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Infant object categorization transcends diverse object–context relations

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ABSTRACT

Infants' categorization of objects in different object–context relations was investigated. The experiment used a multiple-exemplar habituation-categorization procedure where 92 6-month olds formed categories of animals and vehicles embedded in congruent, incongruent, and homogeneous object–context relations. Across diverse object–context relations, infants habituated to multiple exemplars within a category and categorized novel members of both animal and vehicle categories. Infants showed a slight advantage for categorizing animals. Infant object categorization appears to be robust to diversity in object–context relations.

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1. Introduction

Perceptual and cognitive development depend on learning about objects in the world, and much formative learning about objects takes place in infancy. Because objects are normally embedded in contexts, perceptions of and cognitions about objects always occur in some context. Context refers to aspects of the internal and external environments that are present during object information processing (Clark & Carlson, 1981; Spear, 1978). External context (ground) defines characteristics of the setting in which the object (figure) is processed and encoded. Some attributes of object context may be integral to object processing, others may be incidental. Nonetheless, both may be important, and so context may influence or give meaning to how we sense and think about objects. Thus, object identification, memory, and categorization may depend on contextual cues (Estes, 1973). In short, context informs object perception and cognition.

The ability to categorize an object correctly across variation in contexts must constitute an important cognitive achievement in infancy. In this paper, we investigated infant object categorization across variation in external contexts.

The role of context in infant perception and cognition has received attention in the past from various quarters. For example, it has been argued that, when infants monitor object information in their environment, context cues are salient to them, and in the view of some investigators context cues might even receive priority over object cues in attention allocation. Colombo, Laurie, Martelli, and Hartig (1984) observed that surrounding contextual segments aid infants' discrimination of

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linear and curvilinear segment orientation (the configural superiority effect); and Haaf, Lundy, and Coldren (1996) found that infants habituated to a focal stimulus more quickly when the context was constant than when the context varied and so concluded that infants attend to context information while encoding central stimuli. Infants also encode information about the context in which they learn an operant contingency (Amabile & Rovee-Collier, 1991; Borovsky & Rovee-Collier, 1990; Butler & Rovee-Collier, 1989; Hayne, Rovee-Collier, & Borza, 1991; Shields & Rovee-Collier, 1992), and infants' stimulus recognition is better when a stimulus is presented in the same visual context in which it was encoded than when presented in a new context (Chun & Jiang, 1998; Haaf et al., 1996). Such findings indicate that infants process both object and context information.

However, the tasks of object identification and categorization call on the perceiver to disregard or generalize over contextual variation in order to extract object identity in the first case or object category information in the second case. Thus, in navigating a multidimensional world that is constantly changing, infants must monitor the environment and differentiate object–context relations by deploying their attention selectively and flexibly. Following this line of thought, some have even concluded that "virtually all learning during infancy is . . . independent of context" (Nadel, Willner, & Kurz, 1985, p. 398). Similarly, researchers in child language have long observed that, over the course of development, children have to learn to "decontextualize" a word to understand its appropriate referential meaning and use it correctly (Snyder, Bates, & Bretherton, 1981; Volterra, Bates, Benigni, Bretherton, & Camaioni, 1979). This being the case, no research that we could find addresses the question of the role of context in young infant's object categorization.

Object categorization refers to shared representations of like objects and is in evidence when organisms treat discriminably different objects equivalently. Young infants possess remarkable categorization skills, and they readily categorize objects, such as faces, animals, furniture, vehicles, tools, and plants (e.g., Behl-Chadha, 1996; Bomba, 1984; Bornstein & Arterberry, 2003; Oakes, Madole, & Cohen, 1991; Younger, 1993; see Bornstein, 1984; Madole & Oakes, 1999; Quinn & Eimas, 1996 for reviews). Many studies have analyzed the bases of infant categorization by focusing on features intrinsic to objects, like the face or type of movement (e.g., Arterberry & Bornstein, 2001; Arterberry & Bornstein, 2002; Quinn & Eimas, 1996; Vidic & Haaf, 2004). In the present study, we were concerned with the role of external context in determining object group membership for infants.

Using a multiple-exemplar habituation-test design, we habituated 6-month olds with up to eight object exemplars from one category (e.g., animals) and then tested them with two novel exemplars, one a familiar-category novel exemplar (a ninth animal) and the other a novel-category novel exemplar (a vehicle). Infants in different conditions were presented with animals or vehicles depicted in object–context relations that were typical, probable, expected, or congruent (i.e., a monkey on a tree log, a motorcycle on a street) or in object–context relations that were atypical, improbable, unexpected, or incongruent (i.e., a monkey in the middle of a residential street, a motorcycle in a garden; see Fig. 1). (Our use of the term "congruent" with respect to infants simply refers to the statistically real co-occurrence of particular object kinds with particular context kinds.) For the congruent object–context stimuli, we used naturally photographed animals in "nature" scenes and vehicles in "residential" scenes. To produce stimuli for two incongruent object–context conditions (objects in incongruent and homogeneous contexts), we digitally manipulated these naturally occurring object–context relations. Therefore, we also included an experimental control in which we produced digitally manipulated congruent object–context scenes in natural object–context relations but ones where the objects were not originally photographed. Because a large literature in infant perception and cognition is based on object-only homogeneous context-neutral stimulus presentations, we also included that condition. Thus, the experiment had four conditions.

In addition, to test the potential generality of object–context relation findings we tested infants in all conditions in two contrasting stimulus domains, animals and vehicles. Developmental studies that have contrasted animate with inanimate stimuli have suggested that infants may possess some advantage for natural kinds over designed artifacts (Ellsworth, Muir, & Hains, 1993; Gelman, 1990; Hart, Field, Del Valle, & Letourneau, 1998; Keil, 1989; Kemler Nelson, Frankenfield, Morris, & Blair, 2000; Legerstee, 1992; Legerstee, 1997; Premack, 1990). Behl-Chadha (1996), for example, reported that 3-month olds possess a mature and exclusive animal category, but not a vehicle category (infants included vehicles in a furniture category but not in an animal category). More generally speaking, Rakison and Poulin-Dubois (2001) pointed out that animate and inanimate objects differ in fundamental ways: (a) animates are agents insofar as they initiate action in a causal event, but inanimates can only be acted on; (b) animates grow and reproduce; (c) animates can have mental states such as knowing, perceiving, and emoting; (d) animates possess parts that are directly related to biological function (e.g., limbs permit movement); and (e) animates are capable of communication and reciprocity. Furthermore, on the basis of extensive review, they concluded that infants start to discriminate animate from inanimate characteristics around 6 months of age. In consequence of this literature, we included and compared infants' categorization of animals and vehicles across diverse object–context relations.

We took as evidence of infants' categorization, first, infants' habituation of looking to varying stimuli within a category, second, infants' dishabituation recovery of looking at a novel posthabituation-posttest stimulus, and, third and fourth, respectively, infants' generalization of looking to a familiar-category novel exemplar and dishabituation recovery of looking to a novel-category novel exemplar in a posthabituation test. If object context is critical to object categorization, we would expect that natural congruent object–context relations permit or even facilitate categorization and, reciprocally, that unnatural incongruent object–context relations perhaps inhibit or interfere with categorization. If infants categorize objects independent of their context, we would expect them to do so independent of congruent or incongruent contexts.

(A)

(B)

(C)

(D)

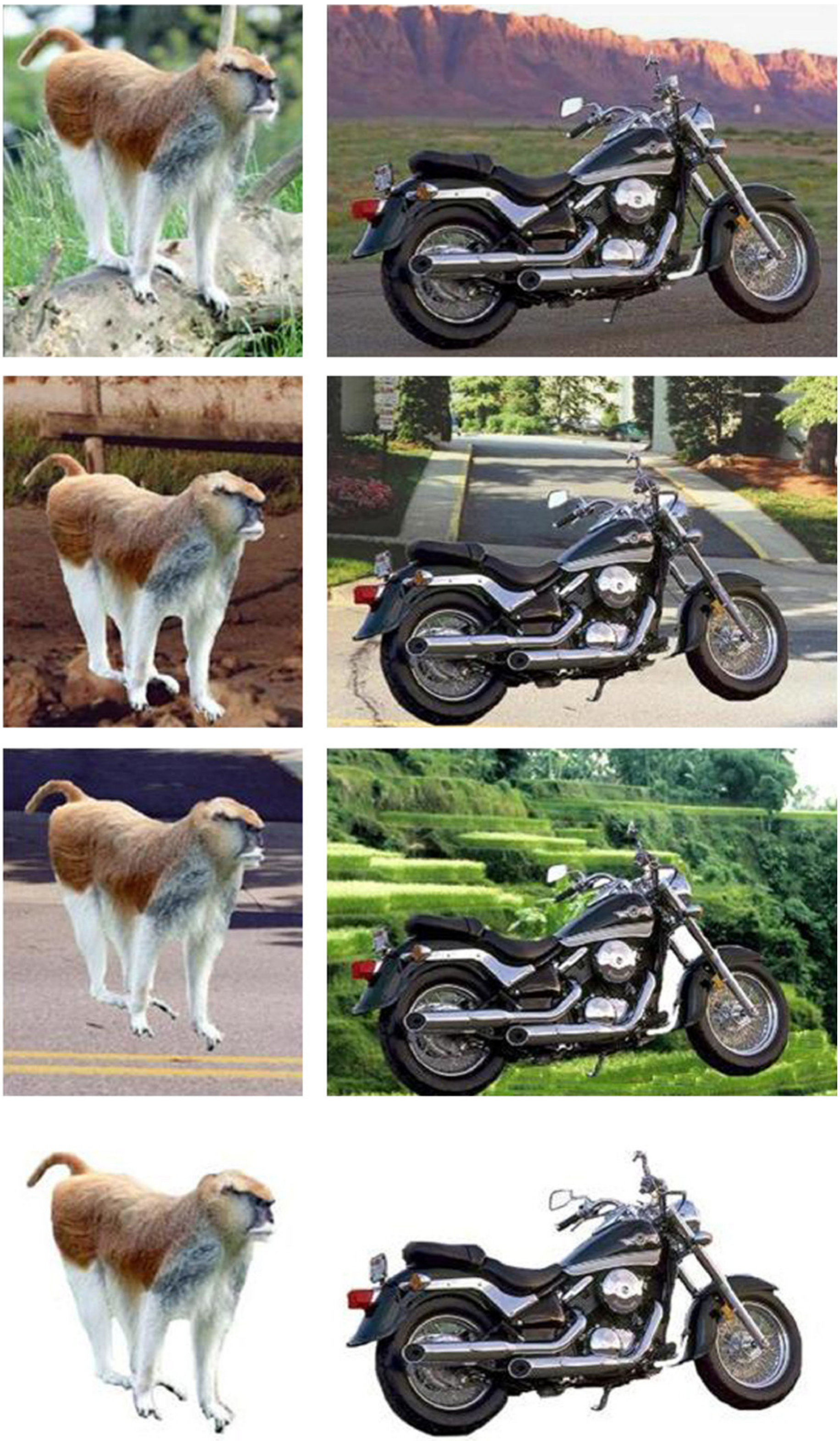

Fig. 1. Stimuli used in the (A) natural congruent object–context, (B) artificial congruent object–context, (C) incongruent object–context, and (D) object-only homogeneous context conditions.

2. Method

2.1. Participants

Ninety-two infants (*M* age = 181.51 days, *SD* = 9.07, 49 females) participated: 20 were tested in a natural congruent object–context, 32 in an artificial congruent object–context, 20 in an incongruent object–context, and 20 in a homoge-

Table 1
Object–context pairings for the images.

Object	Natural congruent object–context	“Artificial” congruent object–context	Incongruent object–context
Animals			
Bear	Amongst grass and rocks	Green field with trees in distance	Street, trees in distance
Bird	Edge of a lake	Alongside lake	Road, trees in distance
Cow	Green pasture on hillside	Garden with grass, flowers, and stones	Driveway, house in distance
Elk	Arid landscape, with bushes	Green and brown field with live oak trees	Parking lot, wood and brick wall in distance
Horse	Pasture with flowers and fence	Snow-covered forest	Parking lot, building in distance
Monkey	Tree log amongst tall grass	Arid field, placed on boulders	Road, yellow center line visible
Sheep	Green pasture	Green hillside (steppes)	Road, sidewalk visible
Squirrel	Tree branch	Green field with flowers	Driveway, wall in distance
Tiger	Green field	Sandy surface with beach grasses	Parking lot, store in distance
Vehicles			
Coup	Road, alongside side walk, flowers in distance	Parking lot, wood and brick wall in distance	Green and brown field with live oak trees
Delivery truck	Parking lot, street light in distance	Parking lot, store in distance	Green field with flowers
Hatchback	Gas station, pumps in distance	Street, trees in distance	Arid field, placed on boulders
Motorcycle	Road, mountain in distance	Road, yellow center line visible	Green hillside (steppes)
Pick up truck	Road, houses in distance	Parking lot, building in distance	Sandy surface with beach grasses
Sports utility vehicle	Parking lot, trees in background	Driveway, house in distance	Garden with grass, flowers, and stones
Sports car	Brown gravel driveway, stone wall in distance	Driveway, wall in distance	Snow-covered forest
Utility golf cart	Sidewalk, brick wall in distance	Road, sidewalk visible	Alongside lake
VW Bug	Driveway, house in distance	Road, trees in distance	Green field with trees in distance

neous context object-only condition. An additional 19 infants ($ns = 7$ in the natural, 3 in the artificial, 6 in the incongruent, and 3 in the homogeneous conditions) began the procedure, but their data were excluded because 16 fussed, 1 parent interrupted, and there were 2 experimental errors. Infants were all term and healthy at birth and at the time of testing. Families were recruited through the use of purchased mailing lists of newborns in a suburban metropolitan area and represented middle to high SES on the Hollingshead (1975) Four Factor Index of Socioeconomic Status (Bornstein, Hahn, Suwalsky, & Haynes, 2003).

2.2. Materials and apparatus

To assess infants' object categorization in the four different object–context relations, color photographs of nine animals and nine vehicles were first obtained in their natural environments, such as fields, forests, or lakesides (“nature” scenes) and streets, driveways, or parking lots (“residential” scenes) and subsequently digitally manipulated in a variety of ways (see below). The total stimulus set consisted of 72 full-color digitized images (Table 1). For the natural congruent object–context condition, the animals and vehicles were presented as they had been originally photographed, such that the animals appeared in “nature” scenes and the vehicles appeared in “residential” scenes (Fig. 1A). To make the incongruent object–context condition stimuli, we digitally manipulated the congruent object–context condition stimuli. Using a computer graphics software package, the target objects in the natural congruent object–context scenes were extracted from their contexts and then imported into new contexts with animals placed in “residential” scenes and vehicles placed in “nature” scenes for the incongruent condition (Fig. 1B). As a result, however, a congruent versus incongruent context comparison is confounded with natural versus manipulated images (in manipulated images the naturalness of figure-ground relations or the transition between figure and ground, edges, shading, lighting, and so forth may be distorted in some way – objects may look as if they are not part of the same scene, for example). Thus, the manufacture of incongruent scenes also creates other possible perceptual differences between congruent and incongruent scenes that could constitute a basis for possible differences observed, separate from any difference in object–context relations. We therefore created an experimental control, an artificial congruent object–context condition: Animals were placed in other “nature” scenes, and vehicles were placed in other “residential” scenes (Fig. 1C). The same objects and contexts served in the artificial congruent and incongruent conditions thereby controlling for the possibility that specific objects or contexts or object–context relations might affect object categorization. When objects are presented to participants in psychological studies, for experimental purposes the objects are often presented in neutral contexts, that is stripped of their normal context and hence of their ecological validity (Bronfenbrenner, 1979; Gibson, 1979). The use of stimuli that are of limited ecological validity in psychological research has been questioned (Neisser, 1976; Schmuckler, 2001). For comparison, completeness, and theoretical sakes, therefore, we also included an object-only homogeneous context condition. For the object-only homogeneous context scenes, each object (animal or vehicle) was placed in a white context (Fig. 1D).

The same objects served in all four conditions. Images in whole subtended 23° high by 29° wide on average, and target objects were 19° high by 26° wide. The percentages of the display that contained the target object did not differ between animals ($M = 66.36\%$, $SD = 14.02$) and vehicles ($M = 72.92\%$, $SD = 20.14$), t (70) = 1.60, *ns*, or across conditions, M natural congruent = 61.16%, $SD = 17.27$, M artificial congruent = 71.74%, $SD = 14.74$, M incongruent = 71.74%, $SD = 14.74$, and M homogeneous = 71.74%, $SD = 14.74$, $F(3, 68) = 2.12$, *ns*. Finally, the stimulus images with structured backgrounds were also uniform in mean spectral density across categories and conditions at both low (0.03–4.95 cy/cm) and high (11.55–16.50 cy/cm) spatial frequency bands, contrast *F*s ranging from .21 to .45, *ns*.

Altogether, the images we used varied substantially from one another (Table 1), they are representative of stimuli commonly used in infancy studies, and many researchers have demonstrated discrimination among animals and among vehicles in infants of the same age or younger than participated here (e.g., Behl-Chadha, 1996; Oakes et al., 1991).

2.3. Procedure

All infants were tested in a 1.5 m × 2.1 m dimly lit room. The stimuli were presented on a 21 cm × 29 cm videomonitor which was placed on a table at the infant's eye level. Each infant sat approximately 50 cm in front of the monitor in a reclining infant seat, with the parent in a nearby chair behind the infant. Parents were asked not to interact with infants during testing. A videocamera (positioned 38 cm behind and 18 cm above the monitor) projected the infant's face onto another monitor in an adjacent room. The camera and the rest of the testing room were occluded from the infant's view by curtains. A room adjacent to the testing room housed a VCR for presenting the images, a VCR and monitor for recording infant looking, and a microprocessor for collecting data on infants' looking.

Infants were randomly assigned to one of the four experimental conditions. For each condition, there were two habituation categories (animals and vehicles), and approximately half of the infants were habituated to one and half to the other. During the habituation phase, infants had the opportunity to view eight of the nine available images from the habituation category. The presentation order and which eight images were presented were determined randomly.

Infants were habituated following a standard infant-control procedure (Bornstein, 1985). All trials began with a minimum fixation of 0.25 s, and all trials terminated when the infant looked away for two continuous s or after 30 s of continuous looking at an image. The next image was presented following a 5-s intertrial interval. Between trials the monitor was dark. The mean of the first two trials determined the habituation baseline. The first trial had to last at least 5 s to be included in the baseline. The habituation phase ended when mean looking on two consecutive trials was 50% or less of the baseline; these two trials constituted the habituation criterion. Thus, the minimum number of trials in the habituation phase was 4. On each habituation trial, infants viewed a different image; if the habituation phase continued past eight trials, images were re-presented in their original order (*ns* = 4, 14, 8, and 5 for the natural congruent, artificial congruent, incongruent, and homogeneous conditions, respectively).

Following habituation, infants were presented four test trials followed by one posttest trial. On the test trials, infants viewed a familiar-category novel image (the ninth exemplar from the habituation category not seen during habituation) and a novel-category novel image (an exemplar from the object category not seen during habituation). The test stimuli were determined randomly with the constraint that each image served as a test stimulus at least once. The test series employed an ABBA design, and half of the infants viewed the familiar-category novel image on the first and last test trials, and the other half of the infants viewed the novel-category novel image on the first and last test trials. Following the test phase, all infants viewed a totally novel stimulus display for one trial.

Two experimenters conducted the study: One operated the VCR to present the stimuli, and the other recorded the infant's fixations via microprocessor. Infants were judged to look at the stimulus when a corneal reflection of the light from the display was in the center of the pupil. All experimenters were blind to which stimulus was being presented in each trial and the nature and hypotheses of the study. The microprocessor calculated the baseline, determined when the infant met the habituation criterion, and signaled the end of each trial by illuminating a LED. To obtain a measure of scoring reliability, a third experimenter also scored infant looking, either during the testing session or at a later time from the videorecord. Agreement was obtained for 95% of the sample, $r = .96$.

3. Results

Analyses for outliers (Fox, 1997) on all dependent variables were conducted, but no infants were excluded from the analyses. Preliminary analyses also tested for gender differences; as no main effects or interactions with gender were found, the analyses that follow include girls and boys together.

Table 2
Trials to habituation criterion and mean looking times (s) in habituation and test for different object–context relations.

Condition		Habituation			Test	
		Trials	Baseline	Criterion	Familiar category	Novel category
Natural congruent object–context	*M*	7.35	18.73	6.49a	5.92a,c	13.34b
	SD	3.41	7.12	3.49	3.20	8.40
Artificial congruent object–context	*M*	8.06	18.45	5.19a	6.02a,c	7.59b,c
	SD	4.08	7.38	3.19	5.06	5.56
Incongruent object–context	*M*	7.45	20.56	7.77a	9.56a,c	11.87b,c
	SD	3.38	8.17	4.04	5.34	6.23
Homogeneous object–context	*M*	7.35	13.23	5.73a	9.62a,c	12.15b,c
	SD	3.69	9.03	3.20	8.23	8.15

Note. Means in the same row with different letters significantly differ from each other.

3.1. Habituation analyses

The number of trials to habituation is shown in Table 2. A 2 × 4 ANOVA with habituation category (animal, vehicle) and condition (natural congruent object–context, artificial congruent object–context, incongruent object–context, homogeneous object–context) as between-subjects factors revealed no main effects or interactions, all Fs < .98, *ns*.

Infants' mean looking times during the habituation and test phases are also shown in Table 2. Infants' looking during the habituation phase was analyzed in a 2 × 4 × 2 ANOVA with habituation category and condition as between-subjects factors and trial (baseline, criterion) as a within-subjects factor. This analysis of the first categorization criterion revealed the expected main effect for trial, $F(1, 84) = 291.91$, $p < .001$, partial $\eta^2 = .77$, confirming that infants looked significantly longer on the habituation baseline trials ($M = 17.15$ s, $SD = 8.52$) than on the habituation criterion trials ($M = 6.15$ s, $SD = 3.52$). (Because the habituation criterion was 50% of the baseline, achieving criterion perforce means a significant difference in looking on the baseline and criterion trials. By the same logic, reaching the criterion means that infants habituated to the multiple-exemplar category series.) To rule out factors of fatigue accounting for the decline in looking during habituation, infants' looking to the posttest stimulus was compared to the habituation criterion trials, our second categorization criterion, in a parallel 2 × 4 × 2 ANOVA with habituation category and condition as between-subjects factors and trial (criterion, posttest) as a within-subjects factor. The analysis revealed a main effect for trial, $F(1, 84) = 316.60$, $p < .001$, partial $\eta^2 = .79$, ascribable to a significant increase in looking on the posttest trial ($M = 22.17$ s, $SD = 9.49$) compared to the habituation criterion trials ($M = 6.15$ s, $SD = 3.52$). Infants in all conditions thus gave evidence that they habituated to object categorical variation in all conditions.

3.2. Test trial analyses

To address the third and fourth criteria for categorization, a 2 × 4 × 3 ANOVA was conducted with familiarization category and condition again between-subjects factors and trial (criterion, familiar-category novel exemplar, novel-category novel exemplar) as a within-subjects factor. This analysis revealed a main effect for condition, $F(3, 84) = 4.24$, $p < .01$, $\eta^2 = .13$, a main effect for trial, $F(2, 168) = 24.59$, $p < .001$, $\eta^2 = .23$, a Condition × Trial interaction, $F(6, 168) = 54.50$, $p < .05$, $\eta^2 = .08$, and a Category × Trial interaction, $F(2, 168) = 7.16$, $p < .001$, $\eta^2 = .08$. The main effects for condition and trial were qualified by the interactions. Tests for simple effects with trial as a within-subjects factor were conducted for each condition. These analyses revealed significant main effects for trial for all four conditions, Fs$(2, 28) = 3.19$–13.82, ps < .05. As can be seen in Table 2, the source of the main effect for trial differed across conditions ($HSD = 3.83$, 2.31, 3.62, and 5.05 for the natural, artificial, incongruent, and homogeneous conditions, respectively). Infants in all four conditions generalized, showing nonsignificant differences between mean looking times for the habituation criterion and familiar-category novel-object test trials, the third criterion, but they dishabituated, showing significant increases in looking times to the novel-category novel-object test trial compared to the habituation criterion trials, the fourth criterion.

Tests for simple effects were also used to explore the Category × Trial interaction. Infants who were habituated to animals generalized from criterion to familiar-category test (M criterion = 5.85 s, $SD = 3.15$; M familiar test = 6.96 s, $SD = 5.23$; $HSD = 2.72$), dishabituated from criterion to novel-category test (M novel = 12.72 s, $SD = 8.30$), and showed a significant difference in looking between the familiar- and novel-category test trials. Infants who were habituated to vehicles generalized (M criterion = 6.44 s, $SD = 3.86$; M familiar test = 8.11 s; $SD = 6.39$, $HSD = 2.17$) and dishabituated (M novel = 8.89 s, $SD = 5.61$), but showed no difference in looking between the novel- and familiar-category test trials. As revealed in a separate follow-up study, the advantage for the animal category is likely not due to a simple preference. Fifty-nine infants (M age = 127.12 days, $SD = 9.78$; 22 females) participated, distributed roughly equally across the four conditions (an additional 12 infants began the procedure, but their data were not included due to fussiness or equipment failure). Each infant was presented with all 18 stimuli from the assigned condition, 9 animals and 9 vehicles, in one of two random orders with the constraint that no more than two images from the same category appeared consecutively. Stimuli were presented for 10 s each, and each trial was initiated when the infant was judged to be looking toward the display. Because each scene was shown only a single time, infants could not be biased by previous exposures to the stimuli or influenced by having seen a given object in multiple scenes or a given scene with different objects. The combined durations of infants' initial looking to objects and contexts showed no difference between animals (M = 3.51 s, SD = 3.19) and vehicles (M = 3.42 s, SD = 2.99), $F(1, 55) = .25$, *ns*, nor any effect of condition, $F(3, 55) = .69$, *ns*.

4. Discussion

Six-month-old infants in four conditions of object–context relations met several criteria of object categorization: they declined in looking to multiple category exemplars across an habituation phase, they dishabituated to a novel posttest stimulus, and they generalized looking to a novel exemplar from the familiar category but discriminated a novel exemplar from a novel category. In a nutshell, 6-month olds appear to categorize animals and vehicles and do so independent of the context in which they appear. In addition, infants who were habituated to animals showed significantly more looking to the novel-category exemplar than to the familiar-category exemplar in the test phase, whereas infants habituated to vehicles did not. In infant object categorization, animals may have a slight advantage over vehicles. Finally, these results are not ascribable to preference or processing differences. Convergent data and analyses showed that infants look initially at animals and vehicles equivalently and infants also habituate in similar numbers of trials to animals and vehicles and in each object–context condition.

The process of learning about categories of objects and generalizing to new category members is facilitated by encounters involving multiple objects from a given category. The decline in looking during multiple-exemplar habituation suggests that infants became familiar with animal and vehicle categories in each of the object–context relations, and their looking time declines cannot be attributed to receptor adaptation or effector fatigue as infants showed significant increases in looking to both novel-category novel-exemplar objects and the posttest stimulus.

Importantly, learning about object categories entails encoding object information and generalizing it across multiple contexts. In category learning, infants appear to focus on objects, and learning about object categories in multiple contexts presumably allows infants to ignore contextual information that is irrelevant to the object category *per se*. Whatever their contexts, objects are what is important in an object categorization task, and even if contextual details predict object categories, learning an object category involves learning to disregard certain contextual details.

This finding does not mean that infants are insensitive to object contexts or object–context relations. When the visual context of stimuli remains constant during encoding, infants are less likely to ignore contextual details, and this tendency leads to less success at retrieval if the context is changed at test. Haaf et al. (1996) found that 6-month olds' habituation to the same target object was slower when its background context varied from trial to trial than when a single context was present, and so concluded that, under these conditions, infants allocate attention to both object and context. In perception and recognition tasks, infants have demonstrated sensitivity to context and object–context relations. Infants use contextual information to aid retrieval, for example. Rovee-Collier and colleagues (Butler & Rovee-Collier, 1989; Rovee-Collier, Griesler, & Earley, 1985) trained 3-month olds to move an overhead crib mobile by kicking. During learning, the infants' cribs were lined with a colorful bumper (the context; see Baddeley, 1982). Changes in the bumper did not affect retention of the contingency 1 day later when the memory was easily retrieved. However, after delays of 3, 5, and 7 days, when the same mobile was present at training and retention, retrieval was evident only when the bumper surrounding the crib during the retention test matched the bumper present during training. Apparently, infants deploy their attention to and learn about objects and object–context relations in a selective and flexible fashion depending on prior experience, stimuli, and task (e.g., Ellis & Oakes, 2006; Mareschal & Tan, 2007). When varied objects across even diverse contexts are encoded, the formation of broad object categories ensues and leads to successful recognition of the object category regardless of the context.

The flexibility that underlies adaptive processing of the kind revealed here may change with development over the first 2 years of life. Robinson and Pascalis (2004) first familiarized infants and toddlers who were 6–24 months of age to an image of a toy against one colored background and then tested them either with the same toy and a novel toy presented against the same colored background or with the same toy and a novel toy against a different colored background. Infants at 6 and 12 months generalized looking to the novel toy when the context color changed at test, but dishabituated to the novel toy when color was constant. However, infants at 18 and 24 months recovered attention to the novel toy even when the color changed at test. As might be expected, moreover, the older participants in Robinson and Pascalis demonstrated more selective discrimination in the face of contextual variation.

Infants' categorized both animals and vehicles, but categorization of animals emerged as somewhat more robust than vehicles. In the test phase following habituation, both familiar-category and novel-category exemplars were both novel. Yet, infants who were habituated to animals showed a greater increase in looking to the novel-category exemplar compared to the familiar-category exemplar than did infants habituated to vehicles. Auxiliary findings showed that the advantage for the animal versus vehicle category was likely not due to a preference. Instead, it is possible that the difference in categorization performance reflects a general ontogenetic advantage for natural kinds over designed artifacts (Rakison & Poulin-Dubois, 2001). This finding accords with extant evidence that categorization of designed artifacts may not be as developed or robust for infants as categorization of natural kinds (e.g., Behl-Chadha, 1996). It could be that lower-level perceptual factors account for animate–inanimate processing differences. Hunnius and Geuze (2004) tracked infant eye movements over faces and abstract stimuli. Infants showed less advanced scanning when examining abstract stimuli versus faces. Newborn infants are drawn to faces (Johnson & Morton, 1991), and this biasing mechanism seems to push them to attend to heads, which infants use to differentiate object categories that have faces (e.g., animals) from those that do not (e.g., vehicles; Quinn, Doran, Reiss, & Hoffman, 2009). On a different level, Mandler (1992, 2000) claimed that young infants' category-related behavior is guided by a conceptual understanding about objects. In specific, she proposed that infants' early conceptual categories separate animate entities that are self-starting, move nonlinearly, and cause action at a distance from inanimate objects that are not self-starting, move linearly, and cannot cause action at a distance. Rakison and Poulin-Dubois (2001) concluded that an early animate–inanimate distinction in infancy is rooted in convergent features: (a) onset of motion (self-propelled versus caused motion), (b) line of trajectory (smooth versus irregular), (c) form of causal action (action at a distance versus action from contact), (d) pattern of interaction (contingent versus noncontingent), (e) type of causal role (agent versus recipient), (f) purpose of action (goal-directed versus without aim), and (g) influence of mental states (intentional versus accidental).

Our findings raise some new questions about object–context relations in infancy and infant object categories. Object size and location in the scenes were not factors in this experiment, either in the object–context congruency contrasts or in the animal–vehicle difference, as both parameters varied over only a narrow range. However, future work might investigate variation of object size and location in object categorization parametrically to understand more about the dimensions and robustness of infant object categories. We tested object categorization in 6-month olds immediately after familiarization. Does infant age play a role in object categorization and memory? Does context play a role in infant memory? It has been proposed that memory retrieval becomes increasingly context-dependent as infants develop from 3 to 6 months (Rovee-Collier, 1990). Furthermore, a greater role of context in memory may emerge at different ages in different situations. Generally, learning in multiple contexts is believed to facilitate memory in a new context (Amabile & Rovee-Collier, 1991). Reciprocally, infant memory retrieval appears to depend on some contextual information present during learning. Thus, retrieval fails when critical contextual information is absent. Borovsky and Rovee-Collier (1990) found an interaction obtained between context dependency and delay interval in that dependence faded with time. Memory retrieval in young infants depends on the context in which the memory is acquired (Rovee-Collier, Hayne, & Colombo, 2001, for a review). Long-term object memory appears to be flexible across contexts after a 1-day delay but not longer in 3-month olds (Butler & Rovee-Collier, 1989), and after delays of 5 days but not less in 6-month olds (Borovsky & Rovee-Collier, 1990). Here, we studied object categorization in visual contexts and determined it to be robust only in immediate tests.

How is categorization affected by other kinds of contexts? Fagen et al. (1997) investigated auditory contexts. Three-month-olds were trained in the presence of a musical sequence and tested for retention 1 or 7 days later in the presence of either the same or a different musical pattern. Infants displayed l-day retention regardless of the music that was played during the l-day test; at 7 days, however, retention was seen only when the music being played during the retention test matched the music that was played during training. These data accord with Rovee-Collier's findings that 3-month olds' memory is disrupted at long but not short retention intervals when the visual context present during retention testing does not match the visual context that was present during learning. In the same vein, Rubin, Fagen, and Carroll (1998) trained 3-month olds to kick to control the movement of an overhead mobile in the presence of an ambient odor. Again, retention was assessed 1, 3, or 5 days afterward. During the retention test, the olfactory context was either the same odor, a different odor, or no odor. At 1 day, infants exhibited retention when tested in the presence of the same odor. Infants in the no odor condition exhibited partial retention, whereas memory retrieval was completely disrupted for infants tested in the presence of the different odor. All groups showed forgetting after the 3- and 5-day intervals.

Finally, some contexts are proximal for objects, as visual, auditory, and olfactory environments might be: other contexts may be distal. Contextual dependency in infant object categorization and memory may differ between proximal and distal contexts. Hayne, Boniface, and Barr (2000) used the transition between the infant's home and a testing room in a psychology department. They found the impact of distal surroundings on stimulus encoding may be less important than that of proximal background.

Robust object categorization is adaptive, and knowledge of which objects and contexts tend to co-occur appears to be less influential in infant object categorization than it might be in infant perception or memory. Coincident with reports of older infants' category learning in varied conditions (e.g., Mareschal & Tan, 2008), the present findings indicate that 6-month-old infants' object categorization is flexible in its capacity to transcend variation in object–context relations.

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