Child Development, January/February 2005, Volume 76, Number 1, Pages 279–290

When Less Is More: How Infants Learn to Form an Abstract Categorical Representation of Support

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Two experiments explored how infants learn to form an abstract categorical representation of support (i.e., *on*) when habituated to few (i.e., 2) or many (i.e., 6) examples of the relation. When habituated to 2 pairs of objects in a support relation, 14-month-olds, but not 10-month-olds, formed the abstract spatial category (i.e., generalized the relation to novel objects). When habituated to 6 object pairs in a support relation, infants did not attend to the relation. The results indicate that infants learn to form an abstract spatial category of support between 10 and 14 months and that having fewer object pairs depicting this relation facilitates their acquisition of the abstract categorical representation.

Learning to form an abstract categorical representation is an important developmental achievement that allows infants to recognize novel instances of a previously experienced category as familiar. In the case of spatial relations between objects (e.g., one object *on* another), infants' ability to form an abstract categorical representation allows them to recognize a relation as familiar, regardless of the objects depicting it. This ability develops throughout the latter half of the 1st year (Quinn, Cummins, Kase, Martin, & Weissman, 1996). Whereas 3-month-old infants depend on familiar objects to discriminate above as distinct from below (Quinn, Polly, Furer, Dobson, & Narter, 2002), 6-month-old infants can do so when novel objects depict the relations, demonstrating that their recognition of the relation is independent of specific objects (Quinn et al., 1996). Similarly, 6-month-old infants only discriminate the relation *between* from another relation when familiar objects depict the relations but they do not make this discrimination with novel objects until 9 months of age (Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003; Quinn, Norris, Pasko, Schmader, & Mash, 1999). Thus, infants' ability to form an abstract categorical representation of a spatial relation follows a concrete-to-abstract developmental progression (Casasola & Cohen, 2002; Quinn et al., 2003; Quinn et al., 1996; Quinn et al., 2002). Infants' initial reliance on familiar objects for recognizing a spatial relation eventually gives way to recognizing the relation with novel objects as well.

The current experiments investigate how infants progress from recognizing a particular relation when depicted by familiar objects to also recognizing it when depicted by novel objects and thus forming the abstract categorical representation. The approach taken is similar to that used by Quinn and his colleagues (Quinn et al., 2003; Quinn et al., 2002), who manipulated their experimental procedure to facilitate infants' formation of an abstract spatial category. In one experiment, they gave infants longer familiarization trials with the hope that greater familiarity with the category exemplars would facilitate their ability to discriminate between familiar and unfamiliar relations when novel objects depicted the relations. In a second experiment, they allowed infants to view the novel test objects before the familiarization phase, hypothesizing that familiarity with the novel objects would prevent infants from being distracted by them in the test. In neither experimental manipulation did infants form an abstract categorical representation. Infants did, however, consistently discriminate between familiar and unfamiliar relations when several familiar objects depicted the

This research was supported by National Institutes of Health Grant R03 HD43941-01 and a Hatch grant from the College of Human Ecology at Cornell University to the author. I thank Makeba Parramore Wilbourn and Sujin Yang for help in filming and editing the stimuli, and Jui Bhagwat, Cory Duncan, Kim Ferguson, Michelle Findley, Geunwon Kim, Greggy Laroche, Margaret Mirch, Amanda Leigh Purington, Erica Roizen, and Erika Winkler for their help in participant recruitment and data collection. I am also grateful to Henry Ricciutti and two anonymous reviewers for helpful comments on earlier drafts of this manuscript and to the infants and their parents for generously giving their time to participate in the research. A portion of these findings were reported at the May 2004 International Conference on Infant Studies in Chicago.

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relations, despite their difficulty in making this discrimination with novel objects. Based on these results, Quinn and his colleagues argued that infants' difficulty in forming an abstract spatial category lies in their inability to abstract the relation from familiar objects rather than an inability to encode each object in its relation to the referent object.

The current experiments continue the line of questioning raised by Quinn and his colleagues (Quinn, et al., 2003; Quinn et al., 2002): Can changes in the categorization task facilitate infants' ability to form an abstract categorical representation of a spatial relation? Rather than manipulate familiarization time or experience with novel test objects, the current research manipulated the number of habituation exemplars of the spatial relation provided, a manipulation found to be important in infants' and adults' categorization of form patterns (e. g., Bomba & Siqueland, 1983; Posner & Keele, 1968) and suggested to be important in young children's attention to relational information (Gentner, 1988). Although it may seem that providing multiple exemplars should facilitate infants' formation of an abstract spatial category, it is argued instead that presenting fewer exemplars of a spatial relation, and hence limiting the amount of variation in the objects composing the relation, will facilitate infants' formation of the abstract spatial category.

The notion that presenting fewer objects in a spatial relation will facilitate the formation of the abstract category is suggested by Gentner's (1988) relational shift hypothesis, developed to explain how young children learn to attend to the relational information in metaphors and spatial mapping tasks. Gentner proposed that young children first learn to note similarities in the objects before similarities in the relational information when processing a metaphor or when performing a spatial mapping task. Hence, children learn to shift their attention from objects to relational information. However, even when children can attend to relational information, Gentner proposed that the objects remain important, an assertion supported by young children's greater ease in recognizing the relational similarity across two scenes when perceptually similar, rather than perceptually diverse, objects are used (DeLoache, Kolstad, & Anderson, 1991; Kotovsky & Gentner, 1996; Marzolff & DeLoache, 1994). At least for children then, the objects in a relation appear to influence their attention to relational information.

Similar to Gentner's (1988) relational shift hypothesis, Casasola and Cohen (2002) argued that infants first learn to attend to the objects in a spatial event before the spatial relation. These researchers proposed a specific-to-abstract progression that is the same as that outlined by Quinn and colleagues (Quinn et al., 2003; Quinn et al., 1996; Quinn et al., 2002) but includes the additional stipulation that developmentally, even before infants learn to attend to a spatial relation between familiar objects, they learn to attend to the objects composing the relation. Their theory raises the possibility that objects retain a primary role in how infants process a spatial event. That is, even when infants gain the ability to attend to the spatial relation between familiar objects, they may still attend to the objects before attending to the relation. Hence, objects in a spatial event are posited to be integral in how the relation itself is processed (see also Cohen, 1991). If both theories are correct in suggesting a bias toward objects in how some relational events are first processed, limiting the number of object pairs used to depict a relation should benefit infants more than presenting multiple object pairs in the relation.

This possibility may seem counterintuitive given the numerous studies demonstrating that adults and infants best form an abstract category when viewing many rather than fewer instances of form patterns, such as dots arranged to form a triangle (e.g., Bomba & Siqueland, 1983; Homa, Cross, Cornell, Goldman, & Shwartz, 1973; Posner & Keele, 1968). Bomba and Siqueland (1983), for example, found that 3- and 4-month-old infants acquired the category prototype of a dot pattern more easily when familiarized with 12 rather than 6 exemplars. This result also holds across domains. Gómez (2002) found that adults and 18-month-old infants demonstrated better learning of nonadjacent dependencies in a continuous string of nonsense words when presented with a set size of 24 strings rather than 2, 6, or 12 strings. In these studies, as the number of exemplars increased, infants' ability to attend to and abstract the underlying structure may have been facilitated by the constancy of the element to be abstracted relative to the irrelevant elements that varied across exemplars. These results suggest that presenting infants with many object pairs in a particular spatial relation may direct their attention to the relational commonality and away from the objects composing the relation. That is, providing multiple exemplars of a relation may advance infants from responding only on the basis of specific instances to responding on the more abstract level of the category, a finding that would parallel how infants form abstract categories of objects (Quinn, 1987; Sherman, 1985).

However, research has shown that habituating infants with multiple exemplars of a relation hinders rather than helps their ability to discriminate the

relation. Cohen and Oakes (1993), for example, found that 10-month-old infants habituated to five object pairs in a causal or noncausal relation no longer responded on the basis of causality, an ability they demonstrated when habituated to a single pair of objects (Oakes & Cohen, 1990). Why does this result stand in contrast to those demonstrating that more exemplars lead to better learning of an abstract category (Bomba & Siqueland, 1983; Gómez, 2002)? The difference may lie in the amount of variability ideal for abstracting different types of information. In some instances, increased variability directs infants' attention to the element to be abstracted (e.g., the form pattern, the nonadjacent dependencies) and minimizes their attention to the irrelevant elements (e.g., the individual dots composing the form pattern or the adjacent dependencies in a continuous stream of words). However, where the element to be abstracted is not as easily perceived as the other elements in an event, as may be the case with infants' attention to a causal relation, increased variability actually detracts attention away from the relevant element (the causal relation) and directs attention to the irrelevant, but perceptually more available, element (the objects). If infants are biased in attending to objects before relational information, presenting only a few object pairs in the relation may facilitate their acquisition of the abstract categorical representation.

To explore this possibility, infants in the current experiments were tested on their spatial categorization when presented with few versus many object pairs in a spatial relation. Infants were tested on their categorization of a support relation (i.e., *on*), a spatial category that infants have difficulty forming (Casasola & Cohen, 2002). When previously tested on their categorization of support, 10- and 18-month-old infants were habituated to four object pairs in a support relation and then tested with the familiar and an unfamiliar relation depicted by familiar and, in other test trials, novel objects. Although neither age group formed the spatial category, the 18-month-old infants discriminated between the familiar and unfamiliar relation when familiar objects depicted the relations. Thus, similar to the findings reported by Quinn and colleagues (Quinn et al., 2003; Quinn et al., 2002), infants' recognition of support was tied to familiar objects. The 10-month-old infants, in contrast, provided no evidence of attending to the support relation, suggesting that infants learn to attend to a support relation between 10 and 18 months.

Possibly, presenting fewer or more than the four examples of the support relation provided by Casasola and Cohen (2002) will facilitate infants' ability to form the abstract category. If infants' categorization of support is analogous to how they learn to form abstract categories of form patterns, presenting additional exemplars of support may facilitate their formation of the abstract categorical representation. On the other hand, if infants must first attend to the objects before attending to the support relation, infants may form the abstract categorical representation when viewing only two exemplars of support. To test these two possibilities, in Experiment 1, 14-month-old infants were habituated to either two or six object pairs in a support relation. In Experiment 2, 10-month-old infants were tested to explore whether a change in habituation exemplar number also influences younger infants' spatial categorization. The younger age group was also included to explore developmental changes in infants' spatial categorization. Results from both experiments were expected to provide insight into how infants learn to form an abstract categorical representation of support.

Experiment 1

Infants in Experiment 1 were randomly assigned to one of two conditions. In the two-exemplar condition, infants were habituated to a support relation depicted by two different object pairs. In the six-exemplar condition, infants were habituated to the support relation depicted by six different object pairs. If viewing a limited number of object pairs in a support relation facilitates infants' ability to form an abstract categorical representation, infants in the two-exemplar condition should form the spatial category whereas infants in the six-exemplar condition should not. If, on the other hand, viewing multiple object pairs in a support relation helps infants note the invariance of the support relation across the habituation events, infants in the six-exemplar condition should form an abstract spatial category whereas infants in the two-exemplar condition should not. Finally, if exemplar number does not matter, infants in each condition should respond in the same manner and should discriminate the change in relation with familiar but not novel objects, replicating previous findings (Casasola & Cohen, 2002).

Given findings that children best attend to relational information when viewing perceptually similar objects (Gentner & Ratterman, 1996; Kotovsky & Gentner, 1996; Marzolff & Deloache, 1994), the objects in the current study were created to be perceptually similar to one another. In addition, infants viewed only one type of support relation, in which an object rests on a referent object, to ensure that infants would discriminate between a support and a containment (the novel) relation. Containment was

chosen as the novel relation because infants as young as 6 months can discriminate between containment and support relations (Casasola, Cohen, & Chiarello, 2003). Finally, infants were tested in the same general design and procedure as in Casasola and Cohen (2002) to allow for comparison between the current results and previous findings. In this task, infants were habituated to different instances of a support relation and then were tested on their ability to discriminate between familiar and novel relations when the objects are familiar and when they are novel, thus testing whether they have formed the abstract categorical representation of the relation.

Method

Participants. The participants were 26 (13 males and 13 females) full-term, healthy, 14-month-old infants ($M = 420.45$ days, $SD = 12.41$ days). All infants were from middle-class homes. All parents had completed college or were working toward their college degree. Twenty-one infants were White, 1 was African American, 1 was Asian, and 3 were Hispanic. An additional 10 infants were tested (2 in the two-exemplar condition, 8 in the six-exemplar condition) but were excluded from the final sample: 4 (2 males, 2 females) became too fussy to complete the experimental procedure and 6 (3 females, 3 males) did not meet the habituation criterion.

Participants were recruited through a letter given to parents at the time of their child's birth. Once infants were within the appropriate age range for the current study, parents were contacted again by mail and telephoned. All infants received a t-shirt.

Stimuli. The stimuli were nine pairs of objects, each composed of a figure and a referent object. The figures were constructed from Crayola™ Modeling Magic and shared the same overall shape to be perceptually similar, although they did differ in their individual coloring and features (see Figure 1). Most figures resembled an animal: One resembled a duck, one resembled a cat, one resembled a caterpillar, two resembled dogs, one resembled an elephant, and one resembled a toucan bird. The remaining two figures resembled people: One was a woman wearing a spotted bonnet and the other was a girl with a bow in her hair. Each figure was paired with a particular referent object that could support as well as contain the figure (see the top vs. bottom three rows of Figure 1).

A containment relation and a support relation were videotaped with each object pair. All events began with the objects side by side, with the figure to the left of the referent object. A hand then appeared from the left, lifted the figure, and placed it in either a support or containment spatial relation to the referent object. The final frame of each support and containment event is presented in Figure 1. The events were converted from digital video to QuickTime movies using Final Cut Pro software. Each event was 6 s in duration and was looped five times without pauses to create a trial that was 30 s in duration.

Apparatus. The experiment was conducted in adjoining control and experimental rooms. A chair for infants and their parent was in the experimental room, approximately 127 cm from a 20-in. computer monitor. The monitor was situated on a table approximately 76 cm from the floor and at infants' eye level. A camera, located below the monitor, filmed the infants and allowed the experimenter in the adjoining control room to observe the infants' visual fixations to the events. The experimenter used a specially designed computer program, Habit 2000 (Cohen, Atkinson, & Chaput, 2000) and a Macintosh G4 computer to begin the experimental session, control the start of each trial, and record the duration of infants' visual fixations during a trial. The program also calculated when infants reached the habituation criterion (described next).

Procedure. Infants were randomly assigned to the two-exemplar or six-exemplar condition. Each infant sat on his or her parent's lap and faced the computer monitor. Parents were asked to remain neutral and not influence their infants' looking during the experimental session. Before the start of each trial, a flashing, chiming, green circle was presented on the monitor to direct infants' attention to it. Once infants looked at the monitor, the experimenter depressed a computer key to begin a trial. An event then replaced the flashing circle and the experimenter, using a second computer key, recorded infants' looking time to the event.

The first trial of the experiment was a pretest trial of a stuffed animal being moved side to side by a hand. The purpose of this trial was to accustom infants to the testing room, the attention getter, and the presentation of dynamic events on the monitor. Next, the habituation phase of the study began. Infants in the two-exemplar condition viewed two object pairs and those in the six-exemplar condition viewed six objects pairs. Each object pair depicted the figure being placed in a support relation to the referent object. The object pairs were presented in a semi-random order. Infants viewed these events until their looking time across three consecutive habituation trials had decreased to 50% of their looking time during the first three habituation trials. Once infants reached the habituation criterion or once they

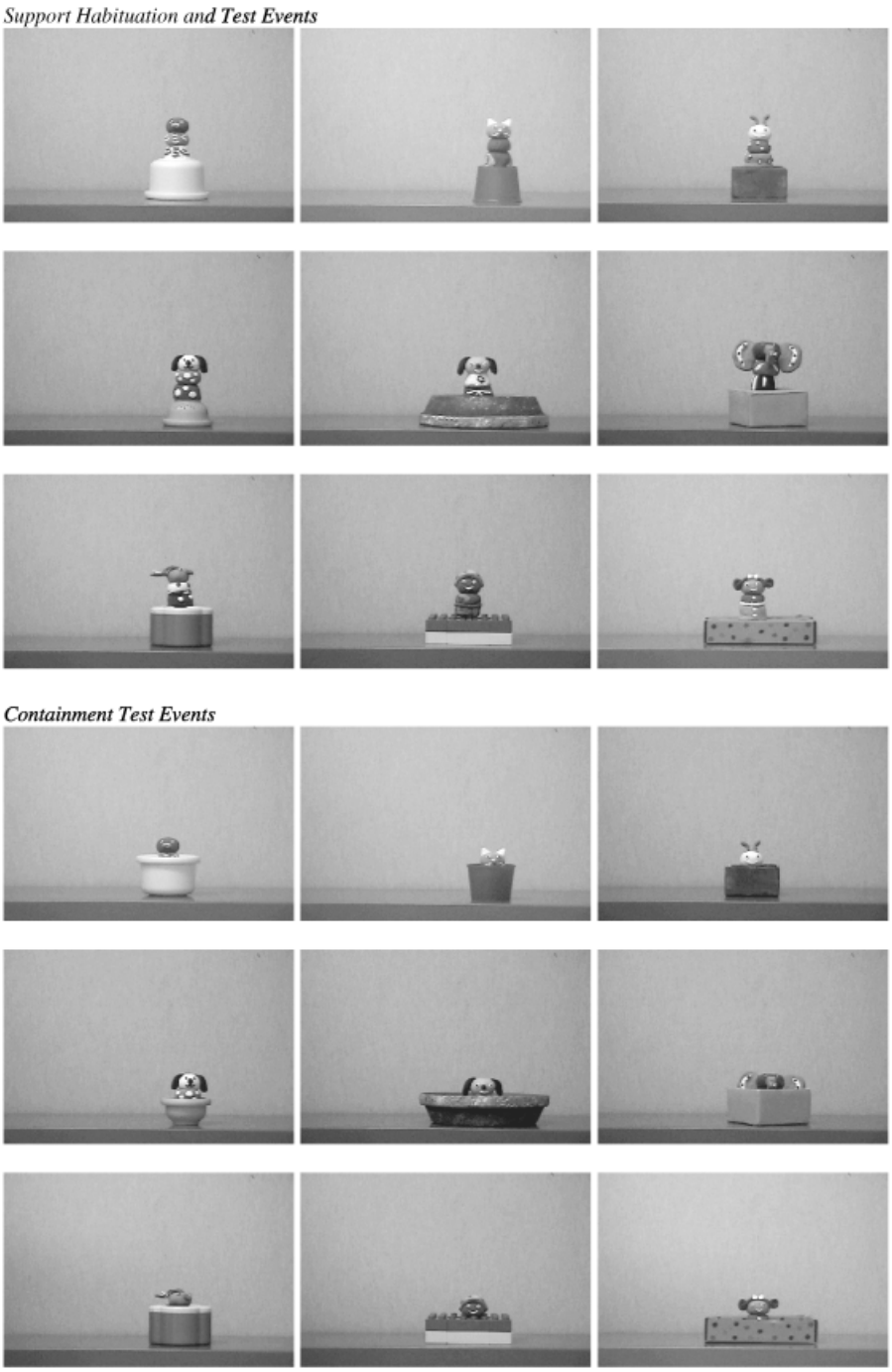

Figure 1. The final frame of the dynamic support events (top three rows) and containment events (bottom three rows) of Experiments 1 and 2.

viewed the maximum of 20 habituation trials, the test phase began.

Infants viewed four test trials. In the familiar test trial, infants viewed one of the support events seen during habituation, chosen at random from among the habituation events. In the second test trial, infants viewed an event with familiar objects (i.e., those seen during habituation) in a novel containment relation. In the third test trial, infants viewed an event with novel objects in the familiar support relation. In the fourth test trial, infants viewed an event with novel objects in the novel containment relation. The presentation order of the four test trials was counterbalanced across participants and gender.

The two conditions were matched in their presentation of particular test object pairs to rule out the possibility that any difference in results could be attributed to the object pairs presented. A second observer recorded the looking time of 10 randomly chosen infants offline. The average correlation between online and offline looking times was .997 and ranged from .934 to .999.

An independent sample of 8 infants was tested to determine whether infants could discriminate among the habituation examples of support. These infants were habituated to a single support event, chosen randomly from the six habituation events used in Experiment 1. Following habituation, infants were tested with the familiar support event as well as three other support events, chosen from the remaining habituation events from Experiment 1. The alpha level here and elsewhere was set at .05, and all significant results are $p < .05$ or better. Compared with their looking time at the support event to which they were habituated ($M = 5.89$ s, $SD = 2.12$ s), infants looked significantly longer at the first novel support test event ($M = 14.73$ s, $SD = 8.95$ s), $F(1, 7) = 7.69$; the second novel support test event ($M = 15.90$ s, $SD = 9.63$ s), $F(1, 7) = 9.86$; and the third novel support test event ($M = 12.81$ s, $SD = 10.04$ s), $F(1, 7) = 4.72$. Hence, infants demonstrated that they could discriminate among the different habituation support events used in Experiment 1. A second independent sample of 8 infants was tested to ensure that infants could discriminate between the support events viewed during habituation and the novel example of support presented during the test of Experiment 1. Infants were habituated to one of the familiar test events from Experiment 1. Once infants had habituated to this event, they viewed the familiar support event and one of the novel support events from the test phase of Experiment 1. Infants looked significantly longer at the novel ($M = 14.05$ s, $SD = 9.96$ s) than familiar support event to which they had been habituated ($M = 8.59$ s, $SD = 6.65$ s), $F(1, 7) = 9.37$. Thus, infants demonstrated the ability to discriminate among the various habituation and test support events.

Results

Habituation phase. Infants in the two-exemplar condition viewed an average of 8.50 habituation trials ($SD = 2.81$ trials) with 6 infants viewing 6 habituation trials, 2 infants viewing 9 habituation trials, and 4 infants viewing 12 habituation trials. Infants in the six-exemplar condition viewed an average of 9.21 habituation trials ($SD = 2.99$ trials), with 4 infants viewing 6 trials, 7 infants viewing 9 trials, 1 infant viewing 12 trials, and 2 infants viewing 15 trials. The first analysis compared infants' average looking time during the first three trials of habituation versus the familiar test event, which presented one of the habituation events. A 2 (sex: male vs. female) $\times$ 2 (condition: two exemplar vs. six exemplar) $\times$ 2 (trials: average of the first three habituation trials vs. familiar test trial) mixed-model analysis of variance (ANOVA) yielded a significant main effect for trials, $F(1, 22) = 70.86$. Infants' average looking time to the first three trials of habituation ($M = 18.77$ s, $SD = 6.19$ s) was significantly longer than their looking time to the habituation event presented as the familiar test event ($M = 6.78$ s, $SD = 4.65$ s). Hence, infants demonstrated a significant decrease in looking time from habituation to test. The analysis also yielded a significant Sex $\times$ Condition interaction, $F(1, 22) = 5.84$. Male infants looked longer than females in the two-exemplar condition but looked less than females in the six-exemplar condition. There were no other significant effects. In particular, there was no interaction of trials with sex or condition, indicating that each gender and infants in each condition demonstrated the same decrease in looking from habituation to test.

Test phase. Infants' looking time to the four test events was analyzed in a 2 (sex) $\times$ 2 (condition) $\times$ 2 (spatial relation: familiar vs. novel) $\times$ 2 (objects: familiar vs. novel) mixed-model ANOVA. The analysis yielded a significant main effect for objects, $F(1, 22) = 5.49$. Infants looked reliably longer at the novel objects ($M = 10.95$ s, $SD = 7.57$ s) than at the familiar objects ($M = 8.07$ s, $SD = 5.97$ s). Although the analysis yielded a significant main effect for spatial relation, $F(1, 22) = 5.30$, this effect was qualified by a significant Spatial Relation $\times$ Condition interaction, $F(1, 22) = 4.11$. To explore this interaction, infants' looking times in each condition were analyzed separately. In addition, planned comparisons were used to explore whether infants discriminated between the familiar and unfamiliar relations with both familiar and novel objects to test whether infants had formed an abstract categorical representation of support.

Infants in the two-exemplar condition looked significantly longer at the novel spatial relation ($M = 13.25$ s, $SD = 9.23$ s) than at the familiar spatial relation ($M = 8.90$ s, $SD = 6.94$ s), $F(1, 11) = 6.76$. As can be seen in the top graph of Figure 2, when the objects were familiar, these infants looked significantly longer at the novel relation ($M = 11.92$ s, $SD = 8.53$ s) than at the familiar relation ($M = 7.03$ s,

$SD = 5.69$ s), $F(1, 10) = 11.02$. Also, when the objects were novel, these infants looked significantly longer at the novel relation ($M = 14.58$ s, $SD = 10.07$ s) than at the familiar relation ($M = 10.78$ s, $SD = 7.79$ s), $F(1, 10) = 6.67$. Thus, infants in the two-exemplar condition responded in a manner consistent with having formed an abstract categorical representation of support.

In contrast, infants in the six-exemplar condition looked an approximately equal duration to the novel versus familiar relation, $F(1, 13) < 1$, *ns*. Infants in the six-exemplar condition did not discriminate between familiar and novel relations when the objects were familiar, $F(1, 13) < 1$, *ns*, or when they were novel, $F(1, 13) < 1$, *ns* (see the bottom graph of Figure 2). However, these infants did tend to look longer at the novel objects ($M = 9.46$ s, $SD = 5.83$ s) than at the familiar objects ($M = 6.87$ s, $SD = 4.01$ s), $F(1, 13) = 3.60$, $p = .08$. Hence, infants in the six-exemplar condition provided some evidence of attending to the objects but no evidence of attending to the spatial relation.

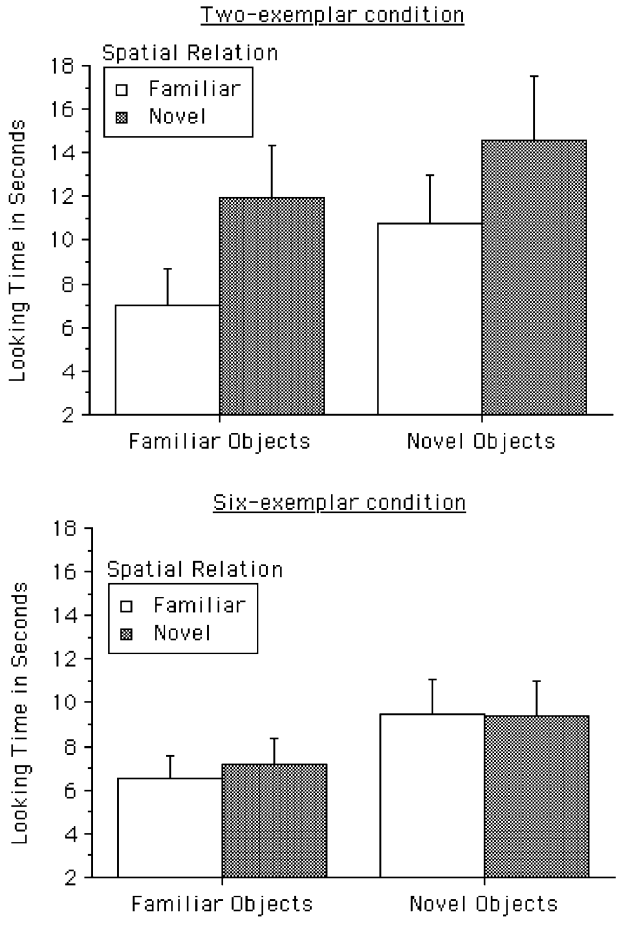

Figure 2. The looking time with standard error of 14-month-old infants in each condition of Experiment 1 to the familiar support relation versus the novel containment relation when the objects depicting the relations were familiar versus novel.

Discussion

The results of Experiment 1 indicate that 14-month-old infants formed an abstract categorical representation of support when habituated to two object pairs in a support relation but not when habituated to six object pairs in this relation. In fact, infants in the six-exemplar condition provided no evidence of attending to the relation. In addition, the attrition rate for infants tested in this condition was much higher than in the two-exemplar condition, further suggesting that the six-exemplar task was more difficult than the two-exemplar task. In sum, the results suggest that experience with two objects in a support relation was more effective in helping infants form an abstract categorical representation of support than experience with six objects in this relation.

One reason for these results is that infants who were habituated to six examples of support (i.e., six object pairs) were distracted by the changing objects and, consequently, had difficulty focusing on the relation. This possibility is consistent with the arguments raised by Gentner (1988) and Casasola and Cohen (2002) that, developmentally, children and infants first attend to the objects that compose a relation before attending to the relation. Because infants in the two-exemplar condition viewed the same events more frequently, they had more opportunities to become familiar with the events and to process both the objects and the relation. Thus, limiting the number of object pairs depicting the support relation allowed infants to attend to the relation as well as the objects. However, some variation in the objects pairs is critical for infants' ability to form the abstract categorical representation. Infants in the control studies who were habituated to a single support event did not form an abstract categorical representation of support, responding to each novel support event as unfamiliar. Quinn and colleagues (Quinn et al., 2003; Quinn et al., 2002) similarly found that infants familiarized to a single object in relation to the referent object did not form the abstract categorical representation of the relation. Hence, some variation in the objects composing a relation is necessary for infants to form of an abstract categorical representation of support. However, limiting the amount of variability in the objects can facilitate their formation of the abstract representation, at least in the case of a support.

If viewing only two exemplars of support aids 14-month-old infants in forming an abstract category of support, it may also aid 10-month-old infants who have difficulty attending to a support relation (Casasola & Cohen, 2002). If allowed to become highly familiar with both the objects and the support relation, 10-month-old infants may form the abstract categorical representation or at least may learn to attend to the support relation between familiar objects. This possibility is explored in Experiment 2.

Experiment 2

Experiment 2 was conducted to determine whether the same conditions that aid 14-month-old infants in forming an abstract category of support also aid 10-month-old infants. When previously tested on their categorization of support, 10-month-old infants provided no evidence of attending to the support relation (Casasola & Cohen, 2002). However, infants' difficulty may have resulted from viewing four different object pairs in a support relation during habituation. Similar to 14-month-old infants, 10-month-old infants' performance on the categorization task may improve if habituated to only two object pairs in a support relation. Even if 10-month-old infants fail to form an abstract categorical representation of support, they may at least progress in the specific-to-abstract progression by attending to the support relation between familiar objects. In addition, exploring how younger infants respond to the support events when habituated to only two object pairs in a support relation may provide further insight into how infants learn to form this abstract categorical representation.

Method

Participants. The participants were 12 (6 males and 6 females) healthy, full-term, 10-month-old infants ($M = 295.58$ days, $SD = 20.80$ days, range = 268–328 days). All infants were White and were from middle-class families in which the parents had completed college. Three additional female infants were tested, but their data were excluded because they did not meet the habituation criteria (2 infants) or because of a computer error (1 infant).

Stimuli, design, apparatus, and procedure. The stimuli, design, apparatus, and procedure were identical to the two-exemplar condition of Experiment 1. A second observer recorded the looking time of 5 randomly selected infants offline. The average correlation between online and offline looking times was .995 (range = .992–.999).

Results

Habituation phase. On average, infants viewed 10.75 habituation trials, with 4 infants viewing 6 trials, 2 infants viewing 9 trials, 3 infants viewing 12 trials, 1 infant viewing 15 trials, and 2 infants viewing 18 trials. Infants' looking times were analyzed in a 2 (sex: male vs. female) × 2 (trials: average of the first three habituation trials vs. the familiar test) mixed-model ANOVA. Infants demonstrated a significant decrease in their averaged looking to the first three habituation events ($M = 17.75$ s, $SD = 6.44$ s) relative to the familiar test event ($M = 7.19$ s, $SD = 5.11$ s), $F(1, 10) = 20.26$. Thus, infants significantly decreased their looking time from habituation to test. The analysis did not yield any other significant effects.

Test phase. Infants' looking time to the test events was analyzed in a 2 (sex) × 2 (spatial relation: familiar vs. novel) × 2 (objects: familiar vs. novel) mixed-model ANOVA. The analysis did not yield any significant effects. Infants provided no evidence that they discriminated between the novel spatial relation ($M = 8.00$ s, $SD = 5.81$ s) and the familiar spatial relation ($M = 8.32$ s, $SD = 6.68$ s), $F(1, 10) < 1$, *ns*. They also failed to discriminate between novel objects ($M = 8.67$ s, $SD = 6.58$ s) and familiar objects ($M = 7.64$ s, $SD = 5.88$ s), $F(1, 10) < 1$, *ns*. Thus, the 10-month-old infants provided no evidence of discriminating any change in the spatial events from habituation to test.

Discussion

Despite viewing only two object pairs in a support relation during habituation, 10-month-old infants failed to form an abstract categorical representation of support. They also did not discriminate the familiar support relation from the novel containment relation when familiar objects depicted each relation. In fact, infants did not respond to any changes in the events, including the change in objects, suggesting that the task was too difficult for them. The results are consistent with previous findings that 10-month-old infants do not attend to a support relation (Casasola & Cohen, 2002) and provide additional evidence that support is a more difficult spatial relation for infants to discriminate and categorize compared with above versus below (Quinn et al., 1996),

between (Quinn et al., 2003), and containment (Casasola et al., 2003). When compared with the results of Experiment 1, the current results indicate that infants gain the ability to form an abstract categorical representation of support when habituated to two object pairs in a support relation between 10 and 14 months of age.

General Discussion

The current experimental studies explored the effect of exemplar number on infants' ability to form an abstract categorical representation of support. When habituated with only two object pairs in a support relation, 14-month-old infants formed the abstract categorical representation, discriminating between the familiar support relation and a novel containment relation when the objects depicting the relations were familiar and when they were novel. In contrast, when habituated with six object pairs in a support relation, infants provided no evidence of discriminating between the familiar and novel relations. The results indicate that 14-month-old infants best learn to form an abstract categorical representation of support when presented with two rather than six exemplars of the relation. For 10-month-old infants, viewing only two exemplars of support did not facilitate their categorization of the relation, suggesting that infants must be older for the reduced number of object pairs to aid their categorization of support.

Before addressing the significance of the results, it is worth considering whether the current results could be explained by infants' response to simple perceptual cues, a possibility given that the perceptual cues associated with each relation were very different. In the support events, the figure always remained visible throughout the event, whereas in the containment events, the figure became partly occluded by the referent object (see the top vs. lower portions of Figure 1). Potentially, infants responded to the containment events as novel because, for the first time, the referent object occluded the figure. Thus, infants may have used the presence or absence of the figure's occlusion as the basis for discriminating between the two spatial relations. However, this possibility seems unlikely for several reasons. First, if infants only relied on the figure remaining visible or becoming occluded as the basis of their discrimination, infants in both conditions and experiments should have responded in the same manner. Second, previous studies demonstrated that 6-month-old infants discriminate a containment relation from other relations on the basis of the relation and not on the basis of the figure's occlusion (Casasola et al., 2003). Likewise, 14-month-old infants tested on their ability to link a novel word to a containment relation or a support relation discriminated between the relations from different angles, including a high angle in which there was no difference in the occlusion amount of the figure in the containment and support events (Casasola & Wilbourn, in press). Together, these findings strongly suggest that infants in the current study were responding to the spatial relation and were not responding solely on the basis of simple perceptual cues.

Consistent with the arguments advanced by Gentner (1989; Gentner & Ratterman, 1991) and Casasola and Cohen (2002), the number of object pairs used to depict a support relation influenced how infants responded to the events. With two object pairs, 14-month-old infants formed the abstract categorical representation of support, an ability not demonstrated by 18-month-old infants habituated to four object pairs in a support relation (Casasola & Cohen, 2002). With six object pairs, the 14-month-old infants behaved in a manner similar to the 10-month-old infants in Experiment 2: They provided no evidence of attending to the relation. The contrast in results between the 14-month-old infants across conditions demonstrates that even when infants have the ability to form an abstract categorical representation of support, their ability to do so may be dictated by the number of object pairs depicting the relation. Infants seem to attend to objects first, a conclusion not only supported by the difference across conditions but also by infants in the six-exemplar condition who discriminated the objects but not the support relation. Thus, several findings in Experiment 1 indicate that the 14-month-old infants encoded the objects before the relation. This result is consistent with other findings revealing processing biases in infants (Wilcox, 1999). Four-month-old infants attend to the head and face of animals before their body (Spencer, Quinn, Johnson, & Karmiloff-Smith, 1997) and to the overall configuration of a pattern before the letters composing it (Freeseman, Colombo, & Coldren, 1993). The current results point to another processing bias: At 14 months, infants attend to the objects before a support relation.

The results of the 14-month-old infants in Experiment 1 also fit within the specific-to-abstract progression outlined by Casasola and Cohen (2002). Although the 14-month-old infants in the six-exemplar condition did not discriminate between familiar and novel relations, they provided some evidence of discriminating the objects in the events. Thus, if infants attended to any element in the events, it was the objects, the first step in the specific-to-abstract

progression. Of course, infants in the two-exemplar condition formed the abstract categorical representation and demonstrated that infants can be at the last step in this progression with this relation. The current results provide further support for this progression and demonstrate how it describes both developmental change and infants' spatial categorization when viewing few versus multiple object pairs.

The current results are reminiscent of 10-month-old infants' discrimination of causal versus noncausal launching events (Cohen & Oakes, 1993). If habituated to a single pair of objects, 10-month-old infants discriminated between causal and noncausal dynamic events (Oakes & Cohen, 1990). However, if habituated to five object pairs, each depicting the same relation, infants no longer responded on the basis of causality (Cohen & Oakes, 1993). These results parallel those in Experiment 1 and suggest a commonality in how infants learn to attend to different types of relations. Both sets of findings point to competition between infants' attention to objects and to relational information, at least for infants' categorization of causal and support relations. Several recent findings also have demonstrated that objects influence attention to spatial information and that object information may be more accessible than spatial information in particular tasks. For example, there is a degree of cross-over between attention to what versus where (Kovacs, Maguire, & Newcombe, 2002). Objects influence children's and adults' memory for location (Hund & Plumert, 2003), and object function influences adults' description of the spatial relation between two objects (Carlson-Radvansky, Covey, & Lattanzi, 1999). Similarly, Irwin and Brockmole (2004) found that saccadic eye movements suppress adults' response to spatial information but not their ability to recognize an object. Hence, there is converging evidence that objects can influence attention to spatial information and may be easier to process than spatial information.

What is the mechanism by which infants learn to abstract the support relation from specific objects to form the abstract categorical representation? One promising possibility is the process of comparison outlined by Gentner (1988; Gentner & Namy, 1999; Gentner & Ratterman, 1991). Gentner has argued that comparison leads to the recognition and abstraction of relations, advancing children from simply noting similarity between objects to also noting similarity in the relations. The 14-month-old infants in the two-exemplar condition of Experiment 1 had more opportunities to compare the habituation support events than did infants in the six-exemplar condition. Perhaps the continual comparison of the two support events, in combination with viewing only two object pairs, explains why infants in the two-exemplar condition formed the abstract categorical representation of support. Thus, repeated experience with only two object pairs in a support relation motivated infants to compare the events on multiple levels, which in turn may have highlighted the underlying relational commonality.

This possibility would explain why infants in Quinn and colleagues' (Quinn et al., 2003; Quinn et al., 2002) experiments did not form an abstract categorical representation of a spatial relation, even when provided with longer familiarization trials. In Quinn and colleagues' studies, infants received only one familiarization trial of each exemplar such that infants could not compare the unique referent object depicted on each familiar event beyond their initial presentation. Infants might have formed the abstract spatial category if given the same duration of total familiarization time but had this time distributed across several trials. However, limiting the amount the variability in the object pairs while still providing some degree of variability may also be necessary. One task for future studies is to test the role of comparison relative to the number and familiarity of the object pairs to delineate how each contributes to infants' ability to form an abstract categorical representation of support.

Finally, one remaining question is whether the current results characterize how infants learn to form an abstract categorical representation of all spatial relations. Because the perceptual cues associated with support are minimal (neither the figure nor the referent object ever changed in appearance), limited variability among objects was ideal for motivating infants to attend to and abstract the relation. The current results thus may generalize best to relations whose perceptual cues are minimal and, consequently, less salient than the objects that compose the relation. The proposal that consistency with a limited set of familiar objects facilitates the acquisition of abstract concepts has been raised in other domains. Stigler and Stevenson (1992), for example, suggested that Asian teachers' use of the same objects to explain different mathematical concepts aids children's acquisition of these concepts. It may be that for relational concepts that are less apparent relative to the objects composing the relation, limiting the amount of object variability may facilitate the acquisition of the abstract representation.

However, the current results may not generalize to all spatial relations. For spatial relations whose perceptual cues are readily apparent (e.g., contain-

ment events in which the inserted object changes in appearance when placed in a referent object), infants may be able to attend easily to these relations with minimal competition from the objects composing the relation. For these relations, limiting the number of objects depicting the relation may not be necessary, and in fact, infants instead may benefit from increased variability, analogous to how they learn to form an abstract category of a form pattern (Bomba & Siqueland, 1983). This possibility thus predicts that the amount of variability ideal for generalization varies as a function of the perceptual cues associated with a spatial relation. Increased variability may be best suited to elements to which infants can readily attend, whereas limited variability may be best suited to elements to which infants have difficulty noting. The feasibility of this argument remains to be tested, but doing so will begin to delineate the types of information for which increased variability is an asset versus those for which limited variability and consistency of the elements are optimal. After all, how learning generalizes from specific to more abstract instances is an issue that permeates many abilities in development, not only infants' ability to form an abstract categorical representation of support.

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