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Six-Month-Old Infants' Categorization of Containment Spatial Relations

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Abstract

Six-month-old infants' ability to form an abstract category of containment was examined using a standard infant categorization task. Infants were habituated to 4 pairs of objects in a containment relation. Following habituation, infants were tested with a novel example of the familiar containment relation and an example of an unfamiliar relation. Results indicate that infants look reliably longer at the unfamiliar versus familiar relation, indicating that they 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 indicate that by 6 months, infants can recognize a containment relation from different angles and across different pairs of objects.

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 before 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* before other spatial terms such as *in front of* (Johnston & Slobin, 1979). These claims have been supported by experimental studies that show that toddlers recognize containment before 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 & Palermo, 1975). However, research has yet to explore whether very young infants, those in their first 6 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.

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In several 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 6-month-old infants 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, 3-month-old infants no longer formed a category of above versus below (Quinn, Cummins, Kase, Martin, & Weisman, 1996). Likewise, 6-month-old infants no longer form a category of between when familiarized to different shapes between the two bars and tested with novel shapes (Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003). 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, 2002). 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 between spatial relation to novel shapes (Quinn et al., 2003). Thus, 6 months is the youngest age at which infants demonstrate the ability to form an abstract categorical representation across unfamiliar shapes and so far have demonstrated this ability only with respect to the spatial relations of above versus below. If containment is among the early spatial concepts acquired, one question is whether 6-month-old infants also can 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) reported that 6-month-old infants 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) reported 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) reported 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 proposed 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 vs. containment), Baillargeon and her colleagues argued 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 an abstract 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-fit 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 familiarized 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 an abstract category of containment that discriminates between tight- and loose-fit events. Their results are consistent with those reported by Spelke and Hespos (2001) who similarly found that English-learning infants of 5 months discriminate reliably between tight- versus loose-fit containment events.

Similarly, Casasola and Cohen (2002) found that English-learning infants of 9 to 11 months and those of 17 to 19 months also 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, English-learning 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, consistent with the English semantic category of on). 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 9- to 11-month-old and 17- to 19-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 before support or tight-fit spatial relations.

Despite differences in the type of containment categories formed by the infants in the study by Choi et al. (2001) and those in the study by Casasola and Cohen (2002), both studies provided reliable evidence that 9-month-old infants can form an abstract categorical representation of containment. Can infants younger than 9 months form an abstract category of containment? By about 6 months, infants demonstrate the ability to form an abstract spatial category of above versus below, one that does not depend on infants' familiarity with the specific objects that depict each relation and one that can be generalized to novel objects (Quinn et al., 1996). If containment is among the earliest spatial concepts acquired, 6-month-old infants also should demonstrate the ability to form an abstract category of containment. The following two studies were designed to examine 6-month-old infants' ability to discriminate containment from a different spatial relation. The first of these studies explored infants' ability to form an abstract categorical representation of containment across various pairs of objects. Similar to the infants tested in Casasola and Cohen, infants were tested on their ability to form a category of containment that included both tight- and loose-fit containment. The assumption was made that if infants can form a category of containment that includes both types of fit, they can also form a category of containment that includes only tight fit or only loose fit. The second study explored infants' ability to discriminate containment from other types of spatial relations.

Experiment 1

In the current study, 6-month-old infants were tested on their ability to form a categorical representation of containment. To compare the ability of 6-month-old infants with that of older infants, infants were tested in the same spatial categorization task as the 9- to 11-month-old and 17- to 19-month-old infants in Casasola and Cohen (2002). In this procedure, infants were habituated to four events, each depicting a hand placing an object in a containment spatial relation to a second object. In two of the containment events presented during habituation, the containment relation depicts a loose fit between the two objects, whereas in the remaining containment events, the containment relation depicts a tight fit between the objects. Hence, infants must recognize that tight-fit and loose-fit containment events are both examples of containment. Following habituation, infants viewed test events that presented changes in either the spatial relation only (the objects were those seen previously during habituation), the objects only (the spatial relation was the same as that viewed throughout habituation), or a change in both the objects and the spatial relation. Infants also were tested with one of the containment events viewed during habituation (both objects and spatial relation were those viewed during habituation). If infants are able to form an abstract category of containment, they are expected to look significantly longer at the unfamiliar spatial relation relative to the familiar containment spatial relation, even when each spatial relation occurs with novel objects. If infants look significantly longer at the unfamiliar spatial relation when viewed between familiar objects but not when viewed between novel objects, infants will demonstrate that they can discriminate between the containment relation and an unfamiliar spatial relation. However, without demonstrating the ability to generalize the containment relation to novel objects, infants would provide no evidence of having formed an abstract category of containment. Finally, if infants are unable to attend to the spatial relations presented, they are expected to look significantly longer at test trials that present unfamiliar objects but not at test trials with an unfamiliar spatial relation.

Method

Participants—Fifteen full-term infants of 6 months (±2 weeks), 8 males and 7 females, participated in the study. Eleven infants were Caucasian, 1 was Hispanic, 1 was Asian, and 1 parent did not report ethnicity. In addition, 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 because of fussiness, 5 (1 boy, 4 girls) did not meet the habituation criterion (described later), 3 (2 boys, 1 girl) were excluded because of an experimental error, and 3 (1 boy, 2 girls) heard languages other than English in the home. Although 6-month-old infants have limited comprehension of language, the same procedure as Casasola and Cohen (2002) was used, and for this reason, any infants who were regularly exposed to languages other than English were excluded.

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 third pair of objects was a yellow block and a green peg. A fourth pair of objects comprised two hollow cars. One car was larger and red and the other car was smaller and blue, and could be placed in the larger car when inverted. A fifth pair of objects was a multicolored cup without handles and a white dog bowl with colorful prints along its side. Finally, a sixth pair of objects was stackable turtles and a pole. 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 1 s, 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: (a) the monkey in the wicker basket, (b) the red candle in the cookie cutter, (c) the peg in the yellow block, (d) the small blue car in the inverted large red car, and (e) the cup in the dog bowl. Support events (used for the test trials) were created with the following two events: (a) the peg on the yellow block and (b) the turtle on the pole (the other two turtles were already stacked on the pole). The first and final frames of each event are depicted in Appendix A. Note 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 phases 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 before 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.

Apparatus—Adjoining experimental and control rooms were used to conduct the experiment. In the experimental room, a 20-in. 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 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-in. black-and-white monitor in the control room that was used by the experimenter to observe and record infants' looking times at 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 off-line for interobserver reliability.

A Macintosh G4 in the control room and a specially designed habituation program, Habit 2000 (Cohen, Atkinson, & Chaput, 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 at the events during the testing session, and determined when the infant had reached the habituation criterion.

Procedure—Infants were seated on 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 so that an attention-getter (a flashing, chiming, green circle) appeared on the 20-in. monitor in the experimental room in which the infant sat. Once an infant attended to the monitor, the experimenter depressed a key on the computer keyboard to start a trial with the spatial 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 2 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 s) or until they looked away for more than 1 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 experimental room, the attention-getter (the chiming and flashing circle), and the fact that a visual event would be presented on the monitor. 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 (see the top half of Table 1). These events were presented in random order within a block of four trials. To habituate, infants had to demonstrate a 50% decrease in looking time across 3 consecutive trials from their looking time during the first 3 trials of habituation. Although there were four habituation events, the habituation criterion was calculated across 3 rather than 4 trials. In the study by Casasola and Cohen (2002), most 9-month-old infants had viewed an average of about 9 habituation trials, so it was expected that most of the 6-month-old infants would also view an average of about 9 habituation trials. The use of a fixed window of 3 rather than 4 trials made the habituation criterion easier to achieve and, hence, reduced the number of infants who might become fussy during habituation. Once infants reached this habituation criterion or when infants viewed the maximum of 20 habituation trials, they viewed 4 test trials (see the bottom half of Table 1). One test trial presented an event viewed during habituation, the candle placed in the cookie cutter. Infants also viewed 3 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 in the block during habituation). Another test trial presented a novel pair of objects in the familiar containment spatial relation, the cup being placed in the dog bowl. A fourth test trial presented a novel pair of objects in a novel spatial relation, the turtle being placed on 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. Interobserver 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 a priori preference for any of the four test events, a separate sample of 18 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 4 (event: candle in vs. cup in vs. peg on vs. turtle on) × 2 (trial block: first vs. second block) mixed-model ANOVA did not yield any significant main effects or interactions. In particular, there was no significant main effect for event, $F(3, 51) = 1.28$, *ns*. Infants looked in approximately equal duration at the candle-in event ($M = 11.03$ s, $SD = 9.91$ s), the cup-in event ($M = 12.25$ s, $SD = 8.38$ s), the peg-on event ($M = 12.09$ s, $SD = 10.57$ s), and the turtle-on event ($M = 14.12$ s, $SD = 10.15$ s). In addition, a planned comparison of infants' looking time at the two containment versus two support events did not yield a significant difference in infants' looking times at the containment versus support events, $F(1, 51) = 1.66$, *ns*. Thus, the results from these 18 infants provided no evidence for a priori preference for a particular test event or for a particular type of test event (e.g., support).

One important criterion for establishing that infants can form an abstract category of containment is their ability to treat as equivalent different examples of containment. To ensure that infants could in fact discriminate the habituation containment events from the novel containment event presented during the test trial (i.e., the cup-in event), a second independent sample of 8 infants (4 males, 4 females) was tested. Infants were habituated to a single containment event (candle in, car in, peg in, or animal in). Following habituation, infants were tested with two trials of the habituation event as well as two trials of the test containment event (i.e., cup-in event). The order of the test trials was counterbalanced across participants and gender. Infants' looking times at the test trials were analyzed in a 2 (test event: familiar vs. novel containment event) × 2 (test block: first vs. second test block) ANOVA. The analysis yielded a significant main effect for test event, $F(1, 7) = 6.74$, $p<.05$. Infants looked significantly longer at the cup-in containment event ($M = 8.37$ s, $SD = 6.04$ s) than at the containment event to which they were habituated ($M = 4.83$ s, $SD = 4.13$ s). These results indicate that infants had no difficulty discriminating between the cup-in containment event and a containment event to which they were habituated. Thus, infants demonstrated the ability to discriminate the containment events with the stuffed animal, the cars, the peg, or the candle from the cup-in event. If infants in the main study do not respond to the cup-in test event as novel, it will be because they are responding to the event as equivalent to the habituation containment events and not because they are unable to discriminate between the cup-in event and the habituation containment events.

Results

The first analysis compared infants' looking times at the first three trials of habituation with their looking time at 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 their looking time at the habituation event had decreased significantly when this event was presented during the test phase. Infants viewed an average of 10 habituation trials, with 4 infants viewing 6 trials, 5 infants viewing 9 trials, 3 infants viewing 12 trials, 2 infants viewing 15 trials, and 1 infant viewing 18 trials. Infants' looking times were analyzed in a 2 (sex: female vs. male) × 2 (trials: average of the three habituation trials vs. familiar test trial that presents an event seen during habituation) mixed-model ANOVA. The analysis yielded a significant main effect 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). There were no other significant main effects and no significant interactions. The lack of a Sex × Trials interaction indicates that even though male infants attended to the events longer than the females overall, both genders provided a reliable decrease in looking time at the habituation event as indicated by their decreased looking time at this event presented as the familiar test trial.

The next analysis examined infants' looking time at the four test events. Infants' looking times were analyzed in a 2 (sex) × 2 (object pair: familiar vs. novel objects) × 2 (spatial relation: familiar vs. novel spatial relation) ANOVA. 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 that presented the novel spatial relation of support ($M = 9.68$ s, $SD = 7.39$ s) than at the test trials that 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 × 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 an abstract categorical representation of the spatial relation.

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 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 familiar and novel

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spatial relations 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 and could do so across both tight- and loose-fit examples of containment.

However, an alternate, and arguably more parsimonious, explanation could account for the obtained pattern of results. It is possible that 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 at the events with the containment spatial relation because the first object no longer became partially occluded once moved by the hand 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 amount of occlusion of the first object to discriminate between events with a containment spatial relation and events with a support relation. Thus, the current study investigated the degree to which infants' concept of containment depends 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 degree to which the first object became occluded (i.e., the object moved by the hand), a change in the spatial relation, or a change in both the occlusion amount 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 became occluded 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 occlusion amount of the first object and the spatial relation.

If infants rely on changes in the degree to which the first object becomes occluded when inserted into the referent object to discriminate among the test events, 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 events. On the other hand, if infants in Experiment 1 were responding to a change in spatial relation, infants should respond to both the behind and the support events as novel and respond to the high-angle containment event as familiar. Thus, the test events in the current study addressed the basis on which infants attend to containment events (occlusion amount of the first object or the spatial relation).

Method

Participants—Thirty-three full-term infants of 6 months (± 2 weeks), 16 males and 17 females, participated in the study. Twenty-seven infants were Caucasian, 4 were Hispanic, and 2 were African American. Infants were reported by their parents to have no history of auditory or visual impairment. Data from an additional 24 infants were not used in the final sample for the following reasons: 11 (6 boys, 5 girls) did not meet the habituation criterion (described in Experiment 1), 3 (1 boy, 2 girls) were premature, and 10 (3 boys, 7 girls) became fussy during the testing session and did not complete the study. The high number of infants who became fussy or did not habituate may be due to the fact that infants viewed a single containment event with the same objects throughout habituation. Several of the 6-month-old infants were so bored they cried before completion of the testing session. In addition, many of the infants who did not meet the habituation criterion failed to do so because their looking times during the first three habituation trials was low, making it difficult for these infants to meet the 50% decrease in looking time set for the habituation criterion.

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 occluded when placed in the referent object (see Appendix B for an example of the habituation event with the monkey and basket). For the test phase, new events were filmed from a high (or bird's eye) angle. The first and final frames of the test events with the monkey and basket are depicted in Appendix B. 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 to 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 1 s, 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 because of 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. Thus, in one high-angle event, the spatial relation was familiar but the amount of object occlusion was novel (i.e., the containment event); in a second high-angle event, the spatial relation was novel, but the amount of object occlusion was familiar (i.e., the behind event); and in a third high-angle event, the spatial relation and amount of object occlusion were novel (i.e., the support event). The events were filmed with a Canon ZR-10 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 and procedure—The apparatus was identical to that described in Experiment 1. 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, front-angle containment event during habituation (e.g., car in car, cup in bowl, or monkey in basket) and subsequently 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 a second 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 amount 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 amount 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 amount 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. Because the high-angle support event differed in amount of both object occlusion and angle, it always was presented last. In contrast, the two critical test trials, the high-angle containment and the high-angle behind events, were counterbalanced in order of presentation and were shown before the high-angle support event. Interobserver 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.

As in Experiment 1, a separate sample of 25 infants, 12 females and 13 males, viewed each test event across two blocks of trials to explore whether infants had a prior preference for any of the test events. An equal number of infants were randomly assigned to view the test events with either the animal and basket, the cup and bowl, or the cars. Infants viewed the front-angle containment event, the high-angle containment event, the high-angle behind event, and the high-angle support event, all depicted by the same pair of objects, across two blocks of trials. The order in which the events were presented was counterbalanced across participants and gender. A 2 (sex: male vs. female) × 3 (objects: car vs. cup vs. monkey) × 4 (event: front-angle containment vs. high-angle containment vs. high-angle behind vs. high-angle support) × 2 (trial block: first vs. second block) mixed-model ANOVA did not yield any significant main effects or interactions. In particular, there was no significant main effect for event, $F(3, 57) = .41$, *ns*. Infants demonstrated no reliable differences in their looking times at the front-angle containment event ($M = 7.86$s, $SD = 5.84$ s), the high-angle containment event ($M = 7.26$s, $SD = 6.45$ s), the high-angle behind event ($M = 7.14$ s, $SD = 5.70$ s), and the high-angle support event ($M = 8.20$ s, $SD = 6.85$ s). Planned comparisons of infants' looking times at the front-angle versus high-angle containment events, the front-angle containment versus the high-angle behind, and the front-angle containment versus the high-angle behind event also did not yield any significant difference in infants' looking times among these events, all Fs(1, 57) < 1, *ns*. In addition, there was no reliable difference in infants' looking times at the two containment events versus the two noncontainment events (support and behind), $F(1, 57) = .06$, *ns*. Thus, the separate sample of infants provided no evidence that infants had a priori preference for a particular test event, angle of event (front vs. high angle), or type of event (noncontainment events vs. containment events).

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 viewed an average of 8 habituation trials, ranging from 5 to 16 habituation trials. Infants' looking times were analyzed in a 2 (sex: female vs. male) × 3 (habituation event: car vs. cup vs. monkey) × 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, $F(1, 27) = 59.94$, $p<.001$. Hence, infants demonstrated a reliable decrease in looking time from the start of habituation ($M = 15.89$ s, $SD = 7.58$ s) to the time when this event was presented as the first test trial ($M = 5.44$ s, $SD = 3.57$ s). These results indicate that infants demonstrated a reliable decrease in looking time at 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 support) or on the basis of a change in the amount of occlusion of the object moved by the hand (i.e., from occluded to visible). Infants' looking times during the test trials were analyzed in a 2 (sex) × 3 (habituation event) × 2 (spatial relation: familiar containment vs. unfamiliar spatial relation) × 2 (occlusion amount of the first object: occluded vs. visible) mixed-model ANOVA. The analysis yielded a significant main effect for spatial relation, $F(1, 27) = 18.29$, $p<.001$. As can be seen in Figure 2, infants discriminated reliably between test events with the familiar containment relation (M = 6.27 s, SD = 5.20 s) and test events with an unfamiliar spatial relation (M = 9.85 s, SD = 8.63 s). As is evident in Figure 2, the analysis did not yield a significant main effect for occlusion amount of the first object, $F(1, 27) =.32$, *ns*. Infants looked approximately the same duration at test events with a visible object (M = 8.38 s, SD = 7.62 s) as at test events with an object that became occluded when moved by the hand (M = 7.74 s, SD = 7.06 s). Planned comparisons revealed no reliable difference in infants' looking times at the familiar containment habituation event (M = 5.44 s, SD = 3.57 s) and the test event that depicted the containment event from a high angle (M = 7.09 s, SD = 6.38 s), $F(1, 27) = 1.43$, *ns*. Thus, there was no evidence to indicate that infants were responding to the events on the basis of changes in the degree to which the first object was or was not occluded by the referent object. In contrast, infants did demonstrate a reliable increase in looking time at the test event that presented the object behind the referent object (M = 10.03 s, SD = 8.80 s) relative to the familiar containment test event, $F(1, 27) = 11.99$, $p<.005$. Likewise, infants looked significantly longer at the test support event (M = 9.67 s, SD = 8.59 s) than at the familiar containment test event, $F(1, 27) = 9.38$, $p<.005$. This pattern of results indicates that infants did not respond to the test events on the basis of changes in the amount of occlusion of one object by the referent object, but rather on the basis of a change in the spatial relation presented.

Finally, the difference in results between the experimental group and the control group is not due to a larger sample size in the experimental group. The same results are obtained with a sample of 24 infants in the experimental group. Thus, even with fewer infants and less power in the analysis, infants still provide reliable evidence that they respond to the test events on the basis of the spatial relation and not on the basis of the amount of occlusion of the first object.

Discussion

The results of the current study indicate that infants discriminated between events that presented a containment spatial relation and events that presented a novel spatial relation (i.e., behind or support). In contrast, infants did not look significantly longer at events that presented a change in the amount of occlusion of the first 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 although the first object changed in its amount 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 evidence that the infants in Experiment 1 did not discriminate among the test events based on changes in the occlusion amount of one of the objects in the spatial event. 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 amount of occlusion of the inserted object as a cue for recognizing a containment spatial relation between two objects. Rather, infants have the ability to recognize the spatial relation from 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 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 an abstract categorical representation of containment. In Experiment 2, infants were tested on their ability to recognize a containment relation when the first object did not become occluded on insertion into the referent object. Despite changes in the angle of the event and changes in the amount of occlusion 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 6-month-old infants 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 amount of occlusion 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 different shapes (Quinn et al., 1996), 6-month-old infants can also form a category of containment across different objects. Given the lack of perceptual similarity in the stimuli used in the current study and the stimuli used by Quinn et al. (1996), the similarity in results suggests that infants' ability to form an abstract spatial category is a conceptual distinction and not a perceptual one. Infants appear to be able to form an abstract categorical representation across different types of stimuli (static two-dimensional shapes as in Quinn et al's study and moving three-dimensional objects as in the current study). Hence, infants as young as 6 months can attend to a spatial relation both when there is no motion and when there is dynamic motion as well as when the objects depicting the spatial relation are two dimensional or three dimensional. Furthermore, the results of the current study indicate that infants can form a spatial category when viewing as many as eight objects throughout habituation. In contrast to earlier studies in which either one or four shapes are presented in relation to a single, static referent object, infants in the current study viewed four 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). The 6-month-old infants nevertheless formed a category of containment. In contrast, 6-month-old infants have difficulty forming an abstract spatial category of between when asked to categorize the relation across different shapes (Quinn et al., 2003). Infants have difficulty doing so even though the stimuli are shapes in relation to the same referent object rather than various objects in relation to a changing referent object. Consequently, 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 et al., 2003) or support (Casasola & Cohen, 2002). In addition, infants' ability to recognize and categorize a containment relation within the first 6 months lends support to Piaget and Inhelder's (1967) argument that infants acquire containment as one of their earliest spatial concepts.

When compared with the findings reported by Spelke and Hespos (2001) and Choi et al. (2001), the current studies appear to present contradictory results. Recall that Spelke and

Hespos found that English-learning infants of 5 months discriminate reliably between tight- and loose-fit containment events. Likewise, Choi et al. reported that both Korean- and English-learning infants of 9 to 14 months can form a category of tight-fit containment events that excludes loose-fit containment events (and vice versa). In contrast, the 6-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 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 by Choi et al. can be reconciled if one considers findings from infants' categorization of objects. Quinn, Eimas, and Rosenkranz (1993) and 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. 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 to cats, they would respond to a novel cat as familiar but would respond to a novel dog as unfamiliar (i.e., not pertaining to the category of cats). 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 to a set of land animals that were perceptually similar to one another. 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 Choi et al. (2001). It seems 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., the categorization task was structured so that infants would form a more exclusive category of containment (i.e., one that discriminates between tight- vs. 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 fit and loose fit). Thus, in each case, infants are forming the type of spatial category presented in the task. Hence, the results of the current study simply demonstrate that infants are able to ignore the distinction between tight fit and loose fit 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. Likewise, the current findings cannot address whether infants came to the task with a pre-existing category of containment or whether they acquired the category during the experiment. In both experiments, it is possible that infants acquired the category of containment during habituation. 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 reported by Choi et al. and by Casasola and Cohen, in addition to the current results, suggest that the processes underlying infants' categorization of objects may be the same processes that guide their categorization of spatial relations.

Finally, the current findings lend direct support to the argument posited by Hespos and Baillargeon (2001b) and 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 and colleagues' 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 they show 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 in place to guide infants in acquiring physical knowledge of these types of events the same as or different from 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 before they acquire the ability to form a category of between (Quinn, 1994; Quinn et al., 1999). For each type of spatial category, Quinn has argued that infants undergo a specific to abstract progression in which they learn to recognize the relation between familiar objects before gaining the ability to recognize the relation independent of specific objects. The argument outlined by Quinn is not so different from 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, the physical variables most relevant for determining the physical possibility of the event. At present, it is not possible to ascertain whether the 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 a general purpose learning mechanism may be at play rather than two mechanisms, one for acquiring object knowledge and one for acquiring spatial concepts. Continuing to explore infants' categorization of spatial relations, in particular, in infants younger than 6 months, will make it possible to elucidate the relation between the development of infants' understanding of physically possible and impossible events and their categorization of these events.

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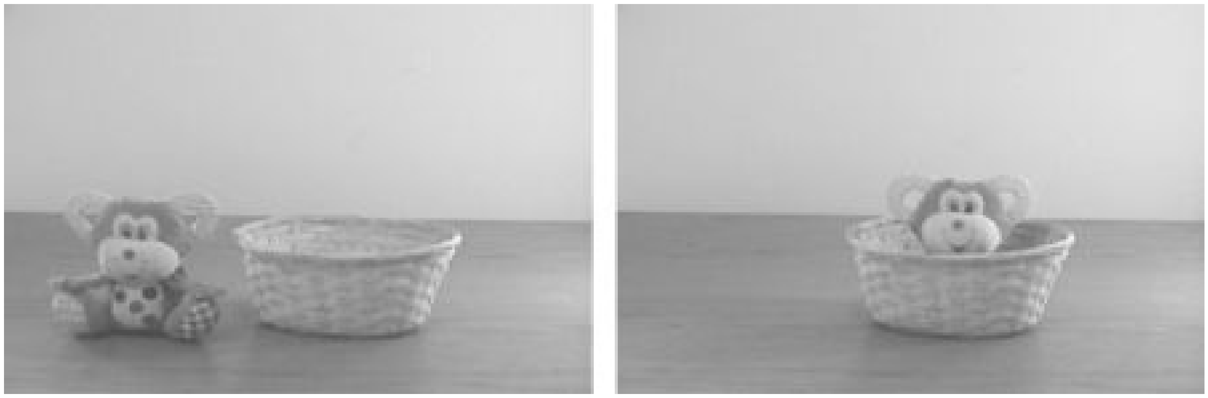
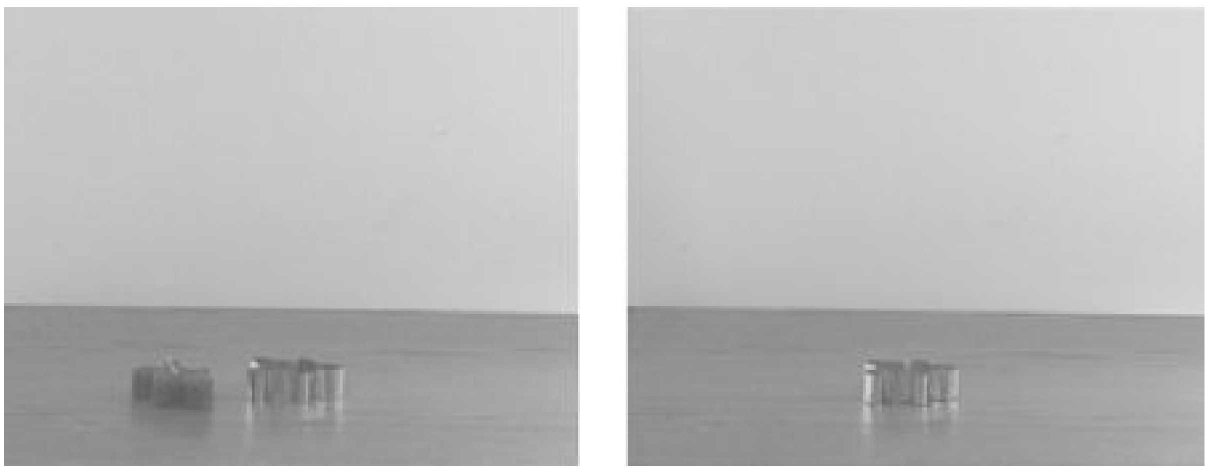
Appendix A

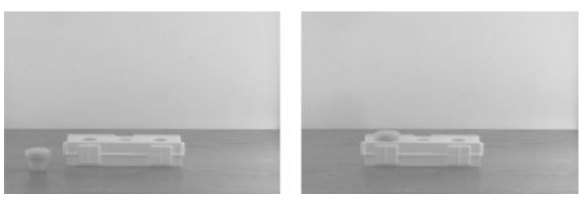
Animal-in event (loose-fit containment):



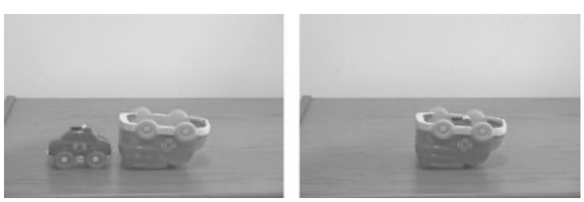
Candle-in event (tight-fit containment):



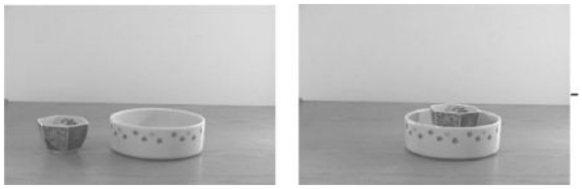
Peg-in event (tight-fit containment):



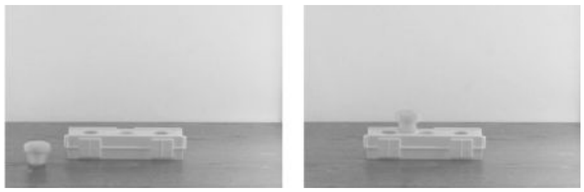
Car-in event (loose-fit containment):



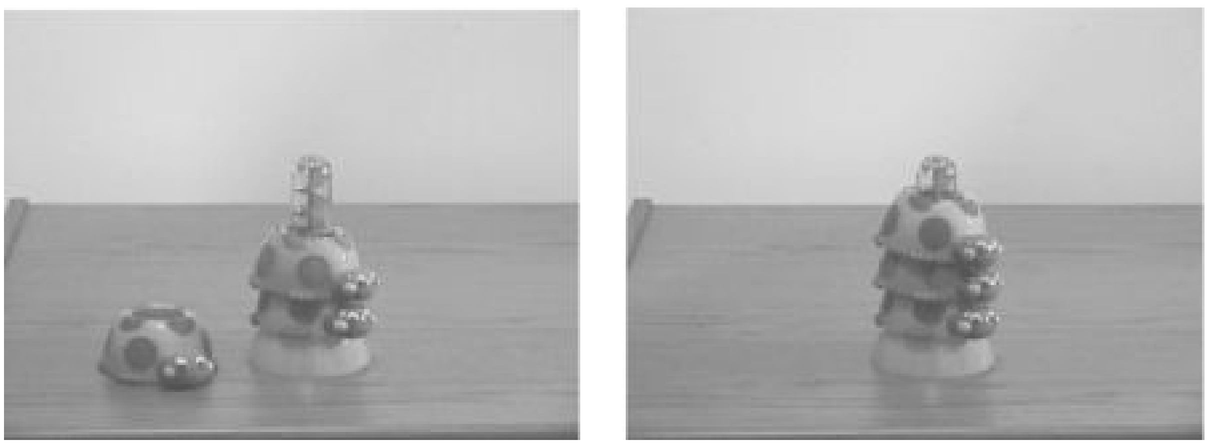
Cup-in event (loose-fit containment):



Peg-on event (loose-fit support):

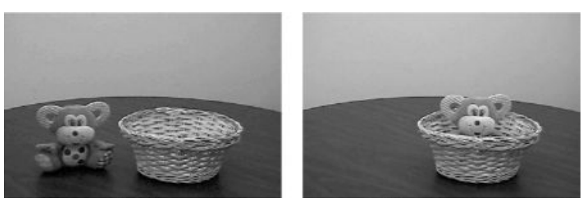


Turtle-on event (tight-fit support):



Appendix B

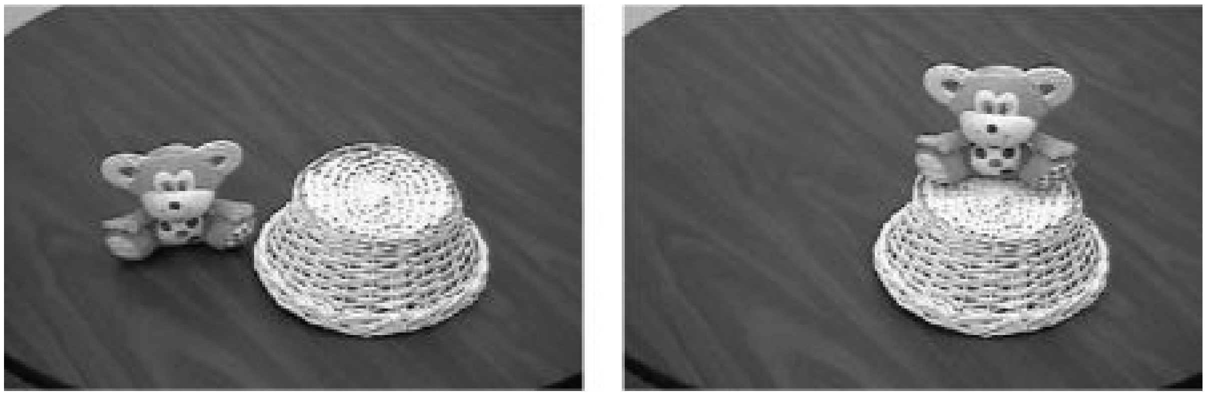
Animal-in habituation event and familiar test event:



High-angle animal-in test event:

High-angle animal-behind test event:

High-angle animal-support test event:



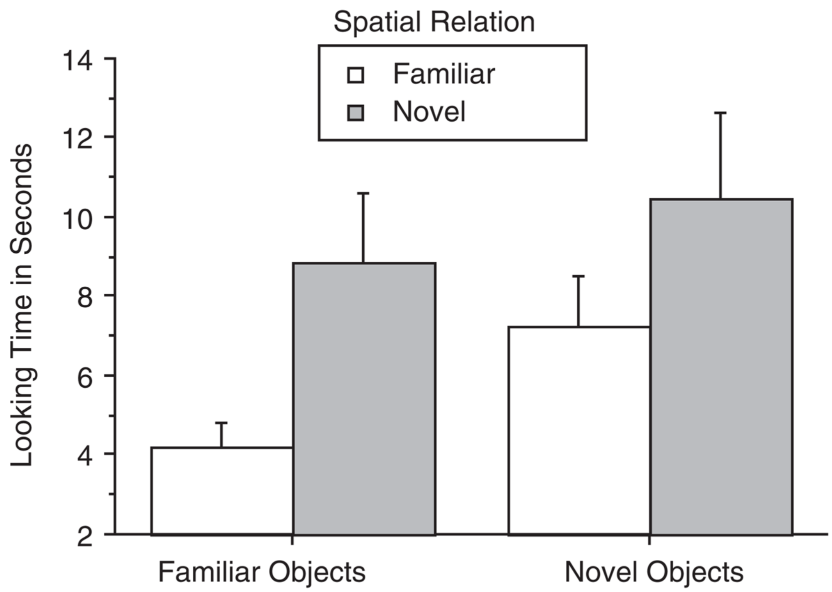


Figure 1.
The looking times with standard error of the 6-month-old infants at each test trial in Experiment 1.

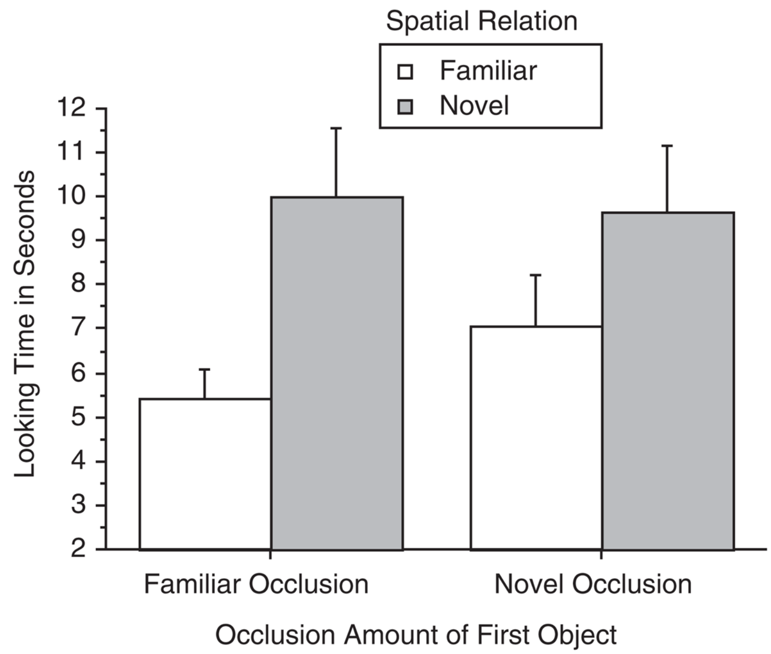


Figure 2.
The looking times with standard error of the 6-month-old infants in Experiment 2 at the familiar containment spatial relation versus a novel spatial relation, when the first object was as occluded as it had been during habituation (familiar occlusion amount) and when the first object remained visible (novel occlusion amount).

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Table 1

Design of Experiment 1

Habituation Event 1	*Animal in*
Habituation Event 2	*Car in*
Habituation Event 3	***Candle in***
Habituation Event 4	***Peg in***
Test Event 1: Familiar objects–familiar spatial relation	**Candle in**
Test Event 2: Novel objects–familiar spatial relation	Cup in
Test Event 3: Familiar objects–novel spatial relation	Peg on
Test Event 4: Novel objects–novel spatial relation	**Turtle on**

Note. The habituation events are presented in italics and the test events are presented in roman. The events presented in bold have a tight fit between the objects.