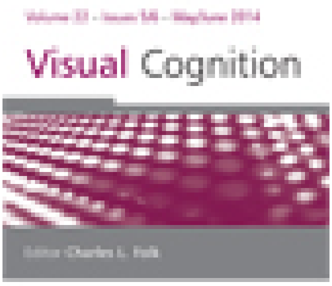

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Infants' object category formation and use: Real-world context effects on category use in object processing

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Infants' object category formation and use: Real-world context effects on category use in object processing

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Three experiments investigated category formation based on real-world encounters with objects and how that category knowledge functioned as a top-down influence on infants' scene processing. 5-month-old infants received various experiences with exemplars of an object category and then were shown a display containing 2 adjacent novel objects, 1 of which was a novel exemplar of the category. If infants recognized this novel exemplar, they could use category information to determine the boundary between the 2 objects. Only infants who experienced object exemplars in situations that closely mimicked everyday infant experiences with objects successfully parsed the display. Results suggest that regularities in the contexts where infants experience similar objects help infants link their experiences and form object categories that can be used to segregate novel scenes. These results shed light on the real-world process of infant knowledge base formation and on how infants use their knowledge base to segment real-world scenes.

Recognition of familiar objects or types of objects in a novel scene helps infants and adults to organize and segregate complex visual information. Evidence for this top-down effect of prior knowledge on scene perception exists in both the adult (e.g., Bravo & Farid, 2003; Goldstone, Lippa, & Shiffrin, 2001) and infant (e.g., Dueker, Modi, & Needham, 2003; Needham & Baillargeon, 1998)

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literatures. Recognizing objects facilitates segmentation of both known and unknown objects, because (1) subtracting out the known objects can simplify a scene and (2) where known and unknown objects intersect, recognizing where the familiar object ends can indicate where an unfamiliar object begins. This top-down effect on visual processing depends upon development of a knowledge base that includes, among other things, knowledge about object categories. Knowledge about the ''kinds'' or categories of objects that exist in the world is vital in assisting infants' parsing of complex visual scenes, but how do infants acquire the necessary knowledge base?

One way would be to retain an exhaustive catalogue of all the objects an infant has seen before, something that would tax even the memory system of an adult. Nonetheless, it appears that infants can remember having seen an object 24 hours before and can use that information to help them segment a novel scene containing that object (Dueker et al., 2003; Needham & Baillargeon, 1998). A knowledge base that would be both more useful and more viable than one that requires the representation of each object the infant has seen is one in which object *categories* are represented. Such a knowledge base would allow infants to generalize object boundary information not just to novel scenes involving a familiar object, but to scenes containing novel exemplars of a familiar category as well. There is also evidence that category-based knowledge about object boundaries remains available to support infant interpretations of novel scenes longer than experience with one of the actual objects present in the scene (Dueker et al., 2003). So, although we know that infant scene processing can benefit from the top-down effects of object category knowledge, what we do not yet know is how infants form object categories from their real-world experience of objects to use for this purpose.

INFANT CATEGORY FORMATION

Despite recent calls to shift the focus of infant categorization research from the presence or absence of categories at different ages to the process by which categories are formed (e.g., Cohen, 2003; Oakes & Madole, 2000, 2003), scientists still know relatively little about this process. Many studies have demonstrated that after seeing multiple examples of a similar kind of thing, even very young infants begin to treat those kinds of things equivalently (the definition of categorization; Mervis & Rosch, 1981) under highly controlled and simplified circumstances (e.g., Behl-Chadha, 1996; Bomba & Siqueland, 1983; Hayne, Rovee-Collier, & Perris, 1987; McGurk, 1972; Oakes & Spalding, 1997; Quinn & Johnson, 2000; Younger & Cohen, 1986) and that infants can use their category knowledge to guide the types of inferences they make in novel situations (e.g., Mandler & McDonough, 1996, 1998; Needham, Dueker, & Lockhead, 2005a). Typically the stimuli used are not real objects, but are pictures, models, or line drawings of objects, and the stimuli are usually presented in isolation. In essence, the researchers have done much of the work for the infants by choosing similar objects and grouping them together. It is doubtful that such experiences are common in the real-world experiences of infants. It is quite possible that these tightly controlled laboratory procedures might be under- or overestimating infants' performance in a real-world situation.

In the research presented here we study infants' visual scene perception using an object segregation task. We chose this particular task for two reasons. First, this task uses three-dimensional objects, making it similar to infants' everyday experiences of objects. Second, prior studies have established that infant perception of a novel test display can be affected by the infant's prior experiences with objects (Needham, 2001; Needham & Baillargeon, 1998; Needham et al., 2005a). However, as in other category research, all of those past studies presented these prior experiences with objects in highly artificial laboratory situations. The point of this set of studies is to learn whether infants could benefit from prior experiences with objects in more realistic situations/settings. First we will briefly summarize the prior research and then we will describe the ways we adjusted the procedures to better mimic infant real-world experiences.

Object segregation and prior experience

Object segregation is the process of determining where one object begins and another object ends. The object segregation task used in the present research presents infants with a display containing two objects, a tall thin blue box and a curved yellow cylinder, that are adjacent and touching one another (see Figure 1). The question of interest is whether infants perceive this display as one or two objects. Infants' segregation of the novel display is assessed by giving infants physical evidence about how many objects are part of the display and observing infant looking responses. The logic is that if the physical evidence of the number of objects in the display (one or two) contradicts infants' interpretation of that display, they will look longer at the unexpected event than at an analogous event depicting the expected composition.

Prior research with this particular display established that for 4- to 6-month-old infants, the composition of the display is ambiguous. That is, after seeing the stationary display, infants showed no clear expectation about whether there were one or two objects present (Needham, 1998; Needham & Baillargeon, 1998). However, a short prior exposure to either individual piece of the display facilitated infant segregation of the test display. Further, while prior experience with *one* object that was similar to an object in the display did not facilitate infant segregation of the test display (Needham, 2001), prior experience with a set of *three* objects similar to one of the objects in the test display did facilitate infant parsing of the test display (Needham et al., 2005a), even when that prior experience happened 72 hours before test (Dueker et al., 2003). Thus, prior experience allowed infants to add information to their knowledge base, in this

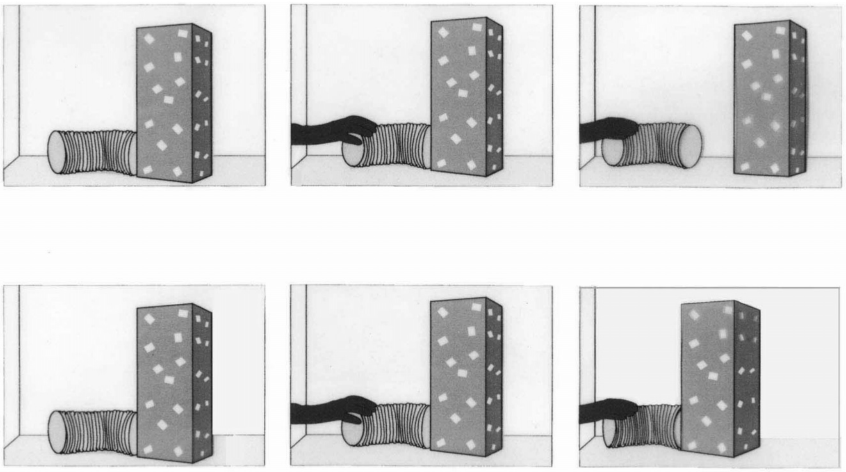

Figure 1. Test display and test events. Top: Move-apart event. Bottom: Move-together event.

case what the boundaries of a particular object or kind of object were, and to use that information later to segment the test display (Needham & Baillargeon, 1998; Needham & Modi, 1999; Needham et al., 2005a). These last sets of results indicate that infants can form object categories and generalize what they know to novel objects in a complex visual scene.

The object familiarization experience that infants were given in the previous experiments was quite artificial—all three similar objects were present in the same place at the same time in an experimental context where all other objects and distractions were excluded. However, it seems unlikely that infants often encounter such situations in their every day lives. Rather, it seems more likely that infants often encounter similar objects singly in different physical contexts. For example, an infant might see a dog in the front yard in the morning, visit her grandmother and see another dog, and still later encounter a dog while on a walk with her father. Prior results suggest that after seeing a few real dogs in a group (Needham et al., 2005a) or many pictures of dogs (Quinn & Eimas, 1996; Quinn, Eimas, & Rosenkrantz, 1993), infants would be able to form a category in the lab, but is this the same process that operates in infants' daily experience? The three experiments below represent our successive approximations of infants' real-world experiences of objects. By manipulating the timing and the presentation of similar objects we learned about the real-world formation of an object category that supported infants' top-down segmentation of a complex visual scene.

Experiment 1 examines the impact of non-simultaneous experiences—can infants form a category when presented with three similar objects individually rather than simultaneously? Experiment 2 examines the impact of background contextual variability, and Experiment 3 examines the impact of contextual regularities embedded in a changing background context.

EXPERIMENT 1

In Experiment 1, infants were presented with the three similar objects (three boxes similar to the blue test box) sequentially rather than simultaneously as had been done in prior research. Recall that after simultaneous exposure to this set of three boxes, infants recognized the test box as a member of a category that they knew something about (namely, what the boundaries of this kind of box were), and they used this knowledge to parse the novel test display into two objects. The simultaneous presentation allowed for easy comparison between the boxes, and comparison is one of the processes known to facilitate infants' and children's category formation (Gentner & Namy, 2000; Namy & Gentner, 2002; Oakes, 2001). There is also evidence that events in which everything is visually available are easier for infants to reason about than are events that involve the infant remembering information and comparing later events to what is stored in memory (Baillargeon, 1992). This suggests that category formation might be more difficult for infants if they were only shown one exemplar at a time. With this experience, which seems more like the kind of experience that infants would have outside the lab, infants would have to hold each box in memory and perform comparisons across remembered objects.

The question is whether simultaneous exposure to all three exemplars is necessary in order for infants' object segregation to be facilitated. If this physical context of simultaneous presentation of the ''set'' is necessary (perhaps because it makes comparison easier) then we would expect that after sequential experience with the boxes, infants' object segregation would not be facilitated. On the other hand, most infants' experiences with similar objects are probably sequential, and there is evidence with older infants that they have conceptual categories based on every day experience with objects like cars and keys (e.g., Mandler & McDonough, 1996) and that these categories can affect their object segregation expectations (Needham, Ormsbee, & Cantlon, 2005b). From this we might expect that sequential presentation would be useful for infants and that their object segregation would in fact be facilitated. Therefore, infants were shown the same three boxes as used in prior studies, but the boxes were presented individually, and infant expectations about the composition of the test display were assessed. Infants saw each box on its own for 10 s rather than all three together for 5 s as had been the case in previous studies (e.g., Needham et al., 2005a). We expected that this change would probably make it more likely that infants could benefit from prior experience with the boxes and it also produced a procedure that was more amenable to later real-world variations.

Method

Participants

The participants were 16 healthy, full-term infants (8 females, 8 males) ranging in age from 4 months, 8 days to 5 months, 25 days (*M* = 4 months, 28 days; *SD* =13.8). Half of the infants saw the move-apart test event (*M* = 5 months, 0 days; *SD* =14.2) and half saw the move-together test event (*M* = 4 months, 26 days; *SD* =14.1). Data from four additional infants was collected and excluded, one due to computer related malfunctions, two due to infant fussiness, and one due to experimenter error.

Infants' names in this experiment and the following experiments were obtained from the Durham County (North Carolina) vital records office and families were contacted via letter and follow-up phone call. Parents were reimbursed for their travel but not compensated for their participation.

Apparatus

The puppet-stage like 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 (No. 2.5 PB 8/2)[1] cardboard with a clear Plexiglas cover that allowed the felt-bottomed objects to move smoothly and quietly across the apparatus floor. The side walls were painted white and the back wall was covered with a brightly patterned contact paper. The infants were tested in a brightly lit room, with four clip-on lights attached to the back and side walls of the apparatus to provide additional light. Two wooden frames, 200 cm high and 69 cm wide and covered with blue cloth, stood on either side of the apparatus to isolate the infants from the experimental room. At the end of each trial, a white curtain was lowered to cover the opening to the apparatus.

There were two objects used in the test trials, a yellow cylinder and a blue box. 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 and the ends were painted bright yellow (No. 2.5Y 8/10). The box was 35 cm high, 13 cm wide, and 13 cm deep. It was covered with bright blue (No. 2.5PB 7/6) contact paper decorated with small (approximately 2 cm on a side) white squares. One corner of the box faced the infants. The left rear wall of the box (not visible to the infants) held a

[1] Numbers in parentheses after colour descriptors refer to Munsell colour chip matches. These matches were made with the objects in their positions on the apparatus, so that lighting conditions would be the same as during the experiment.

magnet. The cylinder lay on the floor of the apparatus with its metallic end set against the box's magnet. This made it possible for the box to move along with the cylinder when the cylinder 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 quietly across the 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 degrees (horizontal) and 27 degrees (vertical) of visual angle from the infants' viewpoint.

In each test event, the cylinder was pulled to the side by an experimenter's hand wearing a lavender spandex glove that was 59 cm in length. The hand entered the apparatus through a wall opening that was partially hidden by a white curtain; the infant could not see the experimenter's face through this opening.

Infants were familiarized (see procedure) with three boxes that were each similar to the test box. Each was identical to the test box (blue with white squares) in its dimensions and had squares or circles of approximately the same size and in the same positions as the squares on the test box. The colours and texture elements for each of the boxes were as follows: green (No. 2.5G 5/12) with white triangles, blue (No. 2.5PB 7/6) with red (No. 5R 4/12) squares, and purple (No. 7.5P 4/10) with white squares.

Procedure

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 behaviour was monitored by two observers who viewed the infant through peepholes on either side of the apparatus. The observers could not see and did not know which test event the infant was observing. Each observer held a joystick connected to a computer and depressed the trigger whenever the infant attended to the events, keeping the trigger depressed for the duration of looking. Each trial was divided into intervals of 100 ms duration. For each interval, the computer determined whether the two observers agreed on the direction of the infant's gaze. Interobserver agreement was calculated for each trial as the number of intervals in which the computer registered agreement, out of the total number of intervals in the trial. Agreement in the experiments reported here averaged 88% per trial per infant. The input from the primary (more experienced) observer was used to determine the end of the trials.

Each infant first received three brief familiarization trials that featured one of the three different boxes. The boxes were presented in a random order. The caretaker and infant were seated in front of the previously described testing apparatus. The screen was raised and one of the boxes was visible, held by a purple-gloved hand. Each box was held approximately 10 cm above the apparatus floor and tilted alternately to the right and left in a smooth continuous motion to maintain infant interest in the object. When the infant had accumulated 10 s of looking at the box, the trial ended with the screen closing. It then reopened showing the next box. After all three boxes had been presented in this manner, the infants were given a brief familiarization trial with the stationary test display. This trial ended when the infant (1) looked away from the display for 2 consecutive seconds after having looked at it for at least 10 cumulative seconds or (2) looked at the display for 30 cumulative seconds without looking away for 2 consecutive seconds.

Following the familiarization trials, each infant saw either the move-apart *or* the move-together test event[2] (see below for description of test events) on each of six successive trials. Each test trial ended when the infant (1) looked away from the event for 2 consecutive seconds after having looked at it for at least 8 cumulative seconds (the length of one event cycle) or (2) looked at the event for 60 cumulative seconds without looking away for 2 consecutive seconds. Each infant completed the entire set of six test trials. There were no reliable differences in looking times during the stationary familiarization trial for the infants who would see the move-apart (M = 16.04; SD = 3.3) versus the move-together test event (M = 16.22; SD =6.5), $F(1, 14) = 0.005$.

Events

Move-together event. At the start of each test trial, the curtain was raised and the infant could see the experimenter's hand on the floor of the apparatus about half-way between the cylinder and the opening in the left wall. After 1 s, 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. The hand paused for 1 s and then pushed the cylinder and the box back to their starting positions (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 signalled that the trial had ended. When this occurred, a second experimenter lowered the curtain in front of the apparatus.

[2] As in Needham and Baillargeon (1998), and all of the other research conducted on object segregation in our lab, a between-subjects design was used: Each infant saw either the move-apart or the move-together test event. Because we assume that the infants are responding to the test event relative to their initial interpretation of the display during the familiarization trial (and we do not want to open up the possibility of elevated levels of looking being a result of surprise that the nature of the display as one or two objects changed between trials), we believe it is important to show each infant only one of the possible compositions of the display.

Move-apart event. The move-apart event was identical to that just described except that only the cylinder moved and the box remained stationary throughout the trial. To accomplish this, the magnet was removed and a weight was placed inside the box to prevent its movement (see Figure 1).

Results

Preliminary analyses. Preliminary analyses were first conducted to determine whether there was a reliable effect of trial or sex on the infants' looking times at the two test events. A two-factor analysis of variance (ANOVA) was conducted with event as the between-groups factor and trial as the repeated measure, which indicated that there was a reliable effect of trial on the infants' looking times. Infants looked reliably less as the experiment progressed, $F(1, 5) = 14.01$, $p < .0001$. There was no differential effect of trial on the infants' looking times at the two test events, $F(1, 5) = 0.45$. A second two-factor ANOVA with event and sex as between-groups factors showed no significant effect of the infants' sex on looking times at the two test events, $F(1, 12) = 0$. Therefore, data were collapsed across trial and sex for further analyses.

Main analysis. The infants' looking times (see Figure 2) were analysed by means of a one-factor ANOVA with event (move-together or move-apart) as the between-subjects factor. This analysis yielded no significant effect of test event, $F(1, 14) = 0.349$, indicating that infants looked about equally at the move-together ($M = 26.7$; $SD = 13.1$) and the move-apart ($M = 30.4$, $SD = 11.9$) test events.

Discussion

It appears that serial presentation of the three box exemplars in this laboratory context does not promote the category formation that would support infants' segregation of the test display. In this context, three exemplars that are similar to the test box and are presented simultaneously appear necessary to facilitate subsequent segregation. This could suggest a number of interesting possibilities. It could be that direct comparison between the three exemplars facilitates category formation, and that infants at this age are not able to hold the non-present exemplars in memory long or well enough for comparison or category formation to occur. However studies of infant memory at this age suggest that this is probably not the case (see Rovee-Collier & Hayne, 2000).

An alternate explanation is that our procedure itself impeded infant category formation. Perhaps comparison between the objects themselves isn't sufficient for category formation. In order to group the objects together, it is necessary for the infants to notice the *similarities* between the objects. Our sequential presentation of the boxes in an unchanging context might have highlighted the differences between each box. In any case, this finding implies that experience

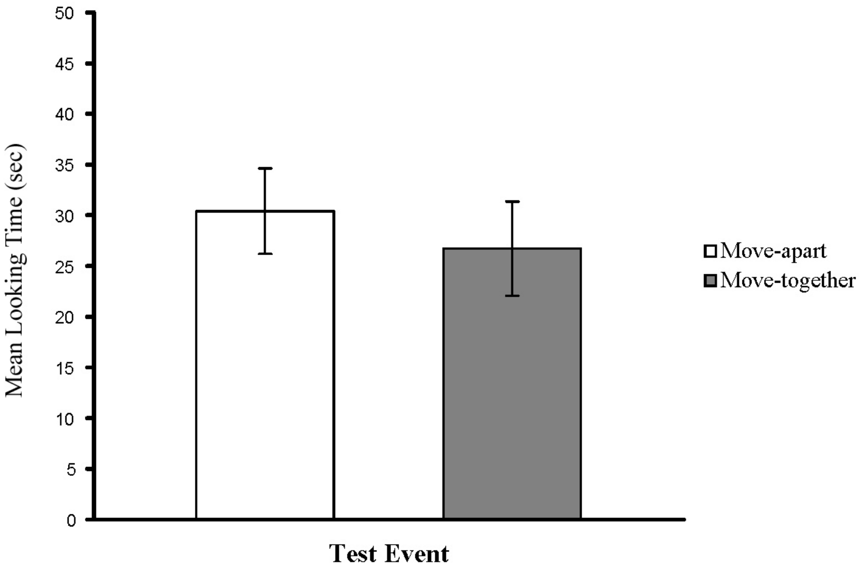

Figure 2. Mean looking time (+*SE*) to test event after immediate prior experience with three similar boxes presented sequentially.

with a small number of similar objects is useful to young infants only if all the exemplars are present at the same time.

However, while our Experiment 1 procedure was more similar to real-world experiences in that it addressed the question of simultaneous versus individual experiences of objects, it was still quite artificial, and it seemed likely that infants could learn from experiences with single exemplars presented sequentially in everyday life. One difference between infants' experience outside the lab and the method of Experiment 1 was the physical context of the experience. In the lab, the physical context was purposefully unchanging. In fact, the only things that changed were the objects themselves. In contrast, outside the lab, sequential experiences with similar types of objects would probably be in varied physical contexts, and there is some infant memory data that suggest that training in varied contexts promotes infants' memory retrieval in a novel context (Amabile & Rovee-Collier, 1991). Despite the fact that this reasoning leads to the (possibly) counterintuitive prediction that changing the context in which infants saw each object would actually facilitate their performance, we sought to create a lab setting that more closely resembled infants' typical experiences outside the lab. Recall the previous example of an infant's exposure to dogs. The infant's three experiences with dogs happened serially, but also occurred in different physical places and separated by longer time intervals than those used in our Experiment 1 procedures.

EXPERIMENT 2

Experiment 2 was an attempt to present the objects of Experiment 1 serially, but to do so in a way that better mimicked the parameters of infants' experiences outside the lab. We designed a version of serial presentation that incorporated longer time intervals between exemplar presentation as well as changes in background physical context in an attempt to learn if this would make the category information more available to infants. If it is the case that varying the background physical context helps infants notice the similarities between the boxes, then we would expect that after this experience, infants would demonstrate facilitated object segregation performance.

Method

Participants

The participants were 16 healthy, full-term infants (8 females, 8 males) ranging in age from 4 months, 9 days to 5 months, 27 days (*M* = 5 months, 8 days; *SD* = 15.3). Half of the infants saw the move-apart test event (*M* = 5 months, 2 days; *SD* = 10.9) and half saw the move-together test event (*M* = 5 months, 14 days; *SD* = 17.2). Data from 11 additional infants was collected and excluded, 2 due to computer related malfunctions, 2 due to infant fussiness, 6 due to intervals between familiarizations and or test being too long (see explanation below), and 1 due to infant failure to habituate.[3]

Apparatus and procedure

The set of stimuli and test events used for these studies was identical to those used in Experiment 1. However, the familiarization procedure with the three similar boxes was changed. Each box—blue, purple, and green—was presented individually to the infant for 10 s as in Experiment 1, but there was a delay of 3.5 min between each presentation. The presenter and location of presentation were changed for each box. In other words, the infant saw three different boxes presented by three different people in three different locations (see Figure 3).

Interval timing was accomplished by the passing of a stopwatch from experimenter to experimenter out of sight of the infant, and data from infants for whom the intervals were not maintained (e.g., it took longer than 3.5 min to reach the lab from the parking lot) were excluded from the analyses (*n* = 2). The

[3] We do not use specific criteria for habituation in our studies. Instead we show the events to all infants for six trials. We reliably find that infants habituate as the trials progress, regardless of what event they see, indicating that they have processed the event and are beginning to lose interest in it. If an infant looks for the maximum possible time (60 s) for each test trial, there is no indication that the infant is processing the task, and, as such, his or her data are excluded.

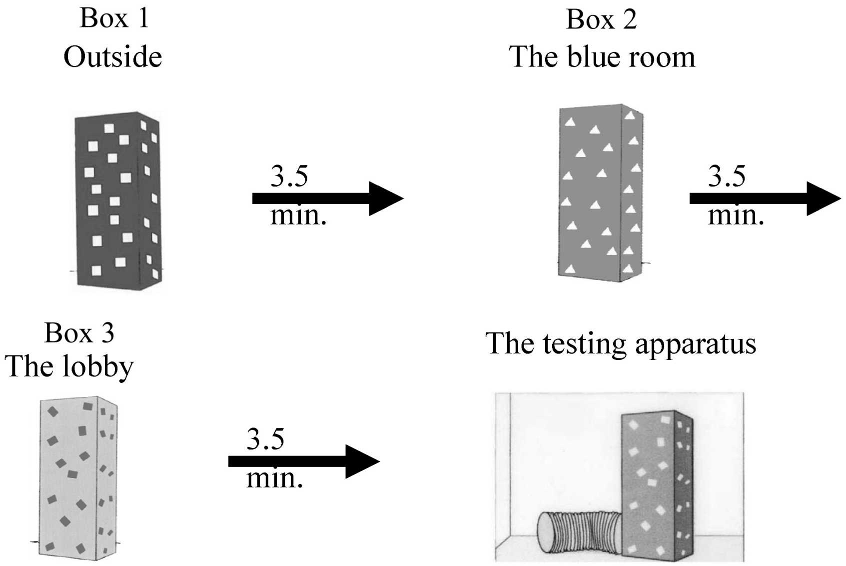

Figure 3. Schematic of procedure for Experiment 2. Box 1: Purple with white squares. Box 2: Green with white triangles. Box 3: Blue with red squares.

order of box presentation was random, and occurred in the following three locations.

Location 1. The first box was presented to the infant outdoors when the caretaker was met at the lab parking space. Experimenter 1 explained what the study was about, received verbal consent from the caregiver to proceed with the study, and showed the infant a box for 10 s, moving the box slowly (in the manner described in Experiment 1) to maintain the infant's attention. The experimenter was standing approximately 60 cm in front of the infant. The box was then hidden, the timer reset, and the caretaker and infant were escorted to the lab.

Location 2. Upon reaching the lab, the caretaker and infant were ushered into a room with walls covered by long blue curtains where Experimenter 2 was sitting. Experimenter 2 chatted with the caretaker and infant until exactly 3.5 min had elapsed from the presentation of the first box, and then presented the second box. After 10 s, the box was hidden and Experimenter 2 left the room.

Location 3. The caretaker and infant were escorted to the lobby of the lab, a room decorated with colourful posters and many toys, where the caretaker finished paperwork and chatted with the lab manager. Three and a half minutes after the presentation of the second box, Experimenter 3 entered the lobby, presented the third box for 10 s, and then left the room.

Location 4. The caretaker and child were then escorted to the previously described testing apparatus in yet another room, and the test procedure was begun approximately 3.5 min after the presentation of the last box. Because the amount of time to get the caretaker and infant settled and ready to begin the test trials was variable, the time between the presentation of the final box and the beginning of the familiarization trial with the stationary display was recorded for each infant. Data from infants whose final interval was longer than 4 min ($n = 4$) were not included in these analyses.

Infants first saw a brief familiarization trial with the stationary test display (described in Experiment 1) and then saw either the move-apart or move-together test event. All infants contributed data for the full set of six test trials. There were no reliable differences in the looking times during the stationary familiarization trial for the infants who would see the move-apart ($M = 20.7$; $SD = 9.7$) versus the move-together test event ($M = 16.6$; $SD = 6.9$), $F(1, 14) = 0.93$. There was also no significant difference in the delay between seeing the last box and the beginning of the stationary familiarization trial for infants who would see the move-apart ($M = 3.40$; $SD = 10.5$) versus the move-together test event ($M = 3.39$; $SD = 23.0$), $F(1, 14) = 0.01$.

Results

Preliminary analyses. The data were analysed as in Experiment 1. Infants looked reliably less as the experiment progressed $F(1, 5) = 4.49$, $p < .01$. There was no differential effect of trial on the infants' looking times at the two test events, $F(1, 5) = 0.28$. There was no significant effect of the infants' sex on looking times at the two test events, $F(1, 12) = 0.14$. Therefore, data were collapsed across trial and sex for further analyses.

Main analysis. The infants' looking times (see Figure 4) were analysed by means of a one-factor ANOVA with event (move-together or move-apart) as the between-subjects factor. This analysis yielded no significant effect of test event, $F(1, 14) = 0.638$, indicating that infants looked about equally at the move-apart ($M = 34.64$, $SD = 10.2$) and move-together ($M = 38.56$; $SD = 9.4$) test events.

Discussion

Infant segregation of the test display was not facilitated by sequential presentation of the three similar boxes prior to seeing the test display, even when those experiences happened in distinct physical locations. This finding was a bit surprising given our intuitions about the types of experience infants are likely to have in daily life. There could be several explanations for this finding (as is the

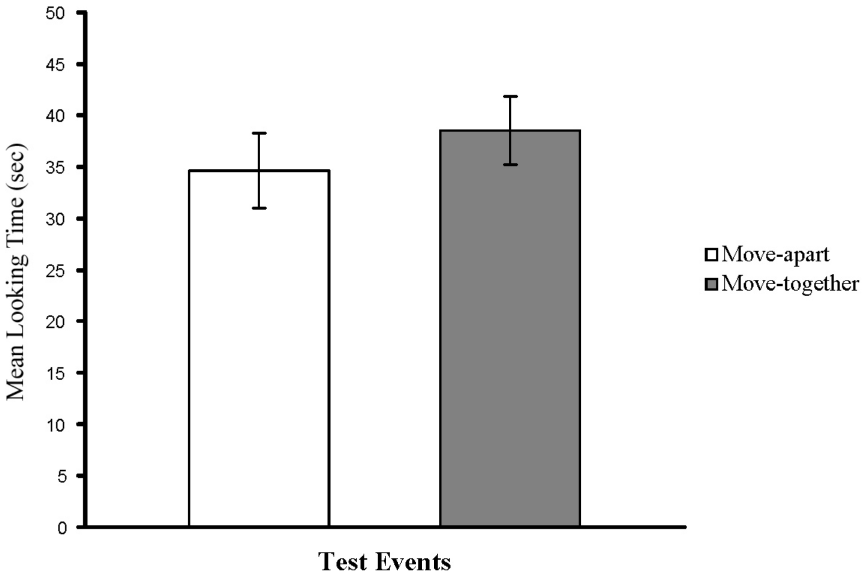

Figure 4. Mean looking time (+*SE*) to test event after prior experience with three similar boxes presented sequentially and in three distinct physical locations.

case with all null findings). First, the task might have just been too difficult for the infants. Previous research has shown that at 6 months old, infants' memory is quite sensitive to changes in the physical context (Rovee-Collier & Gulya, 2000), and for the infants to benefit from their experiences with the objects they certainly needed to remember the various box exemplars. The memory demand could have been too much for infants to overcome.

Reflection on the experiment suggested another alternative. Perhaps the procedure did not accurately capture the essence of infants' everyday experiences. We tried to vary everything except for the objects themselves, with the idea that the background differences would make the similarities among the boxes salient to the infant. We were focusing on how the changing of everything outside of the object could affect infants' understanding of the test display. Although changes in physical context are probably a common experience for infants, it is also the case that similarities often exist among the types of contexts in which specific objects are encountered. Recall the example of an infant's experiences with various dogs. Most dogs wear collars, have leads, and behave in similar ways. Further, the people around the infants may interact with dogs similarly—leaning down to pet them, speaking in ''puppy-voices'' and taking them for walks.

Along with physical contextual variability, there is also some contextual regularity to infants' real-world experiences with similar objects. It could be that infants use these regularities to recognize the similarities between various experiences with objects. In effect, these similarities could help infants link together their experiences in a way that allows them to from a category they can access at a later time. Perhaps it is the interaction of physical contextual variability and regularity that combine to help infants gather category information from their sequential experiences with category exemplars.

EXPERIMENT 3

This experiment is an attempt to include contextual regularity in the infants' physically varied experiences. We wanted to duplicate the procedure of Experiment 2, but include a contextual regularity in all of the infants' experiences with the boxes. This meant we needed a link that could be present during the test events as well. So, the purple glove that was normally present during the test events was worn by each experimenter for all of the trials—familiarization and test, thus providing a mix of variability and regularity in the physical contexts of infants' experiences. If infants need both variation in the physical context (different locations) and contextual regularity (purple glove), we would expect that this prior experience would lead to facilitation in infants' parsing of the test display.

Method

Participants

The participants were 16 healthy, full-term infants (8 females, 8 males) ranging in age from 4 months, 6 days to 5 months, 28 days (M = 4 months, 28 days; SD = 19.0). Half of the infants saw the move-apart test event (M = 4 months, 22 days; SD = 15.3) and half saw the move-together test event (M = 5 months, 5 days; SD = 20.6). Data from 17 additional infants was collected and excluded, 3 due to infant fussiness, 6 due to intervals between familiarizations being too long, 5 due to longer than 4 min between familiarization and test, 2 due to experimenter error, and 1 as a statistical outlier (Z = 3.1).

Procedure and apparatus

The familiarization procedure for Experiment 3 was identical to that of Experiment 2 with the following exception: Each experimenter wore a purple glove (the same one the infants would see during the test trials) on the hand that they were using to present the box during the familiarization trials. The testing procedure was identical to the previous experiments. Each infant first saw a brief familiarization trial with the stationary display, and then saw either the move-apart event or the move-together event. Fifteen infants contributed data for all six test trials and one infant contributed only five trials due to poor visibility for the observers during the last test trial. There were no reliable differences in the looking times during the stationary familiarization trial for the infants who would see the move-apart (M = 18.64; SD = 6.8) versus the move-together test event (M = 17.93; SD = 5.7), $F(1, 14)$ = 0.05. There was also no significant difference in the delay between seeing the last box and the beginning of the stationary familiarization trial for infants who would see the move-apart (M = 3.34; SD = 14.2) versus the move-together test event (M = 3.36; SD = 15.9), $F(1, 14)$ = 0.09.

Results

Preliminary analyses. The data were analysed as in Experiment 1. Infants looked reliably less as the experiment progressed, $F(1, 5) = 5.97$, $p < .001$. There was no differential effect of trial on the infants' looking times at the two test events, $F(1, 5)$ = 0.62. There was no significant effect of the infants' sex on looking times at the two test events, $F(1, 12)$ = 1.86. Therefore, data were collapsed across trial and sex for further analyses.

Main analysis. The infants' looking times (see Figure 5) were analysed by means of a one-factor ANOVA with event (move-together or move-apart) as the between-subjects factor. This analysis yielded a significant effect of test event, $F(1, 14) = 6.28$, $p < .03$, indicating that infants looked reliably longer at the move-together (M = 44.09, SD = 8.2) test event than at the move-apart (M = 30.22; SD = 13.3) test event.

Discussion

After sequential experience with three similar objects in three distinct locations that each included a single contextual regularity, infants showed a clear expectation that the test display was in fact composed of two pieces. This suggests that, given this set of experiences, infants were able to form a category that they could use to disambiguate the test display by generalizing knowledge about the probable boundaries of the test box.

It is important to note that infants could not simply have been attending only to the glove and still have shown facilitation on the object segregation task for two reasons. First, it is unclear how simply recognizing the glove in the test situation would lead infants to attend differently to the two test events, and second, the glove did not act in the same way each time it was seen. For the familiarizations, the glove was present on the hand presenting each box, and at test, the gloved hand reached out and grasped the yellow cylinder—it never touched the test box. In order to have shown facilitated object segregation, infants must have been attending to the boxes as well as the glove. It could be that by including the glove in all of the experiences with the boxes, we merely

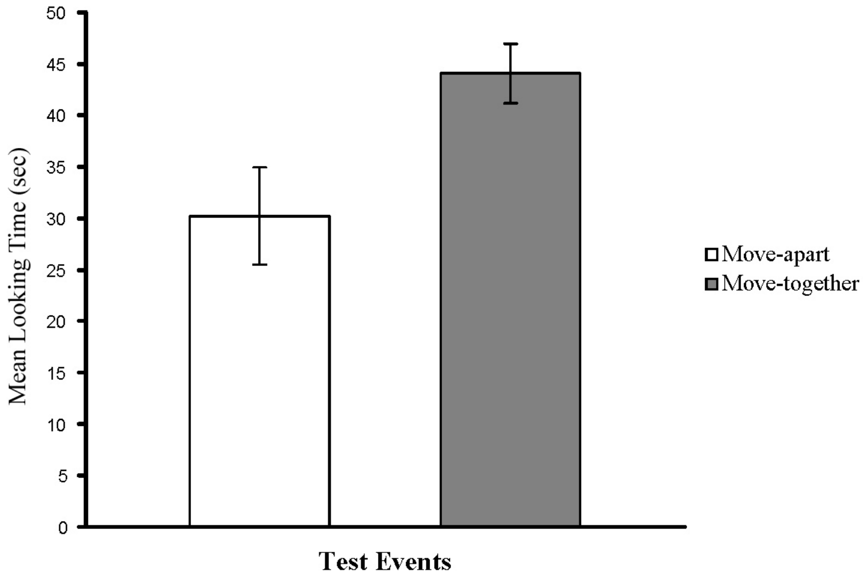

Figure 5. Mean looking time (+*SE*) to test event after prior experience with three similar boxes presented sequentially, in three distinct physical locations with the addition of physical (purple glove) contextual regularity.

increased the overall similarity of the experiences. Alternately, the glove could have served as a salient memory cue that helped infants to access their memories of their previous experiences when the glove was present. In either case, the presence of a physical regularity in the changing physical contexts of infants' experiences with the three boxes seemed to help infants to link those experiences into an object category that facilitated their segregation of the test display.

Cross–experiment analyses. In order to directly compare the results of the three experiments we estimated an overall (Experiment $\times$ Condition) ANOVA model. The resulting model was significant, $F(5, 42) = 2.6$, $p < .04$, but there were no significant main effects or interactions in the model. A series of planned comparisons were estimated to clarify this result. The results of Experiments 1 and 3 were significantly different, $F(1, 31) = 4.73$, $p < .04$, and this effect was driven by a significant interaction between experiment and condition, $F(1, 31) = 4.94$, $p < .03$, indicating that while infants looked similarly at the move-apart and move-together events in Experiment 1, in Experiment 3 they looked significantly longer at the move-together event. This set of results supports the interpretation that changes in physical context are beneficial for category formation since contextual regularity (the purple glove) was present in both

Experiments 1 and 3. The results of Experiments 2 and 3 were not significantly different, $F(1, 42) = 0.2$, nor was there a significant interaction between experiment and condition, suggesting that infant behaviour during these two experiments was similar. In fact, scrutiny of the means shows that the results were qualitatively similar—in both Experiments 2 and 3 the infants looked longer at the move-together event. This pattern suggests that varying the background physical context might have been helpful to some of the infants, but it was only the combination of the varying physical context with an element of contextual regularity that reliably facilitated infant category formation and parsing of the novel scene.

GENERAL DISCUSSION

Taken together, the pattern of results obtained in these studies suggests that infants' scene perception can benefit from sequential experiences with similar objects when those experiences happen in different physical contexts and contain at least one element of contextual regularity. It appears that it is the combination of these two elements that is important because in the presence of only one, facilitation did not occur. Recall that only contextual regularity (in the form of the purple glove) was present in Experiment 1 when each of the boxes was encountered sequentially in the testing apparatus. In Experiment 2, only physical variability was present, with each experience with a box happening in a distinct location. Neither of these types of experiences was useful for infants. It was the combination of the two in Experiment 3 that enabled infants to notice category information that they could use to segregate the objects in the test display.

These results have many intriguing implications for current theories and future research. First, we know something more about how infants develop a knowledge base that can support the top-down segmenting of visual scenes. By studying category formation in more realistic situations, we have learned about the importance of context to the development of object recognition. This beneficial role for changes in the physical context of experience seems counter to some of the information reported from studies of infant memory performance, but we do not actually believe it is an opposing claim. Similar disparate roles for physical context have been found in adult populations as well (Smith, Glenberg, & Bjork, 1978) and have been discussed as representing effects at different stages of memory. Encoding the same or (we would argue) similar information in different physical contexts provides more cues that might overlap with the current physical context making recovery of that information more likely, while information learned in one context and retrieved elsewhere has fewer cues available.

Second, these findings expand what we know about infants' processing of contextual information. The idea that infants notice and can benefit from regularities present in the environment is not a new one. Mervis and Rosch (1981) argued that the remarkable congruence/similarity in categorization between individuals resulted from the similarities people experienced in their natural environments. This similarity in experience was said to result from exposure (and attention) to the correlatedness of sets of attributes in the physical world and the realization that not all possible combinations of features/attributes are present in the natural world. According to Mervis and Rosch, it is the discontinuity between various sets of attributes that form natural category boundaries. Thus, the correlatedness of attributes within objects supports category formation.

We suggest that it is not just the correlatedness of attributes within similar objects in the real world that support category formation, but that it is also the correlation between specific contextual regularities and specific types of objects that help infants to link together their experiences to form categories. In fact, similar objects typically appear in similar types of contexts or scenes, and this natural correlatedness of object kind and overall context supports category formation. For example, spoons are typically encountered in the kitchen and almost always in the presence of food (Mandler, Fivush, & Reznick, 1987). We argue that these contextual regularities help infants to link together their experiences with various spoons to create a category of spoon. That category knowledge could then help infants to recognize spoons in later encounters and this could be a kind of scene-schema knowledge (e.g., Henderson, 2003) in infants

This argument may imply that infant object knowledge becomes less context-dependent over time because once a category is present it would facilitate recognition of a spoon even in an unusual context. Once infants link together experiences with similar objects to form a category they might be able to access that category information later when they encounter a similar object even if the object is in an atypical setting (e.g., a spoon in the infant's crib). New evidence from our lab supports this reasoning. In keeping with the theme of these studies, which was to try to understand infant cognition in context, we were eager to identify a contextual regularity that might be present in infants' real-world experiences (because purple velvet gloves are, at least for most infants, a rarity). To return to the dog example one last time, beyond the physical regularities like leads and dog kennels, infants could also notice similarities in the way other people interact with the dog as well as the word(s) ''Dog'' or ''Doggie'' commonly used to refer to the dog. We thought that language, specifically the labelling of objects, could be one of the contextual regularities that even young infants might benefit from in daily experiences. In fact, recent data suggest that this is the case (Dueker & Needham, 2003, 2005). After parents label the three boxes during familiarization, infants recognize the test box (which is not named by the parents) in the novel test display. It appears that once the experiences with the original three boxes are linked together to form a category, use of that category is no longer dependent upon the specific contextual link. This suggests that while contextual regularities appear necessary for real-world category formation, once a category is established, infants can use it in contexts that do not contain such contextual regularities.

FINAL COMMENTS

The findings from this set of studies have broad implications for the study of infants' understanding of objects in the world around them. Generally, in studies of infant categorization or object understanding, the physical context is kept constant, and contextual regularities that might be available in everyday infant experience are excluded. For example, many studies have addressed whether and at what age infants can discriminate between the category of dog and of cat (e.g., Quinn et al., 1993), but in these studies infants are presented only with a picture (or two pictures) of a dog on a blank background. Even in studies that use realistic models of dogs (e.g., Mandler & McDonough, 1996), other objects that might help infants link this experience to another experience with a dog (e.g., a lead or dog kennel) were not often available. Our results suggest that by stripping away the trappings of an infant's everyday experiences we might be underestimating her competence because the infant no longer has access to the contextual regularities she could use in a real-world situation to link together her various experiences with similar objects. These studies are just a beginning, but the techniques developed here can be used to learn much more about the origins of real-world scene processing and the processes by which scenes become meaningful to us.

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