LEARNING OBJECT CATEGORIES ACROSS TIME IN 4.5-MONTH-OLD INFANTS

By

DEON TERREL BENTON

A Thesis Submitted to The Honors College

In Partial Fulfillment of the Bachelors degree
With Honors in

Psychology

THE UNIVERSITY OF ARIZONA

M A Y 2 0 1 3

Approved by:

____

Dr. Rebecca L. Gómez
Department of Psychology

The University of Arizona Electronic Theses and Dissertations Reproduction and Distribution Rights Form

Name (Last, First, Middle)

Benton, Deon, Terrell

Degree title (eg BA, BS, BSE, BSB, BFA):

BA

Honors area (eg Molecular and Cellular Biology, English, Studio Art):

Psychology

Date thesis submitted to Honors College:

5/1/13

Title of Honors thesis:

Learning Object Categories Across Time in 4.5-month-old Infants

The University of Arizona Library Release Agreement

☑ Yes, make my thesis available in the UA Campus Repository!

Student signature: [signature] Date: 4/29/13

Thesis advisor signature: [signature] Date: 4/29/13

☐ No, do not release my thesis to the UA Campus Repository.

Student signature: ______________ Date: ______________

Abstract

The present study investigated whether infants can connect their learning experiences across time with novel object exemplars to segregate a test display 72 hours later. We examine this question by familiarizing infants to these exemplars by visiting infants in their homes on two days separated by 24 hours and then on a third day 72 hours after the second familiarization session. Immediately following this final familiarization session, we tested infants under one of two conditions: either the infants would view two distinct objects move together (the move-together test event) or move apart (the move-apart test event) after being initially adjoined. When familiarization was immediately followed by a nap, infants looked longer at the move-together test event (violating their understanding that the display contained two distinct, adjoining objects) than at the move-apart test event, suggesting they were able to connect their experiences with the object exemplars across an extended period of time. This result has implications for learning under natural conditions.

Acknowledgments

John Donne once penned, “No man is an IIland, intire of it selfe; every man is a peece of the Continent, a part of the maine.” e.e. cummings, some years later, eulogized the connectedness of mankind by writing, “i am through you, so i.” It is with these reflective words in mind that I would like here to give credit where it is rightly due by extending many thanks to those who have contributed to the completion of this honors-thesis project, in more than one way.

To start, I wish to thank my family – Mom, Dad, James Lockhart, Aaron Benton, Josh Lockhart, and James Duran – for providing your unconditional love, your welcomed humor, and your unflagging support throughout the entire time I have been at the University of Arizona. I am who I am and where I am today because you made me and because you cared. So thank you.

Secondly, I would like to thank Ashley – my rock, my soul mate, my best friend – for lending me your car for all those home visits, for your Excel expertise, and for being, on so many occasions, that voice of reason that helped me sidestep many a potential problems.

And last, but most certainly not least, I wish to thank my mentor, Dr. Rebecca L. Gómez, for her kindly words, for her guidance and advice, and for her professional support throughout the two years I have worked with her. You are the consummate professional to whom I aspire, and it is my hope that I can be for another student what you have been for me.

Introduction

Imagine the task faced by a young infant who, for the first time, finds him or herself hoisted over and peering from mom's or dad's lap into the unkempt desk drawer located in the family study. To the adult with experience in the world, he or she may accurately perceive the drawer as containing pencils, a medley of ballpoint pens, some bits and scraps of paper, a couple CDs, and a now-empty bag of potato chips. To the infant absent such experience, however, the process of discriminating the contents of the drawer may seem like an insurmountable task. Object categorization is therefore a process that involves being able to locate the boundary between two objects in order to represent both objects in a meaningful way (Needham, 2001). In addition, object categorization is a process that involves being able to use prior knowledge with various kinds of entities to perceive perceptual scenes. Therefore, the aim of the present investigation is to systematically investigate whether infants can connect their experiences across time with novel objects to segregate a test display several days later.

Configural information as a cue to the test-display composition

In much the same way that adults first represent the features of objects in the world before they can benefit from their prior experience with these objects, infants must first show evidence that they can represent the features and configurations of items in the world before they can benefit from their prior experience with them. When, and perhaps more importantly how, then, do infants come to represent objects in the real world? Early support bearing on this question comes from a now classic study by Kellman and Spelke (1983), who examined when and how infants represent configural information. In the first experiment of the study, infants were habituated to a rod that moved back and forth behind a stationary occluder, after which point the experimenters tested them by showing them both a fully visible complete rod and a fully visible broken rod in alternating succession. If the continuity of motion in consonance with the alignment of the top and bottom portions of the display suggests unity, then infants should look longer at the broken rod than at the complete rod. Results from this experiment corroborated this hypothesis. Infants assigned to the experimental condition looked reliably longer at the broken rod than the complete rod, suggesting that infants perceive unity in a display containing motion.

Kellman and Spelke conducted a second experiment to investigate whether the unity in the configuration of partly hidden stationary rod parts alone, absent motion, was a salient enough cue to suggest uniformity. Infants were assigned to one of three conditions to investigate this question: an experimental condition and one of two control conditions. Infants in the experimental condition were habituated to a stationary rod whose top and bottom parts were aligned behind an occluder. Infants in the first control condition were habituated to a fully visible rod resting in front of the occluder, and infants in the second control condition were habituated to a partially hidden rod resting behind the occluder. If motion is a salient cue to unity, *i.e.*, if motion gives rise to the percept of a complete rod behind the occluder, then infants in the experimental and second control condition should only dishabituate to the complete rod test display. However, if motion does not necessitate the percept of a complete rod behind the occluder, *i.e.*, if the absence of motion leads infants to perceive unity, then those in the experimental and first control conditions should only dishabituate to the broken rod test display. Somewhat surprisingly, infants displayed a pattern of looking that defied the aforementioned hypotheses. Rather than showing a definitive preference for either the broken rod or complete rod during test, infants in the experimental condition looked about equally at both test displays. Infants in both control conditions, on the other hand, looked decidedly longer at the test display to which they had not been habituated. Notwithstanding the fact that these results fail to address *what* infants might have perceived behind the stationary occluder, they do suggest that when motion is not an available cue, infants appear to neither perceive a complete nor a broken rod behind the occluder. Thus, when the rod pieces are not in motion, infants do not appear to perceive a unitary object, much less the object's identity.

Experiment 3 was undertaken to investigate what it was that infants perceived behind the occluder in Experiment 2. To gain insight into this question, infants in the first condition were habituated to a partly occluded rod, and infants in the second condition were habituated to a display whose rod pieces formed a gap larger than the original occluder and appeared further in the distance. Infants in both conditions were then tested with a complete rod and a broken rod whose gap was larger than the otherwhere occluder. These habituation conditions allowed experimenters to systematically investigate three questions: (i) whether infants perceived only the foremost object in the habituation display (*i.e.*, the occluder), (ii) whether infants perceived an object that was neither a complete nor a broken rod behind the display, or (iii) whether infants perceived an object that *could* be either a complete or broken rod. Results revealed that infants looked longer at the test display whose visual areas differed from the habituation display. Specifically, after habituation to a single rod whose middle section is hidden behind an occluder, infants dishabituated to two rod pieces that were separated from each other by a gap larger than the size of the original occluder. Furthermore, after habituation to two rod pieces behind the same occluder, infants dishabituated to the complete rod. This result suggests that infants respond on the basis of differences in the visual areas represented by the habituation and test displays; that infants are privy to occlusion; and that infants do not perceive the rod as continuous behind the occluder. These results, taken together, suggest that infants do not perceive a definite object behind an occluder, even when that object forms a symmetrical, Michoettian shape or if the rod parts are consistent in color, shape, and texture. Moreover, motion and configural alignment of the top and bottom rod parts relative to the occluder and the background surface appeared to be a salient cue to connection behind the occluder (Kellman & Spelke, 1983).

A number of additional studies have provided further empirical support that infants first represent the configuration of objects by using similar and dissimilar surfaces and use shape and configural differences to segregate a test display (Schmidt, Spelke, & LaMorte, 1986; Kestenbaum, Terman, & Spelke, 1987; Needham, 1999). One study by Termine, Hrynick, Kesetnbaum, Gleitman, & Spelke (1987), for example, examined infants' perception of continuous background surfaces behind occluding objects. Infants in Experiment 1 were familiarized to a partly hidden background surface for a brief, 5-second period. Infants in Experiment 2 were habituated to a partly hidden background surface viewed through an aperture, or opening, so that the edges of the surface were not visible to infants. Presented in this fashion, the partially hidden surface was seen as the background of the scene. Infants in Experiments 1 and 2 were expected to look longer at the discontinuous surface at test if they originally perceived a continuous background surface behind a narrow, horizontal occluder. Infants in Experiment 3 were habituated to a partly occluded surface whose edges were visible and that stood in front of a larger, edge-less background surface. The prediction for this experiment was that if infants perceive a partly occluded surface alone, without reference to the depth relations of the background and foreground surfaces, then infants should dishabituate only to the discontinuous surface. A final experiment was conducted to examine whether depth information exerts an influence on adults' perception of background surfaces.

The looking behavior shown by infants in Experiments 1 and 2 demonstrated that they perceived a continuous background surface behind an occluder. Infants in Experiment 3, however, failed to perceive a continuous background when that background served as the foreground of a scene, a result that seems to cast doubt on the merits of the Gestalt thesis that perception of background surfaces depends solely on pictorial cues. It appears, premised on these results, that infants can perceive continuity of a background surface only when a scene contains no depth information. When depth information is introduced, however, infants appear unable to represent continuity.

Experiential knowledge on object segregation abilities

In addition to the aforementioned research demonstrating that infants use motion and background surfaces as cues to detect unity in visual displays (Kellman & Spelke, 1983; Termine, Hrynick, Kesetnbaum, Gleitman, & Spelke, 1987), recently researchers have begun to investigate the role that experiential knowledge plays in learning. Investigating the role this form of knowledge plays on learning affords the possibility of understanding how infants apply and make use of their prior experience in new situations. Furthermore, the acquisition of this type of knowledge represents an important developmental milestone for young infants because it demonstrates that they can apply prior experiences to new ones and make inferences about novel perceptual scenes based in no small measure on these prior experiences. In brief, experiential knowledge – both for the developing infant and the adult – endorses the interaction with and detection of entities and objects in the world.

The benefits of prior experience on new learning now argued, what research, if any, shows that infants use experiential knowledge to segregate test displays? One of the first investigations examining infants' use of their prior experience to segregate objects comes from a study by Granrud, Haake, & Yonas (1985). Granrud *et al.* examined whether infants can use their prior experience of an object's size to perceive its distance by allowing 5-month-old and 7-month-old infants in Experiments 1 and 2 to play with two disparately sized objects during familiarization and then examining infants' reaching preferences under monocular viewing conditions – where visual cues are eliminated – or binocular viewing conditions – where visual cues like depth perception are abounding – during test.

If infants' judgment of object distances were affected by their unconscious inferences of the sizes of the familiarization objects, then infants were anticipated to reach for the closer object only under monocular viewing conditions. If, however, infants' judgment of object distances were affected by the visual input, i.e., the amount of light entering the eye, then infants were anticipated to reach for the closer object only under binocular viewing conditions. Results revealed that 7-month-old infants were able to use previous experience of an object's size to perceive the object's distance by reaching preferentially for the object in the test phase that appeared closer and resembled the smaller familiarization object only under the monocular viewing condition. Five-month-olds, contrariwise, were unable to make use of their prior experience with an object's familiar size to perceive its distance. This finding suggests that by the time infants reach 7 months of age, they begin to use unconscious inferences of familiar size as a cue to spatial distance.

Other investigations have shown that infants can use their prior experience to make category conclusions about faces. For example, Schwartz (1982), in his doctoral dissertation, found that after habituation to a partly occluded face or a partly occluded checkerboard, five-month-old infants can use their experiences with faces in the real world to generalize to new, within-category faces, in spite of being unable to generalize to new, within-category checkerboard patterns.

Still further, additional studies have examined how infants use their prior experience with a novel object to segregate a display containing that object. Needham and Baillargeon (1998), in a six-part study, investigated whether infants can benefit from prior experience with a novel object by familiarizing them to a box-and-cylinder test display and then testing them with either a move-together test event – in which the objects moved together – or a move-apart test event – in which one object moved while the other remained stationary. The logic behind this design was two-fold: If infants viewed accurately the test display as containing two clearly separable objects, then they should show surprise by looking longer when the test objects suggests singularity by moving together. If, on the other hand, infants viewed correctly the test display as containing only one object, then they should show surprise when the objects separate when moved. In contrast to both of the above predictions, infants looked about equally at the move-together and move-apart test events, suggesting they perceived the test display as containing neither one nor two objects. In subsequent experiments, in which the infants were habituated to either the box alone (Experiment 2) or the cylinder alone (Experiment 4), infants looked reliably longer at the move-together event, suggesting they interpreted correctly the test display as containing two separable objects by drawing on their prior experience with them.

Further evidence for infants' use of experiential knowledge comes from studies in which the experimenters manipulate the number of objects shown to infants during habituation. Dueker, Modi, and Needham (2003), for instance, asked whether infants can use their prior experience to segregate a test display several days later. In Experiment 1, infants were assigned to either the experimental condition or the control condition. Infants in the experimental condition were visited in their home 24 hours prior to the lab visit and were shown the same cylinder used in the test display for 2 minutes. Infants were then brought to the lab 24 hours following this exposure and viewed either the move-together test event or the move-apart test event. The prediction here was that if infants relied on their prior experience with the cylinder to segregate the test display 24 hours later, then infants in the experimental condition should look longer at the move-together test event condition than infants in the control condition. In line with this prediction, infants were found to use their prior experience with the cylinder to segregate the test display 24 hours later. However, infants in the control condition, who did not receive at-home exposure to the cylinder, looked about equally at the move-together and move-apart test events, suggesting that prior experience with the cylinder was critical for segregating the test display 24 hours later.

To investigate whether infants can use their prior exposure to the cylinder to segregate the test display over a longer delay, Dueker *et al*. exposed infants to either the box (Experiment 3A) or cylinder (Experiment 3B) and then tested them in either the move-together or move-apart test-event conditions three days later in the laboratory. Infants looking behavior revealed that they were unsuccessful in calling on their prior experience with the cylinder to segregate the test display three days later. This result, in concordance with the result of Experiment 1, suggested that infants are only able to effectively use their prior experience with one object if testing occurs 24 hours after initial exposure, but not longer.

To test whether infants can use their prior experience with an object category to segregate a test display three days later, infants in Experiment 4 were shown three objects drawn from the test-object category. The term *object categorization*, used here, refers to the process of grouping multiple instances of an object into distinct perceptual categories, independent of specific contextual features (Dueker & Needham, 2005). Moreover, an object category, of the type thought to be used in these studies, is believed to be robust enough to allow infants to integrate over the specific features of each individual object in order to segregate visual scenes containing those objects. Put most forwardly, object categories include the specific contextual information of the entire set of objects represented in that category. Although having specific knowledge of an object's features has been shown to serve as a detriment to object categorization (Needham, 2001), the espousal of a kind of general knowledge that computes over the specific features of an entire set of objects has been generally believed to facilitate infants' recognition of the boundary distinguishing a familiar from an unfamiliar object, enabling infants to successfully segregate a visual display (Dueker & Needham, 2005).

Despite being unable to benefit from their experience with the box alone or the cylinder alone to segregate the test display 72 hours later, prior experience with three similar objects presented simultaneously was enough to facilitate infants' segregation of the test display 72 hours later (Dueker *et al.*, 2003). Thus, infants were not only able to create an object category enabling them to segregate the test display several days after initial exposure to a set of three objects, but they were able to create a general representation of the exemplars premised on an object category that assisted in organizing meaningfully the test display. This result suggests that infants can create categories for object types and use that information to draw certain conclusions about the makeup of a visual scene several days following initial exposure. Though impressive, there are reasons to take issue with the methods used to ascertain these results. These issues will be discussed briefly in the next section.

The Present Experiment

The finding that infants can use category-based knowledge to segregate a test display several days later is informative and impressive, not least because it suggests continuity in memory processing during infancy. Of concern, however, is the extent to which the learning displayed in Dueker *et al.* approximates learning in the real world. It seems highly unlikely, for example, that infants would be exposed to an entire set of objects at one point in time, and even less likely that they would be tested on their expectation as regards the composition of a test display premised on this exposure several days later. This type of learning appears more akin to *cramming* and is unlikely to serve any long-term benefit to infants during scene-segregation tasks. The type of learning that better reflects learning in the real world, however, occurs over more protracted periods of time and involves more complicated stimuli.

In addition, it is possible that infants were using their prior experience with box-like objects to segregate the visual display at test. Few objects are more ubiquitous in society than boxes and objects that are box-like in shape and pattern, and so it is conceivable that in segregating the test display infants were using their outside knowledge of box-shaped objects rather than their presumed object-category knowledge. However, given the stimuli used in the experiment, it is impossible to know exactly whether infants used their outside knowledge of box-shaped objects or object-categories to organize the test display.

Finally, it is possible that the perceptual features of the stimuli acted to enhance infants' segregation of the test display. In plain, infants could have been conceivably using shape dissimilarity as a cue for segregation. Support for this possibility comes from studies demonstrating that 4-month-old infants use shape dissimilarity and familiar-shape information to segregate a test display containing two objects (Needham, 1999; Dueker & Needham, 2005; Needham, Dueker, & Lockhead, 2005).

The stimuli used here were designed to eliminate the possibility that infants use their prior experience with similarly shaped objects in the world to segregate the test display. The stimuli were designed to have straight-edged borders along the top, bottom, and one side and a jagged-edged border along the final side. A new occurrence of the familiarization stimuli was used during test and was adjoined to a complementary, jagged-edged object. This presentation yielded the precept of a complete rectangle and pitted the Gestalt cue of good continuation against the cue of the jagged-edged border (Gomez, Frye, Bishop, & Peterson, under review). This configuration required infants to choose between the two cues in order to successfully segregate the test display at each object's shared border.

In addition to using novel stimuli, we investigate whether infants can connect their learning experiences across time with the object exemplars by visiting them in their homes on two days separated by 24 hours and testing them in the laboratory 72 hours following this second home visit. There are two reasons why we believe that infants might be able to connect their learning experiences with the object exemplars across time to segregate the test display in the laboratory. First, Needham & Baillargeon (1998) have demonstrated that infants can use their prior experience with a box to segregate 24 hours later a test display containing the box and a cylinder. To wit, when infants are exposed to the test box 24 hours before test, they seem to use this experience to guide their segregation performance at test. Second, a burgeoning body of evidence has recently surfaced, headed by Carolynn Rovee-Collier, underscoring the importance of periodic reminders in the maintenance of memories during the period of early infancy. Research by her and colleagues have demonstrated that when infants (*viz.*, those ranging in age from 2 to 18 months) receive periodic reminders in the form of memory primes, their memories of an event continue to persist through time (Hildreth & Rovee-Collier, 1999, 2002; Hayne, Gross, Hildreth, & Rovee-Collier, 2001). So important are periodic reminders to the maintenance of memory during infancy, in fact, that even in the absence of a specific memory representation, memories of training events on either a mobile-conjugate task or train task, can last for up to 13 weeks for 18-month-old infants and up to 1 week for 2-month-old infants (Rovee-Collier, 1999). With these prior studies in mind, we investigate infants' ability to connect their experiences across time.

Method

Subjects

Subjects were 9 full-term infants ranging in age from 4 months, 4 days to 4 months, 13 days (M = 4 months, 8 days). Two of the infants were male and 3 of the infants were female. Five of the infants were assigned to the move-together test-event condition and four of the infants were assigned to the move-apart test-event condition. One infant was excluded from the experiment due to excessive fussiness and failure to complete the experiment. The protocol for discards included not meeting the protocol of being typically developing, having a birth term of at fewest 36 weeks, and having a birth weight of at fewest 5 pounds, 8 ounces.

The infants were recruited through the Parent Connection, a local play group, and through the Tucson Convention Center Baby Fair, a local annual event. Infants were recruited through electronic correspondence, telephone calls, and in-person visits. The parents received $50 USD to compensate for their time spent in the study.

Materials

The infants were familiarized with three exemplars of a novel object across three days. The objects contained rectilinear edges along three sides and jagged borders along the final side and were constructed from wood, measuring 5 inches in width by 14 inches in height by 3 inches in depth. The three familiarization objects were painted blue with red squares, green with white triangles, and purple with white squares (Figure 1). The experimenter wore black raiment and a black, elbow-length, spandex-like glove on the right hand during each familiarization phase. Infants' looking behavior was monitored using a stopwatch.

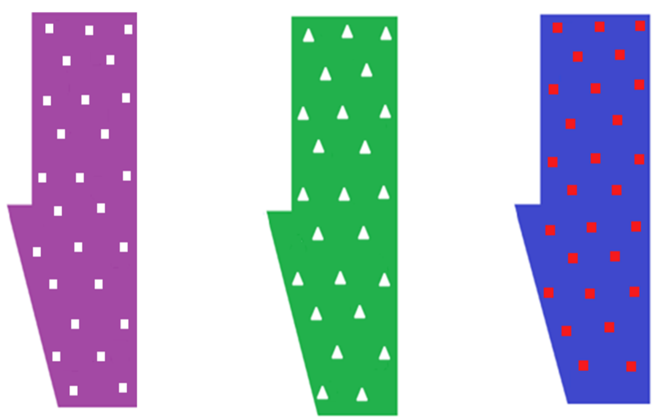

Figure 1. Familiarization stimuli

The display shown during test contained two contiguous objects. One of these objects was a novel instance of the familiarization objects and was adjoined to another object of equal dimensions. The test object and its complement were situated on a makeshift stage to resemble a complete rectangle (Figure 2). The test display measured 14 inches in height by 10 inches in width by 3 inches in depth. The test object maintained the same dimensions as the familiarization objects, differing only in terms of color: the test object was blue with white squares. The adjoining object was painted yellow and did not contain a pattern. The infants viewed either the move-together or the move-apart test-event conditions. Finally, a hand wearing the same black glove used during familiarization lay prone next to the test display.

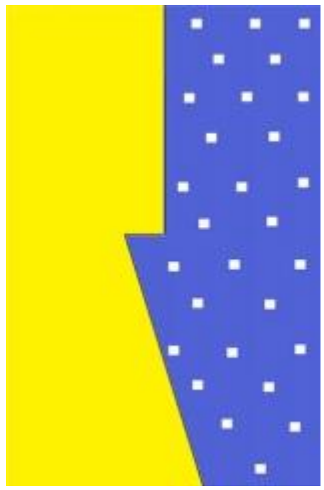

Figure 2. Test stimuli

Procedure

The experiment consisted of a total of 4 phases. The first three phases were familiarization and the final phase was test. The first two familiarization phases, separated by 24 hours, occurred at the infants' homes 30 minutes before their expected nap time. The third familiarization phase occurred at the same time as the first two phases in a playroom in the laboratory 72 hours after Phase 2. During each familiarization phase, infants were seated facing forward on their caregiver's lap 45.7 inches away from the novel exemplar display. At the start of the familiarization phase, the object was covered by a black cloth and an experimenter wearing a black glove was seated behind the object.

At the start of the first familiarization phase on Day 1, the experimenter removed the black cloth from the blue exemplar in order to make the exemplar clearly visible to the infants. The experimenter then lifted the exemplar with the right hand and tilted the object back and forth to maintain infants' looking attention. During this time, the experimenter recorded infants' looking behavior using a stopwatch and held the stopwatch in the left hand. The experimenter showed the object to the infants until they had accumulated 2 minutes of looking time. At the end of the familiarization phase, an experimenter placed a small, non-invasive Mini Mitter Actiwatch on infants' left ankle to record actigraphy data during the nap. The experimenter returned to the infants' home on Day 2 and followed the same procedure as Day 1. The procedure used in Familiarization 3 was identical to the procedures used in Familiarization 1 and 2 with the exception of the familiarization location. Instead of being familiarized to the novel exemplars at their homes, infants were familiarized to the third exemplar in the playroom in the laboratory on Day 3 72 hours after Familiarization 2.

The testing phase (*i.e.*, the fourth phase) immediately followed the third familiarization phase and took place in the testing booth in the laboratory. The test booth consisted of a chair, a projection screen, and a video camera. The test chair was situated approximately 46 inches away from the screen and the video camera used to record the test session was mounted above the projection screen. An experimenter obtained written consent from the caregiver to record the test session prior to testing. The caregiver received instruction to wear opaque glasses to prevent them from seeing the test screen. This component of the experiment was important so to prevent the caregiver from inadvertently biasing the infants' reaction to the test stimuli. At the end of the experiment, experimenters explained the study to the caregivers.

Infants' looking behavior to the test video was recorded from an adjacent test booth by an experimenter. The test stimuli were presented using an Apple Macintosh computer onto which the Habit X 1.0 software was installed. A picture of a bull's eye was presented in the center of the monitor to direct infants' attention to the center. The test-familiarization trial began once the infants attended to the bull's eye. The test-familiarization phase contained the stationary test display and played for 30 seconds. The stationary test display contained a novel exemplar of the familiarization object adjoined to the complementary object as in Figure 2. The test-familiarization trial was designed to allow infants time to interpret the composition of the test display. An experimenter recorded infants' looking behavior during the test-familiarization trial. The picture of the bull's eye reappeared at the end of the test-familiarization trial to redirect the infants' to the monitor for the first test trial.

Immediately following the test-familiarization trial, infants were assigned to one of two test-event conditions where they saw 6 trials of one of the events. These events were the move-apart test event or move-together test event. At the start the move-apart test event, the test display was situated to right of the video screen. A hand wearing a black glove rested 4 inches to the left of the test display. After a 1-second pause, the hand grasped the yellow-painted object and pulled it to the left for approximately 2 seconds. An additional 1-second pause elapsed before the hand pushed the objects back to their original positions (Figure 3A). Finally, the hand resumed its starting position to the left of the test display. In this test-event condition, the yellow-painted object separated from the stationary blue object, indicating that the original test display contained two objects. Each event cycle lasted approximately 8 seconds and was repeated until the infant voluntarily unattended to the video for a consecutive 2 seconds or attended to the video for a cumulative of 60 seconds without attending away for 2 seconds.

The procedure used in the move-together test-event condition was identical to the procedure used in the move-apart test-event condition with the following exception: instead of the yellow-painted object separating from the blue object, the yellow and blue objects moved across the stage in unison, indicating the test display was a contiguous, single-object entity (Figure 3B). Regardless of the test-event condition to which infants were assigned, an experimenter recorded infants' looking behavior during each trial. Each trial ended when infants failed to attend to the test display for 2 consecutive seconds or when the infant attended to the trial for a cumulative of 60 seconds. The infants' attention was directed toward the center of the monitor between each test trial by the picture of the bull's eye.

Figure 3A and 3B. (A) The move-apart test event and (B) the move-together test event

Results

The infants' looking times during test were analyzed by means of an unpaired t-test to compare the looking times of the infants in the move-apart and move-together test-event conditions. Infants looked longer at the move-together test event (M = 20.61 sec) than at the move-apart test event (M = 9.77 sec). In addition, there was a marginally reliable difference between the mean looking times to the move-together and move-apart test events, $t(7) = 9.66$, $p \leq .066$. This analysis reveals that infants segregated the test-display objects at their shared border. Furthermore, this analysis reveals that infants can use their knowledge of the novel exemplars presented during the three familiarization phases to connect their experience across time to create an object category.

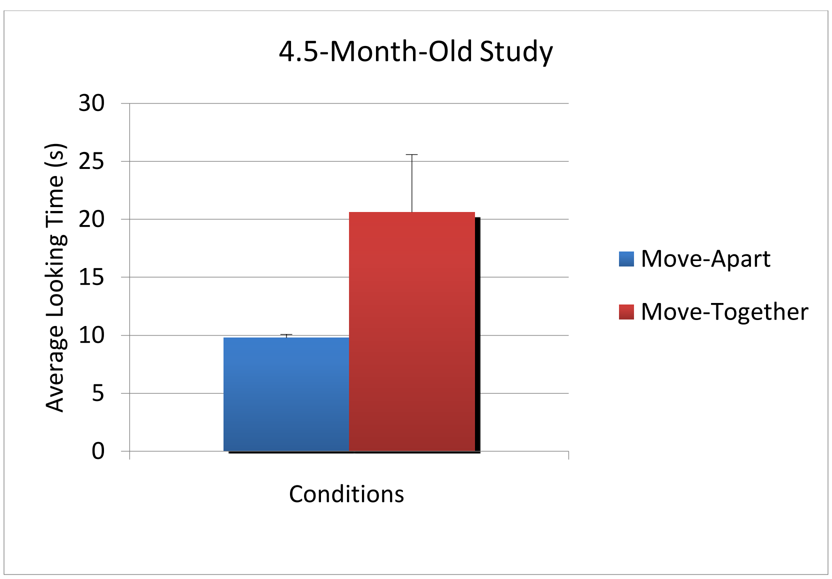

Figure 4: Mean looking times to the two events in both motion-event conditions.

Discussion

The foregoing study examined whether infants can connect their learning experiences with objects over fairly long time intervals to segregate a test display containing two contiguous objects. This question is important to investigate because it has the consequence of demonstrating that infants can use their object-category knowledge to make immediate and long-term inferences about objects in the visual input.

To this end, infants were familiarized to novel object exemplars in their homes over a span of two days and were tested in the laboratory seventy hours following the final home visit. Our results revealed that when sleep immediately followed each brief, two-minute familiarization session, infants looked reliably longer at the move-together test event than at the move-apart test event. This finding is important because it indicates that infants were able to determine that the test display contained two touching objects, which informed their prediction as regards the legality of movement of both exemplars across the stage. In addition, infants appeared to be able to connect their previous experiences with the novel object exemplars, thereby allowing them to segregate a test display containing two objects at their shared border.

It could be argued that infants' longer looking time towards the move-together test event could be explained not as a result of connecting their experiences with the novel objects across time but rather as an artifact of an innate bias toward this motion event. Ensconced in this argument is the suggestion that infants' looking behavior could have been explained by a predisposition for moving displays of greater "contour length" and area (*cf.*, Clearfield & Mix, 1999, 2001; Feigenson, Cary, & Spelke, 2002). Because the adjoined objects in the move-together test event did not change in contour length throughout the course of their movement across the stage than did the objects in the move-apart test event, it is likely that infants were privy to this fact and thus looked longer at it.

This argument, albeit seemingly plausible, does not seem to hold up upon closer scrutiny. For instance, Needham and Baillargeon (1998) have demonstrated that when 4.5-month-old infants are briefly habituated to a display containing a coil adjoined to a rectangular box, infants do not show a preference for either motion event. It appears that when presented in this fashion, infants were uncertain whether the test display comprised one or two units and so, as a consequence, looked equally at both motion events. Our laboratory, using different stimuli and a different design in which infants do not receive prior exposure to the complete test display, has obtained identical results (Gomez, Frye, Bishop, & Peterson, under review). Together, these results call into question the suggestion that infants somehow enjoy a preference for one motion event over another.

A similar argument can be made about the effect of the final familiarization exemplar on infants' looking behavior at the move-together and move-apart test events. It is plausible that infants' performance in the present study is merely a consequence of new learning rather than a result of being able to connect their learning experiences across time. That is to say, it is possible that the presentation of the final familiarization exemplar on the final day of the study was interpreted by the infants as a new learning instance, which could have exerted an influence on how infants choose to respond at test. Even though we believe that the final familiarization object allows infants to connect their learning experiences with all three object exemplars across time, the study's current design makes it difficult to know whether infants were demonstrating evidence for new learning or for connecting their experiences across time.

Our contention, however, is that infants did indeed connect their experiences across time rather than showing evidence for new learning. There are two reasons for this belief. First, in a series of six experiments in which 4.5-month-old infants were familiarized to a single object that was similar but not identical to one of the objects in the test display, Needham (2001) found that infants' looking behavior at test was disrupted by featural differences between the familiarization and test boxes. Infants, in other words, appeared to associate an object's identity with its surface features, and when those surfaces features were made to be confounded or were different at test, they appeared no longer able to recognize the object. Because the features of the third object in our experiment (the colors of the box and squares) were also different from the features of the test object, we believe that infants would be similarly unable to perceive the test display as composed of two adjoined objects because of this difference in features if they were unable to connect their learning experiences across the three familiarization sessions.

The second reason we believe that infants showed evidence for connecting their experiences across time rather than for new learning has to do with the complexity of our stimuli in relation to the lack of complexity of Needham's stimuli. Even though infants in Needham were presented with a test display that contained shape dissimilarity as a freely available potential cue for segregation (*i.e.*, a tall rectangular box adjoining a horizontally positioned cylinder), infants did not seem to use this information to guide their performance at test. Therefore, we do not have reason to believe that when this cue is eliminated, infants would be *more* likely to segregate a test display following exposure to an object similar to one of the test display objects. Indeed, it would be something of a mental leap on the part of the researcher to believe that when perceptual cues like shape dissimilarity are eliminated from a scene, making it such that infants no longer have anything on which to base their segregation performance at test, that they would be even more likely to segregate the test display. It seems more reasonable to conclude that infants would be even less likely to parse a visual scene when perceptual cues are eliminated rather than more likely.

While it is difficult to know for certain whether infants in our experiment would perform similarly to those in Needham's experiment given our use of different and ostensibly more complex stimuli, there are control conditions that can be run to better shed light on this issue that eschew speculation. Perhaps one way to address this issue would be to assign infants to one of two control conditions: in one of these conditions infants would be familiarized to a novel object exemplar immediately before test and in the other condition to two object exemplars across *only* the first two days of the experiment. This design offers the promise of allowing researchers the chance to investigate the discrete influence that the final object has on looking behavior by demonstrating that exposure to the final object before testing does not result in new learning and exposure to the two objects over two days does not result in a connection of both learning experiences leading to the segregation of the test display. Future studies are still needed to address this issue.

One final issue that should be addressed as regards the present investigation involves not having a no-nap condition to which to compare to the nap condition. Despite the fact that our claim here, drawn from the results of the experiment, has been that infants are capable of connecting their learning experiences across time when learning is followed shortly by a period of napping, and although there exists in the infant literature data underscoring the unique role that napping plays on learning (*cf.*, Gomez, Bootzin, & Nadel, 2006), we cannot know for certain whether infants would have performed similarly if learning was instead followed shortly by a period bereft of napping. Our laboratory is currently in the process of collecting these data.

Conclusion

To the extent that the limitations just outlined hold true, additional studies aimed at systematically investigating prior learning, independent of new learning, will greatly enhance our understanding of the unique role played by prior experience on infant-object learning. Be that as it may, the data reported here, in consonance with the configural studies discussed earlier, contribute to the body of research investigating object categorization and object segregation by illustrating that infants as young as 4.5 months of age are not only endowed with the capacity to use configural information in scene segregation after relatively short delays, they appear to have the wherewithal to connect their learning experiences over longer delays.

References

Clearfield, M.W., & Mix, K.S. (1999). Number Versus Contour Length in Infants' Discrimination of Small Visual Sets. *Psychological Science, 10,* 408-411.

Dueker, G.L., Modi, A., & Needham, A. (2003). 4.5-month-old infants' learning, retention and use of object boundary information. *Infant Behavior & Development, 26,* 588-605.

Dueker, G.L., & Needham, A. (2005). Infants' object category formation and use: Real-world context effects on category use in object processing. *Visual Cognition, 12,* 1177-1198.

Feigenson, L., Carey, S., & Spelke, E. (2002). Infants' Discrimination of Number vs. Continuous Extent. *Cognitive Psychology, 44,* 33-66.

Gómez, R.L., Bootzin, R.R., & Nadel, L. (2006). Naps promote abstraction in language-learning infants. *Psychological Science, 17,* 670-674.

Gómez, R.L., Frye, S., Bishop, K., & Peterson, M.A. (2013). Prior experience can override configural cues in scene segregation in 4.5-month-old infants. Tucson, AZ.

Granrud, C.E., Haake, R.J., & Yonas, A. (1985). Infants' sensitivity to familiar size: The effect of memory on spatial perception. *Perception & Psychophysics, 37,* 459-466.

Hayne, H., Gross, J., Hildreth, K., & Rovee-Collier, C. (2001). Repeated reminders increase the speed of memory retrieval by 3-month-old infants. *Developmental Science, 3,* 312-318.

Hildreth, K., & Rovee-Collier. (1999). Decreases in response latency to priming over the first year of life. *Developmental Psychobiology, 35,* 276-290.

Hildreth, K., & Rovee-Collier. (2002). Forgetting functions of reactivated memories over the first year of life. *Developmental Psychobiology, 41,* 277-288.

Kellman, P.J., & Spelke, E.S. (1983). Perception of partly occluded objects in infancy. *Cognitive Psychology, 15,* 483-524.

Kestenbaum, R., Termine, N., & Spelke, E.S. (1987). Perception of objects and object boundaries by 3-month-old infants. *British Journal of Developmental Psychology, 5*, 367-383.

Needham, A. (1999). The role of shape in 4-month-old infants' segregation of adjacent objects. *Infant Behavior and Development, 22,* 161-178.

Needham, A. (2001). Object recognition and object segregation in 4.5-month-old infants. *Journal of Experimental Psychology, 78*, 3-24.

Needham, A, & Baillargeon, R. (1998). Effects of prior experience in 4.5-month-old infants' object segregation. *Infant Behavior and Development*, *21*, 1-24.

Needham, A., Dueker, G.L., & Lockhead, G. (2005). Infants' formation and use of categories to segregate objects. *Cognition, 94,* 215-240.

Rovee-Collier, C. (1999). The Development of Infant Memory. *Psychological Science, 8,* 80-85.

Schmidt, H., Spelke, E.S., & LaMorte, A. (1986) *The development of Gestalt perception in infancy.* Paper presented at the International Conference on Infant Studies, Los Angeles, CA.

Schwartz, K. (1982). Perceptual knowledge of the human face in infancy. Unpublished doctoral dissertation, University of Pennsylvania, Philadelphia, PA.

Termine, N., Hrynick, T., Kestenbaum, Gleitman, & Spelke, E.S. (1987). Perceptual Completion of Surfaces in Infancy. *Journal of Experimental Psychology, 13,* 524-532.