Delineating the Boundaries of Infants’ Spatial Categories: The Case of Containment

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Spatial categorization has a long history in the research of infant cognition and perception. Many conclusions are drawn from the approach wherein infants are habituated to examples of a spatial category X and then display an attention recovery (i.e., dishabituation) to a contrasting category Y. However, the distinction infants make between X and Y does not warrant a distinction between X and another category Z. Here we examine the boundaries of infants’ spatial categorization by contrasting the spatial category containment with support and occlusion. Eight-month-olds were habituated to 3 exemplars of containment and were tested with novel containment versus support events, or with novel containment versus occlusion events. The infants looked significantly longer at the support than at the containment events, but they looked about equally at the occlusion and containment events. The results suggest that 8-month-olds treated exemplars of containment as belonging to the same category, generalized this category to novel examples, and distinguished it from support but not from occlusion (this last distinction emerged by 11 months). Thus, spatial categorization in the 1st year, like several other domains of cognition, may be tied to specific contrasts. Whether infants form a broad or narrow spatial category depends on the contrasting category.

Spatial concepts constitute an important foundation for early physical knowledge. The ability to distinguish spatial relations guides infants to categorize a physical event, access their knowledge about the event category, and predict how objects should behave or interact (e.g., Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001a, 2001b, 2006; Wang & Baillargeon, 2008a; Wang, Baillargeon, & Brueckner, 2004). Previous research has shown that whether infants use information about a particular object property (such as height) depends on at least two factors: a) infants’ categorization of an event, and b) their knowledge about what object-property information is critical for predicting outcomes of events in that category. For example, although 11-month-old infants detected a change to an object’s height after the object was hidden behind a cover, they failed to detect the same change after the object was hidden under the cover (Wang & Baillargeon, 2006; Wang & Mitroff, 2009). In other words, infants attended to and used information about the object’s height in the context of occlusion but not covering events (for similar event-specific effects across various spatial relations, see, e.g., Hespos & Baillargeon, 2001a, 2001b, 2006; Wang, 2011; Wang, Baillargeon, & Paterson, 2005; Wang & Kohne, 2007). Thus,
the distinction infants make between spatial relations leads to the discrepancy in their use of the same object-property information across different types of physical events.

From word learning to object recognition, the contrast involved in the task can influence infants’ attention, which in turn affects their categorization (e.g., Eimas & Quinn, 1994; Oakes, Coppage, & Dingel, 1997; Quinn, Eimas, & Rosenkrantz, 1993). However, the role of contrast has not received adequate attention in the research of spatial concepts in infancy. Examining whether spatial categorization depends on contrasting categories can inform us about the boundaries of spatial categories. The goal of the present research is to delineate the boundaries of infants’ spatial categories, specifically their categorical representation of containment.

From a very young age, infants demonstrate an ability to distinguish between spatial relations. For example, after being habituated with dots at various positions above a bar, 3-month-olds looked longer at a dot presented below the bar than at a dot presented at a new position above the bar, suggesting that they distinguished between the relations above and below (Quinn, 1994). A hallmark of abstract categorization is the ability to generalize to novel exemplars. The 3-month-olds in the study described demonstrated some generalization to novel locations (within a limited range). However, infants failed to generalize when the test item involved a novel shape (e.g., habituated to dots above; tested with triangles above or below) until they were about 6 months of age (Quinn, Cummins, Kase, Martin, & Weissman, 1996), suggesting that abstract categorization is more difficult and thus emerges later than mere discrimination between two spatial relations.

Habituation experiments provide stringent evidence that infants form an abstract categorical representation. In the domain of spatial categorization, infants are typically shown a number of exemplars demonstrating the same spatial relation with different pairs of objects during habituation trials. After attention decreases, infants are shown an example of the familiar relation or an example of a novel relation during test trials. Significantly longer looking times during the novel-relation test trials compared with the familiar-relation test trials, whether familiar or novel objects are used to demonstrate the relation, are taken to indicate that infants form an abstract category of the familiar relation and consider the example of the novel relation as something new and distinct from the familiar relation. As such, the investigation of spatial categorization in infancy typically involves contrasts between two relations. Different from the violation-of-expectation paradigm widely used for studying physical reasoning in infancy wherein violations are utilized to pique infants’ interest, the habituation paradigm invites infants to compare across examples presented in the habituation and test trials. Indeed, comparison, as a computational and learning process, plays an important role in cognitive development across the domains of memory, object categorization, language acquisition, and rule learning during infancy and beyond (e.g., Gentner, Loewenstein, & Hung, 2007; Gentner & Medina, 1998; Gentner & Namy, 2006; Oakes, Kovack-Lesh, & Horst, 2009; Özçalışkan, Goldin-Meadow, Gentner, & Mylander, 2009; Waxman & Klibanoff, 2000). Through comparison, infants and children can arrive at a conclusion or explanation that helps them organize or make sense of the examples they observe.

Infants in their 1st year are capable of forming abstract spatial categories (Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003; Quinn et al., 1996); for example, 6-month-olds distinguish containment from support as evidenced by their prolonged looking time at the latter after being habituated to the former. However, less is known about the boundaries of these spatial categories. When infants give evidence for distinguishing between Category X and Category Y in the habituation paradigm, it is often concluded that infants form an abstract
category of X. However, does using one contrasting category in test trials warrant the conclusion that infants “have” that abstract spatial category? If infants give evidence for forming an abstract category, for example, containment, when it is contrasted with support, should we conclude that they have an adult-like category of containment? If infants’ category of containment is similar to that of adults, we should expect infants to distinguish containment from a wide variety of contrasting categories. Conversely, if the boundaries of the containment category formed by infants deviate from those by adults, infants may distinguish containment from some but not other categories. The present research addresses the issue of spatial category boundaries by contrasting containment with occlusion and support.

Comparing Occlusion and Containment Events

Even very young infants are equipped with basic object principles that allow them to consider some constraints of object behavior. For example, 2.5-month-olds expect an object to continue to exist whether it has been completely hidden behind or inside another object (Hespos & Baillargeon, 2001b), suggesting that young infants apply the principle of object continuity in both occlusion and containment events. However, despite the apparent generality of object knowledge, infants’ physical knowledge is event-specific under many circumstances (for a review, see Wang & Baillargeon, 2008b). For example, infants at about 3.5 months recognize that height is an important factor to attend to when watching occlusion events; however, they tend to ignore height information when watching containment events until they are about 7.5 months old (Baillargeon & DeVos, 1991; Hespos & Baillargeon, 2001a, 2006; Wang, 2011). A similar pattern is observed in infants’ consideration of width in occlusion and containment events: They use width information in occlusion events at 3 months, but it takes another month for them to start using the same information in containment events (Wang et al., 2004). These experiments provide converging evidence that infants distinguish between occlusion and containment events and that their expectations about occlusion are not generalized to containment. The distinction made by infants between these two types of events seems surprising, given their perceptual similarities. In these experiments, an object was moved along a similar trajectory and became hidden to the same degree, whether it was behind or inside another object. To distinguish between occlusion and containment, infants must notice the different depths at which an object was lowered, without relying on information about how much of the object was hidden. Although these physical reasoning studies have demonstrated that infants’ detection of a physical violation depends on the type of spatial relation involved, such evidence is often regarded as disconnected from infants’ responses in habituation tasks. The disconnection is derived from the assumptions that physical reasoning tasks require infants to make predictions of event outcomes (e.g., will an object remain visible?), whereas habituation tasks rely more heavily on the comparison process (e.g., is X the same kind of relation as Y?).

Young infants seem to understand basic functions of containers and gradually learn more about the spatial relation containment. For example, 3.5-month-olds demonstrated their basic knowledge about containment events when they were intrigued by seeing an object being inserted inside a container through its closed top, and when they recognized that if an object was placed inside a container, the object and container should move together (Hespos & Baillargeon, 2001b). On the other hand, it takes longer for infants to attend to cues that are useful
for predicting whether an object will fit through the rim of a container. Smitsman, Dejonckheere, and De Wit (2009) presented infants with an object suspended above a container but then blocked infants’ view as the object descended into the container. Twelve- and 16-month-olds, but not 6- or 9-month-olds, displayed prolonged looking times when the object appeared inside a container too narrow to hide it. These results suggest that 6- and 9-month-olds needed motion cues (i.e., watching the object as it descended into the container) to predict whether an object would fit inside a container. Additionally, Dejonckheere, Smitsman, and Verhofstadt-Dene`ve (2005) showed that with motion cues, 12-month-olds, but not 6- or 9-month-olds, detected a violation in a containment event when an object collided with the front of a container and miraculously continued to descend into the container. However, 9-month-olds succeeded at detecting the violation if the object collided with the rim of the container at multiple points (e.g., on the front, left, and right of the container). Therefore, both 9- and 12-month-olds attended to the rim of the container during the events (an important cue for categorizing the event as containment), but 9-month-olds needed more visual cues than did 12-month-olds to detect the violation. Together, these studies suggest that although infants appear to understand some basic aspects of containment by 9 months of age, their knowledge about this spatial relation continues to develop past their 1st year of life.

Although infants in their 1st year possess limited knowledge about containment, Casasola and colleagues (2003) observed an early ability to form an abstract category of containment. Six-month-old infants were habituated to containment events demonstrated by four different object–container pairs, and then they received test trials. During the first test trial, infants always saw an object–container pair seen during habituation in a containment relation (thus, exactly the same as one of the habituation events). In the remaining three test trials, infants viewed an object–container pair seen before in a novel support relation; a novel object–container pair in a familiar containment relation; and another novel object–container pair in a novel support relation. The 6-month-olds looked significantly longer at the test trials involving the novel relation than they looked at those involving the familiar relation, regardless of whether the novel or familiar pair was used to demonstrate the relation. These results were taken to indicate that the 6-month-olds formed an abstract category of containment across habituation events, which allowed them to generalize the category to examples involving novel stimuli and to distinguish this category from another spatial relation, support (Casasola et al., 2003, Experiment 1).

However, in the report by Casasola et al. (2003), a consistently larger portion of the object was hidden in containment than in support events. Thus, infants could have relied on how much of an object was hidden, rather than on the spatial relation per se, to distinguish containment from support. To test this possibility, a follow-up experiment filmed test trials from a high angle so that objects were always visible in occlusion, containment, and support events (Casasola et al., 2003, Experiment 2). Six–month-old infants were habituated to a single containment event seen from the original, low angle. Next, they were tested with a high-angle containment event, a high-angle occlusion event, and a high-angle support event. All of the events were conducted with the same stimuli. The infants looked significantly longer at the occlusion than at the containment event, and significantly longer at the support than at the containment event. Thus, the result provides some evidence that the 6-month-olds did not merely attend to information about how much of the object was hidden when making a distinction between different events. However, the same stimuli were used during habituation and test trials; therefore, evidence is still needed to conclude that infants form an abstract category of containment, generalize it to
different objects, and distinguish it from occlusion. Habituating infants to multiple exemplars of containment and testing them with novel stimuli in containment and occlusion relations would provide stronger evidence that infants form an abstract category of containment in contrast to occlusion.

The Present Research

In two experiments, we investigated the boundaries and the developmental changes of infants’ containment category. Experiment 1 examined 8-month-olds’ ability to form an abstract category of containment when it was contrasted with occlusion or support. Although Casasola et al. (2003) found that 6-month-olds were able to form an abstract category of containment when it was contrasted with support, we suspected that the perceptual difference between containment and occlusion would be less salient and therefore the contrast would be more challenging for infants. Under this rationale, we chose a slightly older age, 8 months. Previous research on infants’ understanding about containment shows a developmental progression from 6 to 9 months (Dejonckheere et al., 2005), supporting our choice of 8-month-olds for the present task that was more taxing than the task used in previous studies. Experiment 2 examined the developmental change of the containment category by testing older infants, aged 11 months old.

EXPERIMENT 1

Eight-month-old infants watched live events in which an object was lowered inside a container during habituation trials and was lowered inside, behind, or on top of a container during test trials. The experiment was administered in a similar way as in the study by Casasola et al. (2003), with three important modifications. First, containment was contrasted with occlusion in one condition and with support in the other condition during test trials, after the infants had been habituated to containment events demonstrated by different object–container pairs (as opposed to a single habituation pair).

Second, efforts were made to equate the end state of the object within each condition, to ensure that infants could not rely on other factors, such as degree of object visibility at the end of the events, and to distinguish between spatial relations. To this end, infants were seated at a specific height for each condition such that from their perspective, the object always became fully hidden during the habituation and test trials in the occlusion condition, whereas it always remained visible during the habituation and test trials in the support condition. The only aspect of the event that allowed infants to distinguish between containment and occlusion was whether the object was lowered directly inside the container or farther away, behind the container. Similarly, to distinguish between containment and support, the infants had to discern whether the object was lowered inside or on top of the container.

Third, we used live events rather than filmed events in both conditions. As mentioned earlier in the Introduction, some of the test events in the previous study were filmed from a high angle to ensure that the object remained visible during test trials (Casasola et al., 2003, Experiment 2). Inspired by this design, the infants in the support condition of the present experiment were seated at a high angle during both habituation and test trials to minimize the difference between object visibility at the end of our live events.
If the 8-month-olds formed an abstract category of containment during the habituation trials, they should look significantly longer at the occlusion or support test events than at the containment test events, regardless of whether the stimuli were novel or familiar. In contrast, if infants this age have not yet formed an abstract category of containment that excludes occlusion or support, they should look about equally at the two relations during the test trials.

Method

Participants. Thirty-six healthy full-term 8-month-old infants participated (20 boys, 16 girls; $M_{\text{age}} = 8.0$ months; range $= 7.4$ months–8.7 months). Half of the infants participated in the occlusion condition ($M_{\text{age}} = 8.0$ months) and half participated in the support condition ($M_{\text{age}} = 8.0$ months). An additional 14 infants were tested but excluded due to fussiness or inattentiveness ($n = 9$) or observer error ($n = 5$). In this and the following experiment, participants were recruited through birth announcements or local hospitals and were primarily Caucasians from middle-class backgrounds. All parents were offered a small gift or travel reimbursement but were not otherwise compensated for participation.

Apparatus and stimuli. All events were presented in a wooden display box (104 cm wide $\times$ 106.3 cm high $\times$ 56.3 cm deep) mounted 75 cm above the floor. Its back was covered by a foam board with a rectangular window (27.5 cm $\times$ 35 cm) that was centered and extended from the bottom of the back; the window was covered with white ribbons. Infants faced the front opening of the display box (97 cm $\times$ 45 cm), and a curtain was lowered to cover this opening between trials.

The stimuli for the occlusion condition consisted of five object–container pairs (Table 1): One pair was used exclusively in habituation trials, two pairs exclusively in test trials, and two pairs in both habituation and test trials. Three of the objects in each set were commercially made (a toy hippo, toy giraffe, and saltshaker) and two were constructed with mailing tubes, foam core, and contact paper (a short and a tall cylinder). The objects ranged from 3 cm to 6.5 cm wide and 4 cm to 7 cm high. Two of the containers were commercially made (a blue and a yellow plastic cup), and three were constructed with mailing tubes or cardboard and covered with contact paper. The containers ranged from 7 cm to 12 cm wide and 8.5 cm to 18 cm high. Within each pair, the container was always taller than the object and therefore could fully hide it. The stimuli for the support condition were the same as those for the occlusion condition, except for the modifications of the yellow cylinder and the green saltshaker. Specifically, they were extended at the bottom by inserting a tube so that each of them became tall enough for infants to see the top from their seated position after the cylinder or saltshaker was lowered inside the container (see Procedure and Figure 1).

All infants were tested in a brightly lit room. Four 60-W lamps provided additional light in the display. Two frames (each 71 cm $\times$ 182.3 cm) covered with beige fabric stood at an angle on both sides of the display to isolate the infant from the rest of the room. A small hole was cut into the fabric on each frame to allow observers to monitor where infants were looking during the experiment while remaining hidden from infants’ view and unable to see the presented events.
### TABLE 1
Object–Container Pairs Used for 8- and 11-Month-Old Infants During Habituation and Test Trials

<table>
<thead>
<tr>
<th></th>
<th>Habituation</th>
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<tbody>
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<td>Pair 1</td>
<td>Pair 2</td>
<td>Pair 3</td>
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<td>NF</td>
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<td><strong>Pairs:</strong></td>
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<td><strong>8-month-olds</strong></td>
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<tr>
<td>Object</td>
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<td>Cylinder</td>
<td>Giraffe</td>
<td>Hippo</td>
<td>Tall Cylinder</td>
<td>Cylinder</td>
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<tr>
<td>Relation</td>
<td>Inside</td>
<td>Inside</td>
<td>Inside</td>
<td>Behind On-top</td>
<td>Behind On-top</td>
<td>Inside</td>
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<tr>
<td><strong>Pairs:11-month-olds</strong></td>
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<tr>
<td>Object</td>
<td>Saltshaker</td>
<td>Cylinder</td>
<td>Zebra</td>
<td>Frog</td>
<td>Cylinder</td>
<td>Box</td>
</tr>
<tr>
<td>Relation</td>
<td>Inside</td>
<td>Inside</td>
<td>Inside</td>
<td>Behind</td>
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Events. Each trial started with a static display showing an object (about 18 cm from the front and 41 cm from the left of the opening) and a container (about 17 cm from the front and 40 cm from the right of the opening). Across all trials, the object stood about 4 cm to the left of the container. At the beginning of each event (Figure 1), the experimenter’s bare right hand grasped the container and rotated the opening of the container toward the infant 90° to show the
hollow interior (2 s) and then paused. In the support condition, the container was inverted for two test trials (see Procedure) so that its closed end faced up to afford the support relation, and the experimenter rotated the closed end 90° toward the infant. After the infant had looked at the paused scene for 2 cumulative seconds, the hand returned the container to its starting position (2 s) and rested behind the object on the stage floor (2 s). After the infant had looked at this display for 2 cumulative seconds, the hand grasped the top of the object (1 s), lifted it until its base was about 4 cm higher than the container (1 s), and moved the object to the right (1 s). The object was then lowered inside, behind, or on top of the container (2 s). After the object contacted the surface, the hand released the object (1 s) and paused for 1 s. Next, the hand grasped the object again (1 s), lifted it from inside, behind, or the top of the container until its base was 4 cm above the container (2 s), and moved it to the left of the container (1 s). Finally, the object was lowered to its starting point (2 s), followed by another pause (1 s). The event sequence (starting from lifting the object) was repeated until the trial ended (see Procedure).

Procedure. Each infant was seated on the parent’s lap centered about 50 cm from the front of the display box. The infant’s eye level was 85 cm and 105 cm above the room floor in the occlusion and support conditions, respectively. The 85-cm eye level (about 10 cm above the stage floor) in the occlusion condition ensured that each object became fully hidden whether it was lowered inside or behind the container. The 105-cm eye level (about 30 cm above the stage floor) in the support condition ensured that each object remained visible to infants whether it was lowered inside or on top of the container; otherwise, the object would have become fully hidden in containment events and fully visible in support events, creating a perceptual confound.1

The parents were instructed not to talk to their infants and to keep their eyes closed during the experiment. Infants in both conditions received habituation trials in which they saw containment events and then four test trials in which they saw containment and occlusion events or containment and support events.

In both conditions, the habituation events were conducted with three different object–container pairs in a fixed order. The habituation phase ended when infants’ total looking time during 3 consecutive trials had decreased by 50% from their total looking time during the first 3 trials, or when 20 trials had elapsed. Thus, each infant received a minimum of 4 and a maximum of 20 habituation trials. Originally, we used 4 habituation pairs as in the study by Casasola et al. (2003). But pilot data indicated infants had difficulty habituating to four exemplars, resulting in a high attrition rate. Inspired by Casasola (2005) demonstrating that fewer exemplars sometimes facilitated the categorization process, we chose three, instead of four, habituation pairs to make it easier for 8-month-olds.

During the test phase of the occlusion condition, four different events were each presented once (see Table 1). They included an occlusion event with a novel object–container pair (i.e.,

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1If the infants were to view the events in the support condition at the same seating height as in the occlusion condition, the object would have become fully hidden at the end of the containment events and remained fully visible at the end of the support events. This aspect alone would have created a profound perceptual difference. As a result, when infants responded differently to the containment and support events, it would have been difficult to determine whether the responses reflected their detection of different end states of the object (fully hidden vs. fully visible) or a distinction they made between containment and support. To avoid the potential confound, we chose the high seating position for the infants in the support condition to create the viewing angle similar to the high-angle perspective in Experiment 2 of Casasola et al. (2003).
novel relation and novel stimuli, “Test NN” hereafter), an occlusion event with a familiar object–container pair (i.e., novel relation and familiar stimuli, “Test NF”), a containment event with a novel object–container pair (i.e., familiar relation and novel stimuli, “Test FN”), and a containment event with a familiar object–container pair (i.e., familiar relation and familiar stimuli, “Test FF”). Each of these events had a designated object–container pair. For example, the hippo–box pair was always used in Test NN.

During the test phase of the support condition, the same four object–container pairs were used to demonstrate the four types of events. Hence, the four test events included the combination of a novel support relation with novel stimuli (NN), a novel support relation with familiar stimuli (NF), a familiar containment relation with novel stimuli (FN), and a familiar containment event with familiar stimuli (FF).

Fifteen out of 32 infants viewed Test FF in the first test trial, as in the previous study (Casasola et al., 2003). The order of the remaining three tests (NN, NF, and FN) was counterbalanced across these participants. The rest of the participants viewed Test NN, NF, or FN in the first trial. For these participants, the order of Tests NN, NF, FN, and FF was roughly counterbalanced with a constraint that Test FF was never shown in the first test trial.

Two independent observers, blind to the research hypothesis, the condition, and the order of test event presentation, held a videogame controller and pressed a button on the controller when the infant was looking at the event. The controller was linked to a computer that calculated looking times. At the end of each trial, the observers noted the infant’s state (e.g., fussy or drowsy). The looking times recorded by the primary (and typically more experienced) observer determined the ending of each trial.

Each habituation trial ended when the infant looked away from the event area for 2 consecutive seconds after having looked at it for 5 cumulative seconds, or when the infant had looked at the event area for a maximum of 60 cumulative seconds. Each test trial ended when the infant looked away for 1 s after having looked for 5 cumulative seconds or a maximum of 60 s. The 2-s look-away time was used in habituation to allow infants more opportunity to look at the events so that fewer habituation trials would be needed.

Each trial was divided into 100-ms intervals, and the computer calculated whether the two observers were in agreement within each interval. Percent agreement was obtained by dividing the number of intervals in which observers agreed by the total number of intervals during the events. Agreement ranged from 76% to 99% and averaged 93% (SD = 13%) for test trials.

**Results**

Preliminary analyses of the habituation and test data revealed no main effects of sex or order (FF first vs. FF not first) and no significant interactions of sex or order by condition, relation, or object, all Fs < 2.51, all ps > .05. In the analysis of test data, there was a significant effect of Sex × Order interaction, \(F(1, 28) = 7.29, \ p = .01\), because boys looked longer overall (\(M = 16.29, SD = 1.52\)) than did girls (\(M = 12.91, SD = 3.00\)) in the FF-first group, whereas girls looked longer overall (\(M = 17.15, SD = 4.84\)) than did boys (\(M = 13.15, SD = 4.47\)) in the FF-not-first group. Because this interaction did not interact with condition, relation, or object, the data were collapsed across sex and order in subsequent analyses.
Habituation trials. The 8-month-olds completed an average of 7.0 habituation trials ($SD = 1.99$; range $= 4–13$). Infants’ looking times during the habituation trials were averaged and compared between conditions. The analysis yielded no significant effect of condition, indicating that infants in the occlusion ($M = 31.26$, $SD = 7.61$) and the support ($M = 27.36$, $SD = 2.26$) conditions looked about equally during habituation trials, $t(34) = 1.35$, $p = .19$.

Test trials. Infants’ looking times during the first three habituation trials were averaged and compared to their looking times during Test FF, using a $2 \times 2$ analysis of variance (ANOVA) with trial type (habituation or Test FF) as a within-subject factor and condition (occlusion or support) as a between-subjects factor. The analysis yielded a significant effect of trial type, $F(1, 34) = 148.45$, $p < .0001$, partial $\eta^2 = .81$: Infants looked significantly longer during the first three habituation trials ($M = 41.86$, $SD = 12.95$) than during Test FF ($M = 11.42$, $SD = 5.63$). The results indicated that infants did not recover their attention when watching Test FF, suggesting that they perceived Test FF as old information. This was true across the two conditions given no significant interaction of Trial Type $\times$ Condition, $F(1, 34) < 1$.

To examine whether infants responded to the novelty of spatial relation or object, their looking times during the test trials (Figure 2) were analyzed by a $2 \times 2 \times 2$ ANOVA with condition (occlusion or support) as a between-subjects factor and with relation (novel or familiar) and object (novel or familiar) as within-subject factors. The analysis yielded a significant effect of relation, $F(1, 34) = 11.70$, $p = .002$, partial $\eta^2 = .26$, indicating that infants looked significantly longer at the novel relation ($M = 16.37$, $SD = 4.63$) than at the familiar relation ($M = 12.85$, $SD = 5.52$). The main effect of object was not significant, $F(1, 34) = 2.96$, nor was the effect of the Relation $\times$ Object interaction or the effect of the Relation $\times$ Object $\times$ Condition three-way interaction, both $F(1, 34) < 1$. Thus, infants looked significantly longer at the novel relation than at the familiar relation regardless of whether the objects were novel or familiar.

![FIGURE 2](image-url) The 8-month-olds’ looking times at the novel and familiar relations and objects in the occlusion and support conditions. An asterisk indicates that looking times differ significantly between the two types of events ($^*p < .05$). Error bars represent standard error.
Importantly, the effect of the Relation × Condition interaction was significant, $F(1, 34) = 4.15, p = .049$, partial $\eta^2 = .11$. Planned comparisons, using the Bonferroni-adjusted alpha level of .0125 per comparison (.05/4 comparisons = .0125), indicated that infants in the support condition looked significantly longer at the novel relation ($M = 18.54, SD = 5.01$) than at the familiar relation ($M = 12.93, SD = 6.06$), $F(1, 17) = 10.83, p = .004$, partial $\eta^2 = .39$, whereas infants in the occlusion condition looked about equally at the novel ($M = 14.20, SD = 7.78$) and familiar ($M = 12.78, SD = 6.91$) relations, $F(1, 17) = 1.53, p = .23$. This pattern of response suggests that the 8-month-old infants distinguished containment from support but not from occlusion. The Object × Condition interaction was marginally significant, $F(1, 34) = 4.05, p = .052$, partial $\eta^2 = .11$. However, with the adjusted level of .0125 per comparison, infants did not look significantly longer at the novel object than at the familiar object in either condition.

Discussion

After being habituated to containment exemplars, the 8-month-old infants distinguished containment from support but not from occlusion. The positive results of the support condition echoed those of Casasola et al. (2003), in which 6-month-olds distinguished between containment and support. The negative results of the occlusion condition, however, stood in contrast with their findings. This is not surprising given that we had adapted a stringent criterion for abstract categorization by requiring infants to generalize the containment category to novel examples and by making containment and occlusion test events highly similar in their perceptual appearances.

We pointed out earlier that infants’ high-angle seating position in the support condition was necessary to avoid a perceptual confound (see also Footnote 1). Nonetheless, one could argue that different viewing angles might have contributed to infants’ different responses across the two conditions. Perhaps the high-angle position made it easier for the infants in the support condition to distinguish between containment and support test events by providing a clearer view of the event. However, if it were the case, the same effect should also have been observed in the study by Casasola et al. (2003) wherein the events were filmed at a low angle in one experiment and a high angle in another experiment. But the infants in Casasola et al.’s (2003) did not respond to the difference of the viewing angle; similar results were obtained across their two experiments. In fact, the high-angle position in the support condition of the present experiment, which brought the infants 20 cm farther away from the apparatus and consequently reduced the clarity of the event, might have increased the perceptual demand for processing the containment and support events and elevated the task difficulty of the support condition. Still, the infants in the support condition succeeded in differentiating the two relations, whereas those in the occlusion condition failed to do so. Thus, it is more likely that the different responses across the support and occlusion conditions reflected the boundaries of 8-month-old infants’ containment category, which excludes support but not occlusion.

Curiously, the 8-month-olds in both conditions failed to discriminate between novel and familiar objects, a finding that also diverged from the results of Casasola et al. (2003). One possible explanation could be that the infants in our experiment might have focused on the spatial relations demonstrated by the object–container pairs, rather than the stimuli per se. Given that our primary research question here concerns infants’ categorization of spatial relations, rather than their recognition of familiar objects, we will not discuss this issue further and instead will focus our discussion on infants’ success or failure to distinguish between spatial relations.
The results in Experiment 1 provide compelling evidence for the important role of contrast: Whether infants form an abstract category of containment depends on the contrasting category. The results also imply that 8-month-olds’ categorical representation of containment is not the same as the way (English-speaking) adults demarcate this category linguistically or conceptually. The boundaries of the containment category formed by 8-month-olds seem broader than those formed by adults and have not yet excluded occlusion. Experiment 2 investigated the developmental progression by testing whether 11-month-olds gave evidence for a narrower containment category.

EXPERIMENT 2

The purpose of Experiment 2 was to explore developmental changes of infants’ containment category. Specifically, we asked whether infants at 11 months would succeed at excluding occlusion from their category of containment. Previous research suggests that from 9 to 12 months of age, infants advance their understanding of containment events by considering a wider array of spatial features (Dejonckheere et al., 2005; Smitsman et al., 2009). Thus, we chose the age of 11 months and expected that infants’ knowledge about containment events at this age should allow them to succeed at excluding occlusion from this category. Pilot data indicated that the 11-month-olds were able to distinguish occlusion from containment. However, this positive result could derive from their intrinsic preference for the two object–container pairs used in the novel-relation test trials. If it were the case, removing the habituation trials should preserve their looking pattern. In contrast, if the 11-month-olds responded with longer looking at the occlusion events because they had formed an abstract category of containment during habituation and treated the occlusion events as new information, this looking pattern should diminish when the habituation trials are removed. A control condition with test trials only was conducted with a separate group of 11-month-olds to test the alternative interpretation.

Method

Participants. Thirty-six healthy full-term 11-month-old infants participated (19 boys, 17 girls; $M_{age} = 11.4$ months; 10.9 months–12.3 months). Half of the 11-month-olds were randomly assigned to an experimental (occlusion) condition ($M_{age} = 11.6$ months) and half to a control condition ($M_{age} = 11.3$ months). An additional 12 infants were tested but excluded due to fussiness or inattentiveness ($n = 9$) or parental interference ($n = 3$).

Apparatus and stimuli. The apparatus was the same as in Experiment 1. The stimuli for the occlusion condition consisted of five object–container pairs (Table 1): One pair was used exclusively in habituation trials, two pairs exclusively in test trials, and two pairs in both habituation and test trials. Three of the objects were commercially made (a toy frog, toy zebra, and saltshaker) and two were constructed with mailing tubes, foam core, and contact paper (a box and a tall cylinder). The objects ranged from 3 cm to 6.5 cm wide and 4 cm to 7 cm high. Two of the containers were commercially made (a red and a blue plastic cup) and three were constructed with mailing tubes or cardboard and covered with contact paper. The containers ranged from 7 cm to
12 cm wide and 8.5 cm to 18 cm high. Within each pair, the container was always taller than the object and thus fully hid the object. From the infant’s eye level (10 cm above the stage floor), the object always became fully hidden after it was lowered inside or behind the container. The stimuli for the control condition were the same as those used in the test trials of the experimental condition.

To expedite data collection, we chose a different set of object–container pairs from those in Experiment 1 so that some infants (n = 10) from Experiment 1 could participate in the control condition of Experiment 2, which was designed to obtain baseline data. Care was taken to match these two sets of object–container pairs in their complexity and the type of stimuli used (e.g., a toy zebra was used in Experiment 2 for the same pair in which a toy giraffe was used in Experiment 1; a blue saltshaker was used in Experiment 2 to match the green saltshaker in Experiment 1; see Table 1). The returning and first-time participants’ looking times were comparable (returning, M = 35.27, SD = 9.94; first-time, M = 33.88, SD = 10.96), F(1, 16) < 1. All of the 11-month-olds in the experimental condition participated for the first time.

Events and procedure. The events and procedure for the experimental condition were the same as in the occlusion condition of Experiment 1. The control condition was identical to the experimental condition, except for the removal of habituation trials. Each infant was seated on the parent’s lap. For half of the infants (n = 18), Test FF was used as the first test trial; the order of Tests NN, NF, and FN for this group was counterbalanced across participants. For the other half of the infants, the order of Tests NN, NF, FN, and FF was roughly counterbalanced across participants, with a constraint that Test FF never appeared first. Interobserver agreement across test trials ranged from 87% to 100% and averaged 97% (SD = 2.57%).

Results

Preliminary analyses revealed no significant effects involving sex or order (FF first or FF not first), all Fs < 3.69, all ps > .05. Therefore, the data were collapsed across these two factors in subsequent analyses.

Habituation trials. Infants in the experimental condition completed an average of 8.4 habituation trials (SD = 3.4; range = 5–16). Infants’ looking times during the habituation trials were averaged and compared to those of the 8-month-olds who participated in the occlusion condition of Experiment 1. The analysis did not yield a significant effect of age, indicating that 11-month-olds (M = 32.72, SD = 8.55) and 8-month-olds (M = 31.26, SD = 7.61) looked about equally during habituation trials, t(34) = 0.54, p = .59.

Test trials. Infants’ looking times during the first three habituation trials were averaged and compared to those during Test FF. A two-tailed paired t test indicated that infants looked significantly longer during the first three habituation trials (M = 45.90, SD = 12.38) than during the familiar test event (M = 11.65, SD = 5.69), t(17) = 9.91, p < .0001, suggesting that infants treated Test FF as familiar information.

We next compared the looking times of infants in the experimental and control conditions to a) examine whether 11-month-olds in the experimental condition looked significantly longer at the novel occlusion relation than at the familiar containment relation and b) ensure that the
experimental group’s responses during test trials were driven by habituation/dishabituation and not by specific stimuli used in the test trials. Infants’ looking times during test trials were averaged and analyzed by a $2 \times 2 \times 2$ ANOVA with condition (experimental or control) as a between-subjects factor and with relation (novel or familiar) and object (novel or familiar) as within-subject factors. The analyses yielded a significant main effect of condition, $F(1, 34) = 42.69$, $p < .001$, partial $\eta^2 = .56$, indicating that the control group who received only four test trials looked significantly longer than the experimental group overall.

Crucially, the effect of the Relation $\times$ Condition interaction was significant, $F(1, 34) = 5.46$, $p = .026$, partial $\eta^2 = .14$ (see Figure 3). Planned comparisons, using the Bonferroni-adjusted alpha level of .0125 per comparison ($0.05/4 = 0.0125$), indicated that the 11-month-olds in the experimental condition looked significantly longer at the novel relation ($M = 19.52$, $SD = 12.43$) than the familiar relation ($M = 13.55$, $SD = 8.58$), $F(1, 17) = 10.89$, $p = .004$, partial $\eta^2 = .39$, whereas those in the control condition looked about equally at the novel and familiar relations (novel, $M = 32.58$, $SD = 17.02$; familiar, $M = 36.73$, $SD = 17.44$), $F(1, 17) = 1.11$, $p = .31$. Moreover, the Relation $\times$ Object interaction was not significant for the experimental group, $F(1, 17) = 1.14$, $p = .30$, indicating that they looked longer at the novel relation than at the familiar relation regardless of the stimuli used.

Finally, the effect of the Object $\times$ Condition interaction was also significant, $F(1, 34) = 15.99$, $p < .001$, partial $\eta^2 = .32$. Planned comparisons indicated that the experimental group looked significantly longer at the novel objects ($M = 19.90$, $SD = 13.17$) than at the familiar objects ($M = 13.17$, $SD = 7.06$), $F(1, 17) = 11.14$, $p = .004$, partial $\eta^2 = .40$, whereas the control group looked significantly longer at the familiar objects ($M = 39.76$, $SD = 16.77$) than at the novel objects ($M = 29.55$, $SD = 16.35$), $F(1, 17) = 7.51$, $p < .025$. No other effects were significant, all $Fs < 1$.

![FIGURE 3](image-url) The 11-month-olds’ looking times at the novel and familiar relations and objects in the experimental and control conditions. An asterisk indicates that looking times differ significantly between the two types of events (*$p < .05$). Error bars represent standard error.
Discussion

The results in Experiment 2 suggest that 11-month-olds excluded occlusion from their categorical representation of containment. The control group did not display this looking pattern, ruling out the alternative interpretation that the experimental group’s results were derived from infants’ intrinsic preference for the stimuli used in the novel-relation test trials.

It was somewhat surprising that the control group showed a preference for familiar over novel objects, even though they did not receive any habituation trials and thus had not seen any of these objects. However, the direction of their preference was opposite from what we observed in the experimental group, who looked significantly longer at the novel than at the familiar objects. Thus, these control results still provided evidence against the possibility that the experimental group’s distinction between containment and occlusion relations was derived from intrinsic preferences for the novel objects or from some superficial aspects of the novel-relation test events. Together with Experiment 1, the findings reveal a developmental progression in infants’ ability to form an abstract category of containment and distinguish examples of containment from perceptually similar examples of occlusion.

GENERAL DISCUSSION

The present research examines the boundaries of infants’ spatial categories. Specifically, we asked whether infants’ categorical representation of containment excludes both occlusion and support events. The results reveal a contrast-specific effect: Eight-month-olds formed an abstract category of containment when it was contrasted with support, but not when it was contrasted with occlusion. Furthermore, the boundaries of the containment category undergo a developmental change. At 8 months of age, infants form an abstract category of containment that still includes occlusion and hence is broader than (English-speaking) adults’ sense of “containment.” By 11 months of age, infants have shifted the boundaries of the containment category to exclude occlusion. In the following sections, we discuss the implications of these findings in connection with a) the previous habituation findings, b) the existing physical reasoning research, and c) the broader literature on categorization in infancy and beyond.

Variations in Habituation Findings

In the previous research, 6-month-olds formed an abstract category of containment when contrasted with support (Casasola et al., 2003), whereas 8-month-olds in the present research failed to do so when they were required to exclude occlusion from their category of containment. Our 8-month-olds did succeed, just as the 6-month-olds in the study by Casasola et al. (2003), when the task contrasted containment with support. Although negative results can reflect several different interpretations, one of the plausible interpretations for our results in the occlusion condition is that compared with 11-month-olds, 8-month-olds seemed to form a broader category of containment that included both containment and occlusion events.

We speculate that 8-month-olds’ failure to distinguish containment from occlusion may be due to multiple similarities between these two spatial relations. Perceptually, occlusion and containment are more similar than support and containment. To categorize containment events as
different from occlusion events, infants need to attend to the different depths at which an object is lowered. Recall that 9-month-old, but not 6-month-old, infants noticed a violation when an object collided with the top of a container at multiple points (Dejonckheere et al., 2005). It could be that infants younger than 9 months of age often fail to pay close enough attention to perceptual cues in containment events as objects are descending. In the present study, ignoring perceptual cues, such as how far the object was lowered in relation to the container, would lead 8-month-olds to overlook the perceptual differences between containment and occlusion events.

Perhaps conceptually, occlusion and containment also share more similarity than do support and containment. For example, an object can be lowered behind a container, thereby transforming its function from a container to an occluder. Although a container can also serve as a supporting platform for an object, there are several constraints. For example, the object must be wider or bigger than the opening of the container, and it must be positioned in a specific manner (e.g., when using a coffee mug to support a spoon, the spoon has to be balanced on the mug in a certain position). On the other hand, a container can become an occluder without so many constraints—for example, by simply lowering an object at different depths in relation to the container. The dual functions of containers—to occlude or to contain objects—might have led infants to ignore some perceivable differences between containment and occlusion events, resulting in their difficulty with forming a category of containment that excludes occlusion. However, containment and support also share some similarities (e.g., both involve physical contact between the object and container); thus, future research could directly address whether the differences and similarities described in this article mediate infants’ ability to exclude occlusion or support from containment.

A final note on the different findings between Casasola et al. (2003) and the current study concerns the format of the experiment presentation: We used live events, whereas Casasola et al. (2003) used filmed events. Could the format drive the differences between the present and previous findings? We think not, given that the same presentation format was used for 8-month-olds in the occlusion and support conditions, and yet infants still responded differently across the two conditions. One remaining question is whether live and filmed events may elicit differing levels of processing in general. Previous research suggests that infants tend to engage longer with live events than with the same events that are filmed (Diener, Pierroutsakos, Troseth, & Roberts, 2008). However, the consequence of the live-event preference on infants’ spatial categorization is not fully understood and awaits further investigation.

Spatial Categorization and Physical Reasoning

The present results of 8-month-olds’ failure to distinguish containment from occlusion are surprising, given that much younger infants have demonstrated a discrepancy in their abilities to detect similar physical violations across containment and occlusion events (e.g., Hespos & Baillargeon, 2001a, 2006; Wang et al., 2004). For example, Hespos and Baillargeon (2001a) showed that infants at 4.5 months detected a violation of height in the context of occlusion events when a tall object disappeared behind a relatively short container, but they failed to detect a similar violation in the context of containment events when a tall object disappeared inside a short container (infants detected this last violation at about 7.5 months). To detect a violation, infants need to a) predict the outcome of an event, b) compare the observed outcome with their
prediction, and c) detect the inconsistency between the predicted and observed outcomes. Different processes may underlie the present experiments and the violation-of-expectation research. Specifically, the habituation procedure used in the present experiments requires infants to compare across multiple object–container habituation pairs, ignore perceptual differences across pairs, extract the commonality across pairs (i.e., they all demonstrate the same relation, containment), and finally distinguish containment from occlusion or support in test trials. Detecting a violation in occlusion events at a younger age than in containment events may imply that infants are capable of attending to the key aspect that distinguishes these two types of events. However, it does not provide conclusive evidence for their ability to perform the comparison process described.

During the comparison process, infants may overextend the commonality they detect among containment events and form a global category of “hiding” events, leading the 8-month-olds in Experiment 1 to include the occlusion examples in the category of containment. Alternatively, the 8-month-olds may not have recognized all of the habituation events as examples of containment; however, this interpretation seems unlikely given Casasola et al.’s (2003) findings with 6-month-olds and the present results with the 8-month-olds in the support condition. Additionally, evidence from object categorization suggests that infants categorize objects more globally before they form basic-level object categories (e.g., Younger & Fearing, 1999). The possibility that infants begin by forming a broad spatial category that is gradually refined with age and experience seems consistent with the global-to-basic shift observed in the development of object categorization.

Research on physical reasoning in infancy has demonstrated that infants as young as 3.5 months old attend to the size of an object relative to that of an occluder for the purpose of predicting whether the object should become fully or partly hidden behind the occluder (e.g., Baillargeon & DeVos, 1991). However, it is not until infants are about 7.5 to 8 months old that they begin to use the same information to predict the outcomes of containment events (e.g., Hespos & Baillargeon, 2001a; Wang, 2011). Coincidentally, it is around 6.5 to 8 months of age when infants begin to attend to the portion of an object supported by a platform to predict the outcomes of support events (i.e., whether the object should fall or remain stationary when released on top of the platform; e.g., Hespos & Baillargeon, 2008; Wang, 2003). It could be the case that infants learn about physical rules for containment and support events at around the same age, leading to their heightened sensitivity to the contrast between containment and support. Future research exploring the potential interplay between infants’ learning about physical laws and spatial categories would make important connections between the two bodies of literature.

Categorization in Infancy and beyond

Although not directly addressed by the present research, the development of spatial categorization might parallel the development of object categorization in some ways. In particular, there is evidence for a global-to-basic shift in the object categorization literature (Mandler, Bauer, & McDonough, 1991; Mandler & McDonough, 1998). For example, 3-, 4-, and 7-month-old infants formed a global category of four-legged animals when habituated to both cats and horses. These infants, during test trials, did not prefer to look at a novel dog over a novel cat or horse. In contrast, 10-month-olds were able to form two distinct basic-level categories of cats and horses.
and distinguished these categories from a novel “dog” category (these infants preferred to look
at a novel dog over a novel cat or horse; Younger & Fearing, 1999). The researchers further
hypothesized that younger infants attend to different kinds of information than do older infants
when categorizing objects, which could also be true in the case of spatial categorization. Per-
haps, the 8-month-olds in the present study attended to different features of the events than
did the 11-month-olds, leading the 8-month-olds to form a global category of “hiding” events
and the 11-month-olds to form the narrower category of containment. Whereas adults’ spatial
categories can be richly informed by our extensive knowledge about the physical world, infants’
spatial categories seem more fluid and subject to contextual information such as the contrasting
category, as shown in the present research. Future research can investigate whether spatial cate-
gORIZATION across age indeed shifts from global categories (e.g., hiding events) to basic-level
categories (e.g., separate representations for containment and occlusion).

One of the central questions in spatial categorization research has focused on the role of lan-
guage. On the one hand, some research suggests that infants acquire spatial categories based on
perceptual information and that language is not essential to the learning process (e.g., Hespos &
Piccin, 2009; Hespos & Spelke, 2004, 2007). On the other hand, other research suggests that
additional linguistic cues can facilitate the formation of spatial categories (Casasola, 2005,
2008; Casasola & Bhagwat, 2007; Casasola, Bhagwat, & Burke, 2009; Choi, McDonough,
Bowerman, & Mandler, 1999). The present results demonstrated that infants distinguish contain-
ment from occlusion by 11 months of age, before they begin to regularly produce labels that
describe these relations (e.g., “inside” and “behind”). However, it is likely that by this age,
infants already understand some of these spatial prepositions. In addition, 11-month-olds may
have more experience hearing adults label these spatial relations than do 8-month-olds. Thus,
we cannot exclude the possibility that language plays a role in helping infants form a categorical
representation of containment. Instead, we believe this is an empirical question worth further
pursuit.

Although the role of language in forming spatial categories has largely focused on contain-
ment, support, tight-fit, and loose-fit relations, infants’ categorization of containment and
occlusion relations might also benefit from their exposure to corresponding labels. The contain-
ment and occlusion events used in the present study were highly similar, and distinguishing
between the two required infants’ attention to the cue provided during the narrow time window
when the object was lowered inside or behind the container. Given these subtle differences in
events, it is likely that linguistic cues provided beforehand could direct infants’ attention to
the key aspect of the event and facilitate their differentiation between occlusion and containment.
Future research could test this possibility by labeling these relations for younger infants and
comparing infants’ responses to a no-labeling condition. Using the same label across exemplars
of the same spatial relation might ease the comparison process and hence elevate infants’ ability
to extract commonality within a category and detect differences across categories.

Questions remain regarding the number of exemplars and the familiarity of stimuli that might
aid 8-month-olds in distinguishing between containment and occlusion. Regarding the number
of exemplars, Casasola (2005) found that 14-month-old infants formed an abstract category of
support, when contrasted with containment, if habituated with two support events but not if habi-
tuated with six support events. Thus, future research could explore whether habituating
8-month-olds to two instead of three habituation events facilitates their abstract categorization
of containment that excludes occlusion. Regarding the familiarity of stimuli, it has been
demonstrated that infants can form a spatial category when tested with familiar objects seen during habituation before they can do so with novel objects in test trials (Quinn, 1994; Quinn et al., 1996). Thus, future research could examine 8-month-olds’ ability to distinguish containment from occlusion when test events involve familiar objects only.

Concluding Remarks

In conclusion, the present research underscores the important role of contrasting categories for examining the boundaries of spatial categories in infancy. Rather than claiming that infants’ ability to distinguish one spatial category from another indicates an adult-like categorical representation, it is important to specify the specific contrasting context in which infants display such an ability. Infants may well distinguish containment from support while still conflating containment and occlusion. The development of object categorization is often characterized as undergoing a global-to-basic shift—from forming categories closely tied to object appearance to abstracting commonalities beyond perceptual aspects of the members in a given category. Analogously, the development of spatial categorization may undergo a similar shift. Infants may begin with the ability to form a category defined by perceptual differences and gradually develop their ability to form a category defined to contrast perceptually similar examples.

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