Six-month-old infants' categorization of containment spatial relations

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Abstract

Six-month-old infants' categorization of containment spatial relations was examined in a standard infant categorization task. Infants were habituated to four pairs of objects in a containment relation. They were then tested with four events: one from habituation, one with objects seen during habituation but in an unfamiliar spatial relation, one with novel objects in the familiar containment spatial relation, and one with novel objects in an unfamiliar spatial relation. Infants looked reliably longer at the unfamiliar relative to the familiar spatial relation regardless of object familiarity or novelty, indicating that infants can form a categorical representation of containment. A second experiment demonstrated that infants do not rely on object occlusion to discriminate containment from a support or a behind spatial relation. Together, the results of the current studies indicate that infants are able to recognize a containment relation between two objects from a number of different angles and across different pairs of objects by 6 months of age.

Six-month-old infants' categorization of containment spatial relations

Dating back to Piaget and Inhelder (1967), researchers have posited that children acquire the concept of containment as one of their earliest spatial concepts. Because containment depicts a relatively simple relation between two objects, Piaget and Inhelder argued that infants must learn to recognize containment prior to projective spatial relations, such as one object in front of another, which are more complex because they depict linear order. Similarly, language researchers have cited the cognitive simplicity of containment relative to other types of spatial relations as one reason why young children acquire the spatial term "in" prior to other spatial terms such as "in front of" (Johnston & Slobin, 1979). These claims have been supported by experimental studies which show that toddlers recognize containment prior to either support or occlusion spatial relations, analogous to the order in which they learn to comprehend the corresponding spatial terms of "in", "on", and "under" (Corrigan, Halpern, Aviezer, Goldblatt, 1981; Wilcox and Palermo, 1975). However, research has yet to explore whether very young infants, those in their first six months, can discriminate a containment relation from other types of spatial relations. Although numerous studies have investigated young infants' understanding of containment, these studies have focused on infants' sensitivity to physically impossible events (e.g., Hespos & Baillargeon, 2001a. 2001b) and single events as opposed to categories. The purpose of the current set of studies is to explore other aspects of 6-month-old infants' understanding of containment, namely their ability to discriminate containment from other types of possible spatial relations and their ability to form a categorical representation of the relation.

In a number of studies, Quinn and his colleagues have demonstrated that very young infants have the ability to form a categorical representation of a spatial relation. In one study, Quinn (1994) familiarized 3-month-old infants with a dot in various locations either above or below a bar and then tested them with a dot in a new location on the familiar side of the bar and a dot on the opposite of the bar. Infants looked significantly longer at the dot in a novel spatial relation than at the dot in a new location in the familiar spatial relation to the bar, demonstrating that they discriminated the change in spatial relation between dot and bar. Similarly, Quinn, Norris, Pasko, Schmader, and Mash (1999) found that infants of 6 months form a category of the spatial relation “between” after they were familiarized to a diamond in several locations between two bars. When tested with a diamond outside of the two bars and a diamond in a new location between the bars, they looked significantly longer at the event with a change in spatial relation than at the event with the diamond in the familiar spatial relation, despite its novel location. Thus, by 6 months, infants can discriminate changes in “above” versus “below” and “between” spatial relations. In addition, infants can form a categorical representation of the spatial relation across several locations that maintain the same spatial relation between a shape and a referent object.

However, the ability to form an abstract categorical representation is more difficult for young infants. When familiarized to different shapes (i.e., a dot, an arrow, a triangle) either above or below a dotted bar and tested with novel shapes, infants of 3 months no longer formed a category of above versus below (Quinn, Cummins, Kase, Martin, & Weisman, 1996). Likewise, infants of 6 months no longer form a category of between when familiarized to different shapes between the two bars and tested with novel shapes (Quinn, 2000). Infants' difficulty with this task is not due to having too many shapes presented during familiarization. If tested with one of the many shapes viewed during familiarization, 3-month-old infants can form a category of above versus below (Quinn, Polly, Furer, Dobson, & Narter, in press). Hence, infants are able to form a spatial category across various shapes, if the shapes are familiar, but they have difficulty generalizing the spatial relation to novel shapes. Although 3-month-old infants have difficulty with this task, 6-month-old infants are successful in generalizing the above versus below spatial relation to novel shapes (Quinn et al., 1996). However, infants do not provide evidence until 9 months of age that they can generalize the spatial relation "between" to novel shapes (Quinn, 2000). Thus, 6 months is the youngest age at which infants demonstrate the ability to form an abstract categorical representation of "above" versus "below" across several shapes. If containment is among the early spatial concepts acquired, then infants of 6 months should also be able to form an abstract categorical representation of containment.

Although there is a great deal of research examining very young infants' understanding of containment, the focus of that research has been to outline infants' ability to discriminate between physically possible and impossible events. When viewing live events, infants in their first few months are sensitive to physical violations of containment events (see Caron, Caron, & Antell, 1988; MacLean & Schuler, 1989 for use of videotaped events with older infants). For example, Sitskoorn and Smitsman (1995) report that infants of 6 months look significantly longer at an impossible containment event in which a block was inserted into a box that was too narrow for the block than at a physically possible event. Hence, infants are sensitive to the width of an object relative to its container when discriminating between possible and impossible containment events (see also Aguiar & Baillargeon, 1998, for similar results with 8.5-month-old infants and occluded containment events). In addition, Hespos and Baillargeon (2001a) report that infants as young as 2.5 months of age seem to understand that only containers with open, but not closed, tops can have an object inserted into them. In addition, they seem to understand that objects that are inserted into a container should move when the container is moved, whereas those placed behind a container should remain in place when the container is displaced. Taken together, these studies have amassed considerable evidence demonstrating that very young infants possess a fairly sophisticated understanding of the physical laws governing containment events.

In addition, recent findings reported by Hespos and Baillargeon (2001b) suggest that infants may be able to discriminate containment from other types of events. Whereas 3.5-month-old infants are able to accurately predict the degree to which an object should become occluded when placed behind a screen (Baillargeon & DeVos, 1991), they cannot do the same when an object is inserted into a container (Hespos & Baillargeon, 2001b). In fact, it is not until 7.5 months of age that infants provide evidence that they can take height into consideration when judging the physical feasibility of a containment event. Baillargeon and Wang (2002) report additional findings in which infants are able to reason about a particular variable, such as height, several months earlier if viewing one type of event than when viewing a different type of event. To reconcile these seemingly discrepant findings, Baillargeon and her colleagues propose that infants sort physical events into distinct categories and learn about the physical laws governing each type of event category separately (Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001b).

Given the robust difference in infants' performance across event types (e.g., occlusion versus containment), Baillargeon and her colleagues argue that infants must form categories of events and are capable of doing so within the first few months of life.

The results reported by Hespos and Baillargeon (2001b) and Baillargeon and Wang (2002) provide only indirect evidence that infants can discriminate containment from other types of spatial events and that they can from a category of containment events. However, several studies have demonstrated that infants as young as 9 months of age are able to form a categorical representation of containment. That is, infants can recognize containment when depicted across various pairs of objects and can generalize the relation to novel objects. One motivating factor for investigating infants' categorization of containment has been to explore the relationship between infants' nonlinguistic spatial categories and the language-specific semantic (i.e., meaning) categories formed by toddlers during their acquisition of spatial language. For example, Choi, McDonough, Mandler and Bowerman (2001) explored whether English- and Korean-learning infants of 9, 11, and 14 months form a category of containment that included only tight- or only loose-fit containment events. Interest in the tight- versus loose-fit distinction arises because Korean speakers discriminate linguistically between tight- and loose-fit containment events, grouping tight-fit containment and tight-fit support events into the same semantic category by labeling these events as "kkita." To explore whether the tight- versus loose-fit distinction is one to which all preverbal infants are sensitive, regardless of linguistic background, Choi et al. tested both English- and Korean-learning infants' ability to discriminate between tight-fit and loose-fit containment events. Infants were habituated to different examples of a containment event with a particular type of fit (e.g., tight-fit) and were tested with a novel event with the same degree of fit (e.g., tight-fit) as well as a novel event with a different degree of fit (e.g., loose-fit). Infants in each age group and in each language group (both Korean- and English-learning) looked significantly longer at the familiar than at the novel degree-of-fit containment event, providing evidence that infants can form a category of containment that discriminates between tight- and loose-fit events. Their results are consistent with those reported by Spelke and Hespos (in press) who similarly found that English-learning infants of 5 months can discriminate between tight- and loose-fit containment events.

Similarly, Casasola and Cohen (2002) found that English-learning infants of 10 and 18 months also can form a category of containment. Similar to Choi et al. (2001), their study examined the relation between infants' nonlinguistic spatial categories and the language-specific semantic categories formed by English and Korean speakers. In their study, infants were tested on their ability to form either a category of containment, support, or tight-fit events. However, rather than explore whether infants could form a category of tight-fit containment that excluded loose-fit containment and vice versa, they explored whether infants could group tight- and loose-fit examples of containment into a single category, consistent with the English semantic category of "in". A second group of infants was tested on their ability to form a category of support (which included both tight- and loose-fit support events). In addition, a third group of infants was tested on their ability to form a category of tight-fit (which included both tight-fit containment and tight-fit support, consistent with the Korean semantic category of "kkita"). Although both the 10- and 18-month-old infants provided reliable evidence that they could form a category of containment, neither age group demonstrated the ability to form a category of either support or tight-fit spatial relations. Hence, their results suggest that infants acquire the ability to form a category of containment relations prior to support or tight-fit spatial relations.

Taken together, these experimental findings provide reliable evidence that infants as young as 9 months of age can form a categorical representation of containment events. On the one hand, the findings reported by Choi et al. (2001) demonstrate that infants can form a category of containment that consists solely of one type of containment (e.g., tight-fit). On the other hand, the findings reported by Casasola and Cohen (2002) demonstrate that English-learning infants can form a category of containment that includes both types of events. One question is whether infants younger than 9 months can form a category of containment and whether they would group tight-fit and loose-fit containment into the same spatial category of containment relations. Compared to infants of 9 months, infants of 6 months have not yet begun to comprehend many linguistic terms and are less likely than older infants to be influenced by their linguistic environment. To explore young infants' concept of containment, two studies examining 6-month-old infants' ability to discriminate containment from a different spatial relation are presented. The first of these studies explores infants' ability to form a categorical representation of containment across various pairs of objects. The second study explores infants' ability to discriminate containment from other types of spatial events.

Experiment 1

In the current study, infants of 6 months were tested on their ability to form a categorical representation of containment. In order to compare the ability of 6-month-old infants to that of older infants, infants were tested in the same spatial categorization task as the 10- and 18-month-old infants in Casasola and Cohen (2002). In this procedure, infants are habituated to four events, each of which depicts a hand placing an object in a containment spatial relation to a second object. Following habituation, infants view test events that present changes in either the spatial relation only (the objects are those seen previously during habituation), the objects only (the spatial relation is the same as that viewed throughout habituation), or a change in both the objects and the spatial relation. If infants are able to discriminate containment from an unfamiliar spatial relation (e.g., support), then infants are expected to look significantly longer at the novel relative to the familiar spatial relation when seen between familiar objects. If infants are able to form a category of containment, they are expected to look significantly longer at the unfamiliar spatial relation relative to the familiar spatial relation even when each spatial relation occurs with novel objects. Finally, if infants are unable to attend to the spatial relations presented, then they are expected to respond only to changes in the objects.

Method

Participants. Fifteen, full-term infants of 6 months (± 2 weeks), eight males and seven females, participated in the study. All of the parents reported that their infants did not have a history of auditory or visual impairment. Data collected from an additional 13 infants were not used in the final sample: 2 (1 boy, 1 girl) did not complete testing due to fussiness, 5 (1 boy, 4 girls) did not meet the habituation criterion (described below), 3 (1 boy, 2 girls) heard languages other than English in the home, and 3 (2 boys, 1 girl) were excluded due to an experimental error.

Names of infants and their parents were obtained through the state health department. Parents were informed of the study through a letter sent in the mail. They were subsequently telephoned and invited to participate in the study. All infants were given a t-shirt in appreciation.

Stimuli. The stimuli were six pairs of colorful objects, all of which were either toys or household objects. One pair of objects consisted of a wicker basket and a stuffed animal that resembled a monkey. The monkey was primarily blue with a polka dot stomach, a yellow face, and patterned feet (one foot was yellow-striped and the other was green-checkered). A second pair of objects consisted of a red candle in the shape of a gingerbread man that could be inserted inside a silver cookie cutter of the same shape. A yellow block and a green peg were used as a third pair of objects. Two hollow cars comprised the fourth pair of objects. One car was larger and red whereas the second car was smaller, blue and could be placed in the larger car when inverted. A multi-colored cup without handles and a white dog bowl with colorful prints along its side were used as a fifth pair of objects. Finally, stackable turtles and a pole were used as a sixth pair of objects. Each turtle contained a shell of a distinct color with large polka dots of a contrasting color. The pole was clear with a red corkscrew inside and was attached to a yellow base. The turtles were designed to be stacked on top of one another on the pole.

Dynamic events were created with each pair of objects. At the beginning of the event, the two objects in a pair were placed side by side, with the smaller object in the pair located to the left of the larger object (also known as the referent object). After one second, a hand appeared from the left, lifted the smaller object and placed it either in or on the referent object. The hand then retreated and the two objects were depicted in their spatial relation for an additional second. Containment events were depicted by the following five events: 1) the monkey in the wicker basket, 2) the red candle in the cookie cutter, 3) the peg in the yellow block, 4) the small blue car in the inverted, large red car, and 5) the cup in the dog bowl. Support events (used for the test trials) were created with the following two events: 1) the peg on the yellow block and 2) the turtle on the pole (the other two turtles were already stacked on the pole). It is worth noting that the containment events with the red candle and silver cookie cutter and the green peg with the yellow block as well as the support event with the turtles depicted a tight-fit relation between the objects. The red candle fit tightly in the cookie cutter, the green peg was snug when inserted in the yellow block and the turtle was designed to fit exactly on the pole and the other turtles.

In addition to the events used for the habituation and test phase of the experiment, an event was created for a pretest trial. The event featured a bright pink, stuffed pig that stood in the center of the scene. A hand entered from the left, lifted the pig and moved it as though walking, first to the left and then to the right prior to returning the pig to its original location in the center of the scene.

The events were filmed with a Sony Hi-8 digital video camera and were then transferred to a Macintosh G4 computer where they were converted to QuickTime movies. Each event had a duration of approximately 6 s, but was cycled five times without pauses to create trials with a duration of approximately 30 s in length.

<u>Apparatus</u>. Adjoining experimental and control rooms were used to conduct the experiment. In the experimental room, a 20-inch color monitor was situated on a table approximately 77 cm from the floor. The height of the table was designed so that the monitor would be at eye-level for infants who were seated on their parent’s lap approximately 125 cm from the monitor. The experimental room was sound attenuated to

minimize the possibility of any external sounds distracting infants during testing. Similarly, low lighting and a black, wooden frame that surrounded the monitor from floor to ceiling were used in order to focus infants' attention on the monitor. A small, 6.5-cm opening in the frame below the monitor was created so that a Panasonic camcorder lens could be focused on the infant. This camcorder was linked to a 14-inch black-and-white monitor in the control room that was used by the experimenter to observe and record infants' looking times to the events. A VCR was also linked to this second monitor so that each infant could be videotaped, allowing a second observer to record infant looking times offline for inter-observer reliability.

A Macintosh G4 in the control room and a specially designed habituation program, Habit 2000 (Cohen, L. B., Atkinson, D.J. & Chaput, H. H., 2000), were used to conduct the experiment. The program presented the events on the monitor in the experimental room, controlled the order in which the events were presented, allowed the experimenter to record infants' looking time to the events during the testing session, and determined when the infant had reached the habituation criterion.

Procedure. Infants were seated in their parent's lap in front of the monitor in the experimental room. Parents were instructed to not talk or direct their child's attention during the testing session. To start the experiment, the experimenter began the Habit program to play an attention-getter, a flashing, chiming, green circle on the 20-inch monitor. Once an infant attended to the monitor, the experimenter depressed a key on the computer keyboard to present an event. The experimenter depressed a second key on the computer keyboard for as long as the infant attended to the event. Infants were required to watch the event for a minimum of two, continuous seconds for a look to count as a trial. This requirement ensured that infants attended to the events long enough to view the first object placed in its spatial relation to the referent object. The event (and its repetitions) played for as long as infants attended to the event (maximum 30 seconds) or until they looked away for more than one continuous second. At the end of a trial, infants' attention was redirected to the monitor by the attention-getter, which was replaced by an event at the beginning of the next trial.

The first trial of the experiment was a pretest that presented the event with the pink pig. The purpose of this preliminary trial was to familiarize infants to the testing room and procedure prior to beginning the habituation phase of the experiment. Following the pretest, the habituation phase of the experiment began. During habituation, all infants viewed the same four containment events: the candle in the cookie cutter, the peg in the yellow block, the car in the larger car, and the monkey in the basket. These events were presented in random order within a block of four trials. In order to habituate, infants had to demonstrate a 50% decrease in looking time across three consecutive trials from their looking time during the first three trials of habituation. Once infants reached this habituation criterion, they viewed four test trials. One test trial presented an event viewed during habituation, the candle placed in the cookie cutter. Infants also viewed three additional test trials. One test trial presented a familiar pair of objects in a novel spatial relation, the peg on the yellow block (infants had viewed the peg being placed <u>in</u> the block during habituation). Another test trial presented a novel pair of objects in the familiar containment spatial relation, the cup being placed <u>in</u> the dog bowl. A fourth test trial presented a novel pair of objects in a novel spatial relation, the turtle being placed <u>on</u> the other turtles and the pole. For all infants, the familiar test event was presented as the first test trial. The order in which infants viewed the familiar objects-novel relation, the novel objects-familiar relation, and the novel objects-novel relation test trials was counterbalanced across participants. Inter-observer reliability was determined by calculating the correlation between on- and off-line looking time for 8 randomly chosen infants. These correlations ranged from .990 to .999 with an average of .997.

To ensure that infants did not have an a priori preference for any of the four test events, a separate sample of 8 infants viewed each test event across two blocks of trials. The order in which infants viewed the events was counterbalanced across participants and gender. A 2 Sex (male vs. female) x 4 Event (candle in vs. cup in vs. peg on vs. turtle on) x 2 Trial Block (block one vs. block two) mixed-model analysis of variance (ANOVA) did not yield any significant main effects or interactions. In particular, there was no significant main effect for Event, F (3, 18) = .62, p = ns. Infants looked approximately the same duration to the candle-in event (M = 10.71 s, SD = 8.88 s), the cup-in event (M = 11.48 s, SD = 9.07 s), the peg-on event (M = 13.07 s, SD = 10.37 s), and the turtle-on event (M = 13.43 s, SD = 9.83 s). Thus, there was no evidence for an a priori preference for a particular pair of objects or for a particular type of event (e.g., support).

Results

The first analysis compared infants' looking times to the first three trials of habituation to their looking time to the familiar test trial. The purpose of this analysis was to explore whether infants demonstrated a reliable decrease in looking time from the beginning of habituation to the start of the test phase, indicating that they recognized the familiar test event as one of the events viewed during habituation. Infants' looking times were analyzed in a 2 Sex (female vs. male) x 2 Trials (average of the three habituation trials vs. familiar test trial which presents an event seen during habituation) mixed-model Analysis of Variance (ANOVA). The analysis yielded significant main effects for Sex, F (1, 13) = 5.02, $p < .05$, due to significantly longer looking times by the male infants (M = 11.34 s, SD = 9.12 s) than the female infants (M 6.91 s, SD 4.50 s). There also was a significant main effect for Trials, F (1, 13) = 30.83, $p < .001$, indicating that infants demonstrated a significant decrease in looking time from the beginning of habituation (M = 14.35 s, SD = 7.62 s) to the familiar test trial (i.e., the candle in the cookie cutter event, M = 4.21 s, SD = 2.38 s). The analysis did not yield any other significant main effects or interactions. The lack of a Sex x Trials interaction indicates that, even though male infants attended to the events longer than the females overall, both genders provided reliable decrease in looking time to the habituation event presented as the familiar test trial.

The next analysis examined infants' looking time to the four test events. Infants' looking times were analyzed in a 2 Sex x 2 Object Pair (familiar vs. novel objects) x 2 Spatial Relation (familiar vs. novel spatial relation). The analysis yielded a significant main effect for Object Pair, F (1, 13) = 5.10, $p < .05$, as well as for Spatial Relation, F (1, 13) = 7.18, $p < .05$. Infants looked significantly longer at the two test trials that presented a novel pair of objects (M = 8.89 s, SD = 6.79 s) than at the two test trials that presented a familiar pair of objects seen during habituation (M = 6.54 s, SD = 5.45 s). Likewise, infants looked significantly longer at the two test trials which presented the novel spatial relation of support (M = 9.68 s, SD = 7.39 s) than at those test trials which presented the familiar habituation spatial relation of containment (M = 5.75 s, SD = 3.99 s). These results indicate that infants discriminated reliably between the familiar and novel objects as well as between the familiar containment relation and the unfamiliar support relation. In addition, the analysis did not yield a significant Object Pair x Spatial Relation interaction. As Figure 1 indicates, infants demonstrated significantly longer looking times at the novel than at the familiar spatial relation both when the objects were familiar, $F(1, 13) = 14.41$, $p < .01$, and when they were novel, $F(1, 13) = 7.17$, $p < .05$. This pattern of results indicates that infants did not respond to a novel spatial relation between familiar objects only, but rather were able to recognize the containment relation as familiar even when depicted by novel objects. That is, infants demonstrated the ability to generalize the containment relation to new examples, providing evidence that they had formed a categorical representation of the spatial relation.

Insert Figure 1 about here

Discussion

The results from Experiment 1 indicate that 6-month-old infants can form a categorical representation of containment. After viewing a containment relation between four different pairs of objects, infants responded to this spatial relation as familiar relative to an unfamiliar spatial relation (i.e., support). In addition, infants reliably discriminated between the familiar and novel spatial relation despite object familiarity or novelty. Because infants demonstrated the ability to generalize the containment relation to a novel example of the spatial category (i.e., the novel objects-familiar relation trial), infants responded in a manner consistent with having an abstract representation of the containment spatial relation. In other words, infants demonstrated that they had formed a spatial category of containment.

However, an alternate, and arguably more parsimonious, explanation could account for the obtained pattern of results. Possibly, infants discriminated among the test events on a more basic perceptual level rather than on the cognitive level of spatial categorization. Specifically, infants may have responded to changes in the appearance of the object when the object was inserted into the referent object. Conceivably, in each habituation event, infants may have attended only to the fact that the first object became partially occluded by the referent object when moved by the hand. If so, infants may have looked significantly longer at the events with the support (unfamiliar) spatial relation than the events with the containment spatial relation because the first object no longer became partially occluded as it had during habituation. To explore this alternate explanation, an additional experiment was conducted.

Experiment 2

Experiment 2 was designed to explore whether infants rely on changes in the appearance of an object to discriminate between those events with a containment spatial relation and those events with a support relation. Thus, the current study investigated the degree to which infants' concept of containment is dependent on the partial occlusion of one object by a referent object. Infants in Experiment 2 were habituated to a single containment event. They were then tested with events that presented a change in either the appearance of the first object (i.e., the object moved by the hand), a change in the spatial relation, or a change in both the appearance of the first object and the spatial relation. For example, in one test event, the object was placed in the familiar containment relation to the referent object, but the object no longer changed in appearance when inserted into the referent object because the event was filmed from a high angle (i.e., a bird's eye view). Hence, the object remained fully visible, but was clearly contained by the referent object. In a second test event, also filmed at a high angle, infants viewed the first object placed behind the referent object so that the object was as occluded as it was at the end of the habituation event. Because this event was also filmed from a high angle, it was clear that the object was not contained, but rather was behind the referent object. An additional test event, filmed from the same high angle as the containment and behind events, demonstrated a support relation between the first object and the referent object, an event that depicted a change in both the appearance of the first object and the spatial relation.

If infants rely on changes in the first object's appearance to discriminate among the test events, then they should respond to the high-angle behind event as familiar, because the first object becomes as occluded in this event as it does during habituation. In addition, infants should respond to the high-angle containment and high-angle support events as novel because the first object no longer becomes partially occluded, a change from habituation to test. On the other hand, if infants in Experiment 1 were responding to a change in spatial relation, then infants should respond both to the behind and support events as novel and respond to the high-angle containment event as familiar. Thus, the test events in the current study will address the basis on which infants attend to containment events.

Method

Participants. Twenty-four, full-term infants of 6 months (± 2 weeks), twelve males and twelve females, participated in the study. Infants were reported by their parents to have no history of auditory or visual impairment. Data from an additional 38 infants were not used in the final sample for the following reasons: 10 (3 boys, 7 girls) became fussy during the testing session and did not complete the study, 11 (6 boys, 5 girls) did not meet the habituation criterion (described in Experiment 1), 2 (1 boy, 1 girl) were premature, 3 (1 boy, 2 girls) were excluded because of an experimental error, 5 (4 boys, 1 girl) failed to attend to the stimuli, and 7 (4 boys, 3 girls) became fatigued during the test trials or were not fully habituated when presented with the test stimuli.

Names of infants and their parents were obtained through the state health department. Parents were informed of the study through a letter sent in the mail. They were subsequently telephoned and invited to participate. All infants were given an infant T-shirt or "sippy" cup in appreciation for their participation. None of the infants recruited for the current study had participated in Experiment 1.

Stimuli. The stimuli were three pairs of objects used in Experiment 1: the monkey and the basket, the two hollow cars, and the cup and dog bowl. For the habituation phase of the experiment, dynamic containment events were created that were identical to those used in Experiment 1. These events were filmed from the same eye-level angle as the events in Experiment 1. Consequently, the first object became partly obscured when placed in the referent object. For the test phase, new events were filmed from a high (or bird's eye) angle. For each pair of objects, a high-angle containment, a high-angle behind, and a high-angle support event was created. The sequence of events was identical as those in the habituation event (as well as to the habituation and test events of Experiment 1). The objects were first depicted side by side, with the smaller object to the left of the larger, referent object. After one second, a hand entered, lifted the first object and placed it in a particular spatial relation to the referent object. The hand then retreated so that the objects were depicted in their spatial relation for an additional second. In the high-angle containment event, the first object remained visible when placed in the referent object due to the high-angle view. In the high-angle behind event, the hand placed the object directly behind the referent object. Despite the high angle, the first object in these events remained as occluded as the object had been at the end of the habituation containment event. In the high-angle support event, the object remained fully visible when placed on the referent object. The events were filmed with a Sony Hi-8 digital video camera, transferred to a Macintosh G4 computer, and converted to QuickTime movies. Each event lasted approximately 6 s and was cycled five times without pauses to create trials with an approximate duration of 30 s.

Apparatus. The apparatus was identical to that described in Experiment 1.

Procedure. The procedure for the current experiment was similar to that used in Experiment 1 with the following exceptions. Infants were randomly assigned to view a single eye-level angle containment event during habituation (e.g., car-in-car, cup-in-bowl, or the monkey-in-basket containment event). Once infants reached the habituation criterion by demonstrating a 50% decrease in looking time across three consecutive trials from their looking time during the first three trials of habituation, they were presented with four test trials. All test trials used the same two objects the infant had seen during habituation. For one test trial, infants viewed the front-angle containment event presented during habituation. In an additional test trial, infants viewed the high-angle containment event. Recall that in this event, both the objects and the spatial relation were familiar, but the degree of object occlusion differed from the habituation event. In a third test trial, infants viewed the high-angle behind event, an event with a novel spatial relation but the same degree of object occlusion as the habituation containment event. In a fourth test trial, infants viewed the high-angle support event in which a change in both the spatial relation and the degree of object occlusion was presented.

For all infants, the familiar containment event presented during habituation was presented as the first test trial and the high-angle support event was presented as the last test trial. The order in which infants viewed the high-angle containment and high-angle behind events was counterbalanced across participants. Inter-observer reliability was determined by calculating the correlation between on- and off-line looking times for 10 randomly chosen infants. These correlations ranged from .989 to .999 with an average of .997.

Results

The first analysis was conducted to explore whether infants demonstrated a reliable decrease in looking time from the beginning of habituation to the beginning of the test trials when infants viewed the habituation event as the familiar test trial. Infants' looking times were analyzed in a 2 Sex (female vs. male) x 2 Trials (average of the first three habituation trials vs. the familiar test trial) mixed-model ANOVA. The analysis yielded a significant main effect for Trials, $F(1, 22) = 57.34$, $p < .001$. Hence, infants demonstrated a reliable decrease in looking time from the start of habituation ($M = 16.39$ s, $SD = 7.25$ s) to the time when this event was presented as the first test trial ($M = 5.65$ s, SD = 4.06 s). These results indicate that infants demonstrated a reliable decrease in looking time to the habituation event by the time they viewed this event during the test phase of the experiment.

The next analysis explored whether infants discriminated among the test events on the basis of a change in spatial relation (i.e., from containment to behind or from containment to support) or on the basis of a change in object occlusion (i.e., from occluded to visible). Infants' looking times during the test trials were analyzed in a 2 Sex x 3 Habituation Event (Car In vs. Cup In vs. Monkey In) x 2 Spatial Relation (Familiar Containment vs. Unfamiliar Spatial Relation) x Object Appearance (Occluded vs. Visible) mixed-model ANOVA. The analysis yielded a significant main effect for Spatial Relation, F (1, 18) = 13.86, $p < .005$. As can be seen in Figure 2, infants discriminated reliably between those test events with the familiar containment relation (M = 6.19 s, SD = 4.44 s) and those test events with an unfamiliar spatial relation (M = 9.72 s, SD = 8.28 s). As is evident in Figure 2, the analysis did not yield a significant main effect for Object Appearance, F (1, 18) = .14, p = ns. Infants looked approximately the same duration at those test events with visible objects (M = 8.15 s, SD = 6.75 s) than at those test events with occluded objects (M = 7.75 s, SD = 6.99 s). Planned comparisons reveal no reliable difference in infants' looking time to the familiar containment habituation event (M = 5.65 s, SD = 4.06 s) and the test event that depicted the containment event from a high angle (M 6.73 s, SD = 4.82 s), F (1, 18) = .63, p = ns. Thus, there was no evidence to indicate that infants were responding to the events on the basis of changes in the appearance of the first object. In contrast, infants did demonstrate a reliable increase in looking time to the test event which presented the object behind the referent object (M =

9.85 s, SD = 8.61 s) relative to the familiar containment test event, $F(1, 18) = 8.93$, $p < .005$. Likewise, infants looked significantly longer at the test support event (M = 9.58 s, SD = 8.12 s) than at the familiar containment test event, $F(1, 18) = 7.82$, $p < .01$. This pattern of results clearly indicates that infants did not respond to the test events on the basis of changes in object appearance, but rather on the basis of a change in the spatial relation presented.

Insert Figure 2 about here

Discussion

The results of the current study indicate that infants discriminated between those events that presented a containment spatial relation and those that presented a novel spatial relation (i.e., behind or support). In contrast, infants did not look significantly longer at those events that no longer presented a partially occluded object, unless the event also presented a change in the spatial relation. More specifically, when infants viewed the high angle containment test event, they responded to this test event as familiar despite the fact that the first object changed in its degree of occlusion relative to the containment event seen during habituation. In contrast, when infants viewed the behind as well as the support event, they responded to these events as unfamiliar. These results provide clear evidence that the infants in Experiment 1 did not discriminate among the test events based on changes in the appearance of the objects. Rather, the infants were responding to the distinction between a familiar containment event and a novel spatial relation. In addition, the current findings suggest that infants do not rely on changes in an object's appearance as a cue for recognizing a containment spatial relation between two objects. Rather, infants have the ability to recognize the spatial relation from a number of different angles.

General Discussion

The current studies explored various aspects of 6-month-old infants' understanding of a containment spatial relation. In Experiment 1, infants were tested on their ability to form a categorical representation of the spatial relation. After being habituated to a containment relation between four different pairs of objects, infants demonstrated that they could discriminate the containment relation from the unfamiliar (support) relation, regardless of their level of familiarity with the objects depicting the spatial relation. Because infants were able to generalize the containment relation to a novel pair of objects and respond to this relation as familiar relative to the unfamiliar support relation, infants responded in a manner consistent with having formed a spatial category of containment. In Experiment 2, infants were tested on their ability to recognize a containment relation when the first object did not become obscured upon insertion into the referent object. Despite changes in the angle of the event and changes in the appearance of the contained object from habituation to test, infants still responded to the spatial relation of containment as familiar and discriminated this spatial relation from other types of spatial relations (i.e., support and behind). Together, the findings from the two experiments provide strong evidence that infants of 6 months can recognize a containment relation between two objects and can form a categorical representation of that spatial relation. In particular, the results of Experiment 2 rule out the possibility that infants' recognition and categorization is based on simple perceptual discriminations, such as changes in the appearance of an object, but rather is rooted in recognizing the actual containment relation between two objects.

The current findings demonstrate that, in addition to their ability to form an abstract categorical representation of above versus below across a number of different shapes (Quinn et al. 1996), infants can also form a category of containment across a number of different objects by 6 months of age. What is particularly impressive about the current results is infants' categorization of containment despite the complexity of the stimuli and the number of objects used. Rather than use static images of a simple shape, such as a triangle, in relation to the same referent object, infants in the current study viewed dynamic events with four realistic objects, each in relation to a different referent object. Hence, the number of objects to which infants were exposed was much greater in the current study than in previous reports (e.g., Quinn et al., 1996) and the use of dynamic events rather than fixed images also added complexity to the stimuli. The 6-month-old infants nevertheless formed a category of containment. In contrast, infants of 6 months have difficulty forming a spatial category of "between" when asked to categorize the relation across different shapes (Quinn, 2000). Infants have difficulty doing so even though the stimuli consist of static images of shapes, much simpler in complexity than the objects used in the current study. Hence, infants' ability to form a categorical representation of containment is an earlier developmental achievement than their categorization of other spatial relations, such as between (Quinn, 2000) or support (Casasola & Cohen, 2002). Hence, infants acquire the ability to recognize and categorize a containment relation within the first six months, lending support to Piaget and

Inhelder's (1967) argument that infants acquire containment as one their earliest spatial concepts.

When compared to the findings reported by Spelke and Hespos (in press) and Choi et al. (2001), the current studies appear to present somewhat contradictory results. Recall that Hespos and Spelke (in press) found English-learning infants of 5 months discriminate reliably between tight- and loose-fit containment events. Likewise, Choi and her colleagues report that both Korean- and English-learning infants of 9 to 11 months of age can form a category of tight-fit containment events that excludes loose-fit containment events (and vice versa). In contrast, the six-month-old infants in the current study formed a category of containment that included both tight- and loose-fit containment events. If infants are sensitive to the distinction between tight- and loose-fit containment, why then did they form a category of containment that included both tight- and loose-fit examples of the spatial relation? The differing results between the current study and those reported by Spelke and Hespos and Choi et al. can be reconciled if one considers findings from infants' categorization of objects. Quinn, Eimas, and Rosenkranz (1993) as well as Oakes, Coppage, and Dingel (1997) have demonstrated that the types of object categories infants form differ depending on the types of exemplars to which they are familiarized. Specifically, they found that infants create a more exclusive category of objects when familiarized to a set of highly similar objects, but form a more inclusive category when familiarized to set of variable objects. For example, Quinn et al. found that if 3-month-old infants were familiarized with cats, they would respond to a novel dog as unfamiliar (i.e., not pertaining to the category of cats) relative to a novel cat. However, if infants were familiarized to dogs, which can be highly variable to one another, infants did not discriminate reliably between a novel dog and a novel cat, presumably because the cat could fit within the same category as dogs. Similarly, Oakes et al. found that 10- and 13-month-old infants formed an exclusive category of land animals, one that did not include sea animals, when familiarized with a set of land animals that were perceptually very similar. In contrast, if familiarized to a set of land animals that were highly variable in appearance, infants formed a more inclusive category of animals that included both land and sea animals. Thus, when learning to form a particular category of objects, infants are influenced by the perceptual variability of the objects presented during familiarization and will form more inclusive categories, one that includes different types of animals, if the familiarization examples are more perceptually variable.

In relation to the findings reported by Quinn et al. (1993) and Oakes et al. (1997), the current findings can be viewed as consistent with those reported by Spelke and Hespos (in press) and Choi et al. (2001). It seems to be the case that infants' categorization of spatial relations is similarly influenced by the variability of exemplars to which they are exposed during familiarization. In the experiment conducted by Choi et al. as well as the one conducted by Spelke and Hespos, the categorization tasks were structured so that infants would form a more exclusive category of containment (i.e., one that discriminates between tight- versus loose-fit containment). In the current study, the task required infants to form a more inclusive category of containment (i.e., one that ignores the distinction between tight- and loose-fit). Thus, in each case, infants are forming the type of spatial category presented in the task. The current study simply demonstrates that infants are able to ignore the distinction between tight- and loose-fit in order to form a more inclusive and variable category of containment. However, one question that cannot be answered with the current findings is the extent to which infants' categorization of containment would normally include both tight- and loose-fit containment events in the same spatial category. Unclear as well is whether infants came to the task with a pre-existing category of containment or whether they acquired the category during the course of the experiment. The results of the current study as well as the results reported by Choi et al. only indicate the types of spatial categories that infants are capable of forming, which may or may not be consistent with the types of categories infants possess. Nevertheless, the results of these studies, including the current results, suggest that those processes underlying infants' categorization of objects may guide also their categorization of spatial relations.

In addition, the current findings lend direct support to the argument posited by Hespos and Baillargeon (2001b) as well as Baillargeon and Wang (2002) that infants sort events into categories when learning to reason about the physical feasibility of an event. Stronger support for Baillargeon's claims could be provided if infants younger than 6 months of age also demonstrate the ability to form a categorical representation of containment. Nevertheless, consistent with findings reported by Hespos and Baillargeon (2001a), the current findings demonstrate that infants can recognize the difference between containment and occlusion (behind) events and lend support to the claim that infants can sort these events into different categories. One important contribution of the current studies is that infants are able to discriminate between containment and other types of events, such as occlusion (behind) and support, when viewing videotaped rather than live demonstrations of the events. Thus, infants' ability to differentiate between containment and occlusion is not restricted to the presentation of live events.

What is the relation between infants' expectations of physical events and their ability to form a categorical representation of the spatial relations depicted in these events? Are the learning mechanisms that are in place to guide infants in acquiring physical knowledge of these types of events the same or different than those in place for the categorization of these types of events? Quinn has argued for different developmental trajectories in the acquisition of spatial concepts. His research has demonstrated that infants acquire the ability to form a category of above versus below prior to the time that they acquire the ability to form a category of between (Quinn, 1994; Quinn et al., 1999). For each type of spatial category, Quinn argues that infants undergo a specific to abstract progression in which they learn to recognize the relation between familiar objects prior to gaining the ability to recognize the relation independent of specific objects. The argument outlined by Quinn is not so different than the argument outlined by Baillargeon and her colleagues (Baillargeon & Wang, 2002). Like Quinn, Baillargeon has argued that infants learn about different types of events on an individual basis and undergo a developmental progression whereby infants learn, with each type of event, those physical variables that are most relevant for determining the physical possibility of the event. At present, it is not possible to ascertain whether those processes that guide infants' acquisition of the physical laws governing events are the same processes that guide their ability to form spatial categories. However, the parallels in developmental change between the two aspects of infant cognition are apparent, raising the possibility that perhaps the same sorts of mechanisms are at play. Future research on infant spatial categorization should explore whether infants younger than six months can form a category of containment and whether they can also form other types of categories, such as a spatial category of the relation behind. Exploring categorization in younger infants will also make it possible to explore the relation between the development of infants' understanding of physically possible and impossible events and their categorization of these events.

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Figure Captions

Figure 1. The looking times with standard error of the 6-month-old infants to each test trial in Experiment 1.

Figure 2. The looking times with standard error of the 6-month-old infants in Experiment 2 to the familiar containment spatial relation versus novel spatial relationship, when the objects were occluded and when they were visible.

Figure 1

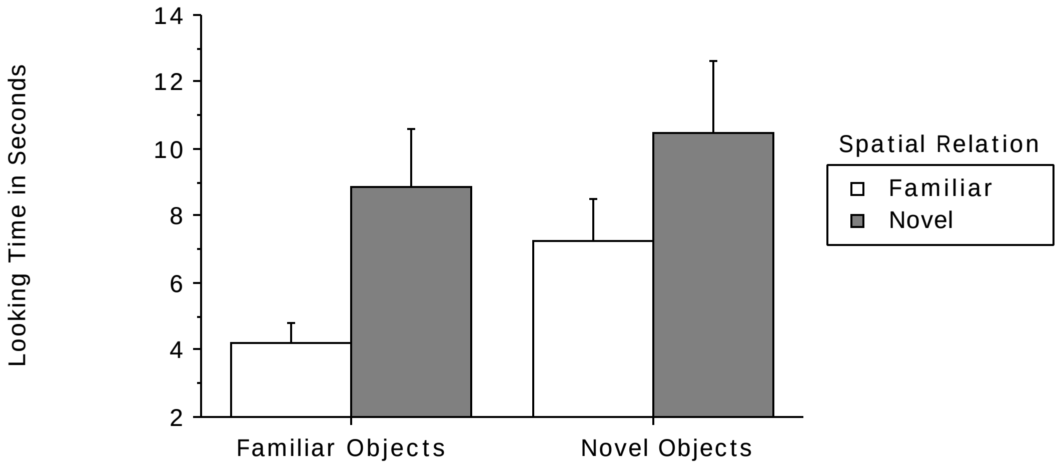
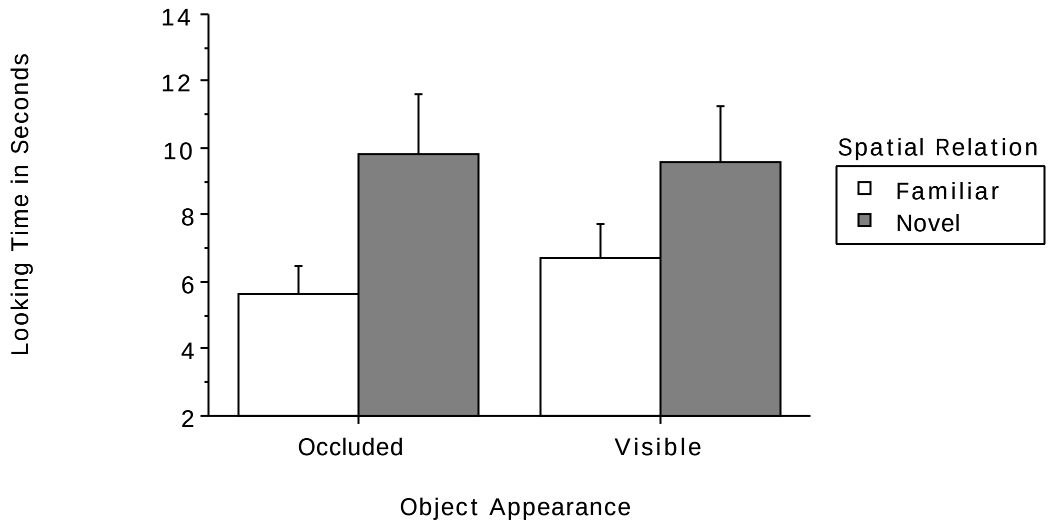

Looking Time in Seconds
14
12
10
8
6
4
2
Familiar Objects
Novel Objects
Spatial Relation
Familiar
Novel

Figure 2


14
12
10
8
6
4
2
Looking Time in Seconds
Occluded
Visible
Object Appearance
Spatial Relation
Familiar
Novel