31\). There was no significant effect of the infants’ Sex on looking times at the two test events, \(F(1, 8) = 1.09\). Therefore, data were collapsed across Trial and Sex for further analyses.

3.2.2. Main analysis

The infants’ looking times (see Fig. 3) were analyzed by means of a 1-factor ANOVA with Event (move-together or move-apart) as the between-subjects factor. This analysis yielded a significant effect of test event, \(F(1, 10) = 7.54, p < .02\) indicating that infants looked reliably longer at the move-together \((M = 41.3, \ SD = 6.4)\) than at the move-apart \((M = 31.1, \ SD = 6.3)\) test events.

3.3. Discussion

The results of Experiment 2 were that infants generalized between two similar objects following a 24-h delay even though infants did not generalize between these same two objects if tested immediately following experience with the similar box. One way of explaining these results is to propose that 24 h after encountering an object, infants begin to forget some of the attributes of that object. This explanation would account for why infants fail to immediately generalize object boundary information from one similar object to another (as in Needham, 2001), but do generalize such knowledge after a 24-h delay. The suggestion is that differences in attributes cannot constrain generalization if they are not remembered. One implication of this
finding is that the relatively poor memory for details that infants exhibit might enhance their benefit from prior experience with similar objects by widening the potential pool of objects to which the infant could apply knowledge based on prior experiences.

Because we have evidence that forgetting has begun by 24 h, the question of how long infants would be able to benefit from prior experience became an intriguing one. How long would prior exposure to one of the test objects, or similar objects, facilitate infants’ segregation of the cylinder and box test display? The remaining experiments address these questions.

4. Experiments 3A and B

How long would prior exposure to the cylinder or box maintain their facilitative effect on infants’ segregation of the cylinder and box test display? To address this question, Experiments 3A and B were conducted using the same procedure as Experiments 1 and 2, except that the delay between familiarization (in the home) and test (in the lab) was 3 days rather than 1 day.

5. Experiment 3A

Would experience with the test box remain useful after a 72-h delay? Infants in this experiment were visited in their homes 72 h prior to viewing the test display, and were given 2 min of visual experience with an exact replica of the test box.

5.1. Method

5.1.1. Participants

Participants were 12 healthy, full-term infants (6 females, 6 males), ranging in age from 4 months, 13 days to 5 months, 26 days ($M = 5$ months, 8 days; $SD = 15.7$). Half of the infants saw the move-apart test event ($M = 5$ months, 7 days; $SD = 14.2$) and half saw the move-together test event ($M = 5$ months, 10 days; $SD = 18.3$). Data from two additional infants were collected and eliminated due to experimenter error.

5.1.2. Apparatus, events, and procedure

The apparatus, events, and procedure used in Experiment 3A were identical to those used in Experiment 1, with two exceptions: the experimenter familiarized infants with the test box (blue with white squares) during the home visit rather than the yellow cylinder, and the delay between home and lab visits was approximately 72 h ($M = 72$ h, 12 min). Eleven infants in this experiment completed the entire set of six test trials, with one infant completing only five trials due to distraction during trial six.

5.2. Results

5.2.1. Preliminary analyses

The data were analyzed as in Experiment 1. Infants looked reliably less as the experiment progressed $F(1, 5) = 5.5$, $p < .0005$. There was no differential effect of Trial on the infants’
looking times at the two test events, $F(1, 5) = 1.05$. There was no significant effect of the infants’ Sex on looking times at the two test events, $F(1, 8) = 0.71$. Therefore, data were collapsed across Trial and Sex for further analyses.

5.2.2. Main analysis

The data were analyzed as in Experiment 1. A 1-factor ANOVA with Event (move-together or move-apart) as the between-subjects factor yielded no significant effect of test event, $F(1, 10) = 0.42$ indicating that infants did not look reliably longer at the move-together ($M = 38.4, SD = 13.1$) than at the move-apart ($M = 33.4, SD = 13.7$) test events.

These data suggest that knowledge gained from the home visit familiarization with the test box was not available to support infant parsing of the test display 3 days later. Thus, there appears to be a limit to the usefulness of such prior experiences. This is a point we will return to later.

6. Experiment 3B

Although experience with the test box 3 days before test did not facilitate infant segregation of the test display, it was important to determine whether experience with the cylinder would also show a similar limit in usefulness. Prior research has suggested that the cylinder seems to be a more complex object for infants to process (Needham & Baillargeon, 1998). In order to show facilitated object segregation of the test display, infants needed more familiarization time with the cylinder (15 s) than with the box (5 s) immediately prior to seeing the display. Needham and Baillargeon suggest that this result could be caused by infants being less familiar with cylinder-like objects or by the complexity of the shape and position of the cylinder. If it is the case that the cylinder is a more complex object for infants, we might expect that it would be processed more deeply than the box. Level-of-processing effects on retention are well documented in both adults (Craik & Tulving, 1975) and infants (Adler, Gerhardstein, & Rovee–Collier, 1998), with information encoded more deeply typically remaining available in memory longer. It seemed necessary then to test whether memory for the more complex object, the cylinder, might remain available to infants after a 72-h delay, even though the memory for the test box did not.

6.1. Method

6.1.1. Participants

Participants were 12 healthy, full-term infants (6 females, 6 males), ranging in age from 4 months, 8 days to 5 months, 16 days ($M = 4$ months, 24 days; $SD = 10.3$). Half of the infants saw the move-apart test event ($M = 4$ months, 28 days; $SD = 9.3$) and half saw the move-together test event ($M = 4$ months, 19 days; $SD = 9.7$).

6.1.2. Apparatus, events, and procedure

The apparatus, events, and procedure used in Experiment 3B were identical to those used in Experiment 1, with one exception: the experimenter’s visit to the infants’ homes was ap-
proximately 72 h (\(M = 71\) h, 40 min), rather than 24 h, prior to testing. Each infant in this experiment completed the entire set of six test trials.

6.2. Results

6.2.1. Preliminary analyses
The data were analyzed as in Experiment 1. Infants looked reliably less as the experiment progressed \(F(1, 5) = 5.85, p < .001\). There was no differential effect of Trial on the infants’ looking times at the two test events, \(F(1, 5) = 0.15\). There was no significant effect of the infants’ Sex on looking times at the two test events, \(F(1, 8) = 0.00\). Therefore, data were collapsed across Trial and Sex for further analyses.

6.2.2. Main analysis
The infants’ looking times were analyzed by means of a 1-factor ANOVA with Event (move-together or move-apart) as the between-subjects factor. This analysis yielded no significant effect of test event, \(F(1, 10) = 0.07, p > .05\) indicating that infants who saw the move-together event (\(M = 29.77, SD = 16.34\)) and those that saw the move-apart event (\(M = 27.4, SD = 14.2\)) looked at the test events about equally.

These results suggest that prior exposure to the cylinder received 72 h prior to testing did not facilitate infants’ segregation of the test display. Thus, although the results of Experiment 1 and prior research (Needham & Baillargeon, 1998) indicated that a prior exposure to the box or cylinder remained useful for segregation purposes 24 h after it was acquired, the present results suggest that experience with the cylinder was not still useful 72 h later.

6.3. Discussion
The results of Experiments 3A and B suggest that exposure to either the box or the cylinder 72 h prior to testing did not facilitate infants’ segregation of the test display. Thus, although the results of Experiment 1 and prior research (Needham & Baillargeon, 1998) indicated that a prior exposure to the box or cylinder remained useful for segregation purposes 24 h after it was acquired, the present results do not suggest that experience with the cylinder or the box was still useful 72 h later. It appears that infant memory for a specific object remains available to support generalizations to a novel situation for more than 24 but less than 72 h. This apparent 72-h limit on the usefulness of learning from prior experience with an object suggests a rather transient benefit from prior experience with a particular object.

7. Experiment 4
The results of Experiments 1–3 imply that prior experience with a specific object remains available to guide infant generalization for a relatively short time (more than 24 but less than 72 h). We were curious about whether other types of prior experience might affect this time period. There is evidence in the adult memory literature that category knowledge is remembered longer than information about specific instances encountered (e.g., Posner & Keele, 1970), and
Bomba and Siqueland (1983) replicated this effect with infants. In fact, infants appeared to treat a prototype (that they had not actually seen) from a familiar category as more familiar than an actual exemplar that they had previously encountered. Given these findings, we wondered whether infants in our task would show longer retention of object boundary information after exposure to several similar objects.

If infants formed a category based on experience with a group of similar boxes 3 days prior to test, it is possible that the information gained from this prior experience would remain available longer than did the experience with a single object. To test this hypothesis, we presented infants with the set of three boxes used in previous category studies (Needham et al., 2003). Prior research with this set of boxes showed that while exposure to no one of the single boxes (Needham, 2001) facilitated infant segregation of the test display, immediate prior exposure to the set of boxes did facilitate infant segregation of the test display. Thus, infants can use category information to segregate the test display. The question for this experiment was whether category information learned during a home visit 72 h before infants visited the lab would remain useful. If infants showed facilitated segregation 72 h after category formation, we could conclude that category information remains available to infants longer than does information about a specific object.

7.1. Method

7.1.1. Participants

The participants were 12 healthy, full-term infants (6 females, 6 males) ranging in age from 4 months, 10 days to 5 months, 25 days (M = 5 months, 8 days; SD = 13.4). Half of the infants saw the move-apart test event (M = 5 months, 9 days; SD = 10.1) and half saw the move-together test event (M = 5 months, 7 days; SD = 17.1). All infants contributed a full set of six test trials to the analyses. Data from two additional infants were collected and excluded, one due to computer malfunction and one due to infant fussiness.

7.1.2. Apparatus, events and procedure

The apparatus, events and procedures for Experiment 4 were identical to those of Experiment 2 with the following exception. During the home visit, infants were familiarized with three boxes that were similar to the test box rather than one similar box. The three boxes used were a blue box with red squares, a purple box with white squares and a green box with white triangles. The boxes were placed side by side but not touching on a flat surface (e.g., a tabletop) approximately 50 cm in front of the infant. During set up and take down, the boxes were hidden from view by a large black drop cloth. The caretaker was asked to hold the infant in a comfortable position facing the boxes. Infants were given 2 min of exposure to the set of three boxes. At the beginning of the trial, the drop cloth was lifted and one of the three boxes was picked up and moved slowly back and forth (to maintain infant interest) for 20 s. Then that box was returned to the table and another box was picked up and moved slowly. Each box was manipulated by the experimenter twice for a total of 40 s per box, and 2 min overall. At the end of 2 min, the drop cloth was replaced. The infants in Experiment 4 visited the lab approximately 72 h (M = 71.5 h, SD = 1.2) after the home visit. There was no reliable difference in the delay between home visit and lab visit for the infants who would see the move-apart (M = 72.0 h,
Fig. 4. Infants’ mean looking time (+SE) to move-apart or move-together test event after prior experience with three similar boxes presented simultaneously 72 h before test.

SD = 1.2) vs. the move-together test event (M = 71.1 h, SD = 1.2), F(1, 10) = 1.4. Nor were there reliable differences in the looking times during the stationary familiarization trial for the infants who would see the move-apart test event (M = 18.0, SD = 9.8) vs. the move-together test event (M = 13.6, SD = 3.7), F(1, 10) = 1.07.

7.2. Results

7.2.1. Preliminary analyses
The data were analyzed as in Experiment 1. Infants looked reliably less as the experiment progressed F(1, 5) = 11.7, p < .0001. There was no differential effect of Trial on the infants’ looking times at the two test events, F(1, 5) = 0.44. There was no significant effect of the infants’ Sex on looking times at the two test events, F(1, 8) = 0.64. Therefore, data were collapsed across Trial and Sex for further analyses.

7.2.2. Main analysis
The infants’ looking times (see Fig. 4) were analyzed by means of a 1-factor ANOVA with Event (move-together or move-apart) as the between-subjects factor. This analysis yielded a significant effect of test event, F(1, 10) = 6.53, p < .03 indicating that infants looked reliably longer at the move-together (M = 42.1, SD = 9.4) than at the move-apart (M = 29.8, SD = 7.0) test events.

7.3. Discussion

After experience with three similar boxes 72 h prior to test, infants showed a clear expectation that the novel test display was composed of two parts. This suggests that infants were able to form a category based on the set of three boxes and that this category included the test box. It also demonstrates that this category remained available in infant memory for at least 72 h, a delay over which equivalent experience with one of the actual objects in the test display had not remained available. This result provides evidence for the continuity of memory processes in infancy and adulthood as both infants and adults seem to retain category information longer than information about a specific exemplar.
Why category information remains available in memory longer has not been satisfactorily explained. One possibility is that category formation might be more difficult than attending to a single object, leading to deeper processing of the information, and deeper processing of information generally leads to longer retention (a classic level-of-processing effect, Craik & Tulving, 1975). Adler et al. (1998) suggest that even young (3-month-old) infants show some evidence of level-of-processing effects on retention. In any case, a level-of-processing account is one possible explanation for this result.

This result suggests that category formation is one mechanism by which infants can retain information learned from prior experience with similar objects. It also suggests that category information is useful for infant object segregation longer than is information gained from experience with one of the objects in the display. Thus, experience with multiple similar objects shows a different pattern of retention over time than does experience with one of the exact objects from the test display.

8. General discussion

The results of the present research combined with prior evidence (Needham, 2001; Needham & Baillargeon, 1998) suggest that infant segregation of the test display is facilitated by experience with one of the test objects (Experiment 1, Needham & Baillargeon, 1998) 24 h prior to encountering the display even though infants are beginning to forget some of the features of the previously encountered object (Experiment 2). Prior experience with a single test object 72 h prior to testing did not facilitate infant segregation of the test display (Experiments 3A and B). However, 72 h after prior experience with multiple objects similar to one of the test objects, infants demonstrated facilitated segregation of the test display (Experiment 4), indicating that object boundary information based on category knowledge remains available in infant memory longer than object boundary information based on experience with a single object.

In order for infants to show facilitated segregation of the ambiguous test display, they needed to remember the relevant prior experience, to recognize that what they had learned previously could apply to this novel situation, and use the knowledge gained from prior experience to reason about the novel test display. It appears that in Experiments 1, 2, and 4, infants recognized one of the objects in the test display as an object they knew something about, and that they used the knowledge gained from prior experience to decode the novel situation—a classic top-down effect.

These findings are consistent with much of the literature on object recognition in infants this age. Although some findings suggest that very long-term retention is possible at this age (e.g., Perris et al., 1990; Rovee-Collier, 1993), these demonstrations usually involve a very lengthy familiarization period (as in Rovee-Collier’s work), extensive contextual support for recall of the initial experience (as in Perris et al.’s study), or stimuli that may be processed in unique ways (such as faces; see Fagan, 1973). Recognition experiments that have utilized procedures and stimuli akin to those used in the current research have yielded performance similar to that found in the current research (e.g., Bushnell et al., 1984; Cornell, 1979; Martin, 1975). The possibility that recognition is involved is further supported by evidence from studies in which
infants received prior exposure to a box similar to the test box immediately prior to testing (Needham, 2001). These studies showed that infants attended to differences in features when determining whether they had seen an object before. Overall, the balance of the evidence seems consistent with the idea that infants’ recognition of the previously seen object is what facilitates their segregation of the test display in this paradigm.

Notably, recognizing an object in the display as one you have seen before is not the only avenue for success. Experience with groups of similar objects also facilitated infant segregation of the test display, suggesting that infants recognized one of the objects as a kind of thing they knew something about (Needham et al., 2003). Interestingly, this type of category information appears to remain available longer than does learning based on experience with a single object identical to one of the test display objects.

One thing that makes the memory performance displayed in this collection of studies especially impressive is that the training and test for all of these experiments happened in different physical locations. Six-month-old infants are quite sensitive to changes in physical context even after only 2 h delays (Rovee-Collier & Gulya, 2000), yet the slightly younger infants in the current studies always encountered the familiarization (either the blue box with red squares or the set of three boxes) in their homes and the test display in the lab, and their memory did not appear to be disrupted by this change in physical context. One possibility is that the procedure itself might be highlighting the focal object/s because when training, the object/s is something novel in the otherwise familiar home environment, and, at test, the same (or similar) object is something familiar in an otherwise novel lab environment (Rovee-Collier, personal communication). In any case, the shift in physical context between training and test did not preclude the infants’ access to their memory about the object/s.

The results in this paper suggest continuity between infant and adult memory processes. Infants and adults show both (a) top-down effects of prior experience on their interpretation of a novel visual scene, and (b) longer retention of general or abstract category information than of information about a specific member of a category. These findings suggest that the process of learning about categories of objects and generalizing to new category members is facilitated by encounters involving multiple objects. One might be concerned that infants are unlikely to encounter multiple objects at once in their ordinary experiences, but recent work from our lab has shown that experiences with similar objects in different contexts can be linked by an element common to all of the situations (Dueker & Needham, 2003). Even though seeing the three boxes sequentially in our lab apparatus prior to testing was ineffective in facilitating infants’ segregation of the test display, seeing the three boxes sequentially in different contexts but with a single common element to link the experiences was effective. These findings bring us closer to an understanding of how learning about objects and object categories takes place in infants’ everyday experiences.

Although laboratory experiments like the ones reported in this paper help us understand fundamental aspects of learning and memory in infants, we must also keep in mind the constraints imposed by infants’ ordinary experiences, as these constraints form the landscape of infants’ learning environment. Both kinds of work are needed to construct an account of infant learning, memory, and generalization that can withstand the rigors of laboratory testing but also can be applied to infants’ real-world experiences.
Notes

1. Because different results were obtained in various the experiments reported in this paper (which are all based on the same test events), observer bias could not be responsible for the results reported for these experiments.

2. As in Needham and Baillargeon (1998), a between-subjects design was used: Each infant saw either the move-apart or the move-together test event. Because we do not want to raise the possibility that elevated levels of looking could be a result of surprise that the composition of the display changed from one trial to another (an occurrence that must be somewhat uncommon in infants’ observations of objects outside the lab), we believe it is important to assess infants’ responses to only one of the possible compositions of the display.

3. Because 4.5-month-old infants perceived this display as ambiguous whether or not they received a familiarization trial with the stationary display, we concluded that the amount of exposure to the whole test display does not affect infants’ perception of the display (Needham & Baillargeon, 1998). As a result, adding this familiarization trial should not facilitate infants’ segregation of the test display. However, this opportunity to study the stationary test display may allow or even encourage infants to compare the attributes of the previously seen box or boxes with the current visible test display.

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