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Hold your horses: How exposure to different items influences infant categorization

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Abstract

We investigated how exposure to pairs of different items (as compared to pairs of identical items) influences 10-month-old infants' ($N = 79$) categorization of horses versus dogs in an object-examining task. Infants responded to an exclusive category when familiarized with pairs of different items, but not when familiarized with pairs of identical items (Experiment 1), even when the frequency of exposure to each item was controlled (Experiment 2). When familiarized with pairs of identical items, infants failed to show evidence of memory for the individual exemplars (Experiment 3). Reducing the retention interval between presentations of different items in the identical pairs condition facilitated infants' recognition of an exclusive categorical distinction (Experiment 4). These results are discussed in terms of how exposure to collections of different items, and how opportunities to compare items, influences infants' categorization.

Every day people categorize as an efficient and effective way of organizing newly acquired information. Because infants are constantly exposed to new information, the ability to form categories may be especially important for them. Indeed, a large number of studies over the last 25 years has shown impressive categorization abilities in infancy (Bomba & Siqueland, 1983; Eimas, Quinn, & Cowan, 1994; Mandler & McDonough, 1998; Oakes & Ribar, 2005; Quinn, 1987; Quinn, Eimas, & Rosenkrantz, 1993; Quinn, Yahr, Kuhn, Slater, & Pascalis, 2002; Reznick & Kagan, 1983; Ribar, Oakes, & Spalding, 2004; Younger, 1985, 1990; Younger & Cohen, 1986; Younger & Furrer, 2003). Moreover, many debates have arisen over both the nature of and how to measure infants' categorization. For example, studies have examined whether the categories young infants form in experiments are exemplar or prototype based (Bomba & Siqueland, 1983; Younger, 1990). Such studies go beyond demonstrating that infants can categorize and begin to explore the processes underlying infants' formation of categorical representations.

It has become increasingly clear that infants' categorization is highly context dependent (Oakes, Coppage, & Dingel, 1997; Oakes & Ribar, 2005; Oakes & Spalding, 1997; Younger & Furrer, 2003), consistent with theories of adults' categorization. For example, Barsalou (1993) pointed out that how entities are conceptualized depends on factors such as encoding context and the person's immediate goal. Yamauchi, Love, and Markman (2002) observed that people

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categorized the same stimuli differently when engaged in different tasks. Consistent with these findings, research has revealed that infants at a particular age do not simply respond to a given set of categorical contrasts regardless of the stimuli used or the way those stimuli are presented. Rather, the category to which infants respond depends on variables such as infant age, the particular stimuli used, and the task. Typically, studies have examined infants' attention to adult-defined *exclusive* categories—those that include a relatively restricted set of items—a compared to adult-defined *inclusive* categories—those that include a broader range of items. For example, researchers have asked under what conditions do infants respond to the exclusive category of dogs *or* cats, as opposed to a more inclusive category that includes both dogs and cats (e.g., Oakes & Ribar, 2005; Quinn et al., 1993). Attention to such distinctions is context-dependent.

At 10 months, for example, infants' attention to the distinction between *land animals* and *sea animals* in an object-examining task depends on the variability of the familiarization stimuli (Oakes et al., 1997) and how frequently during familiarization particular items are presented (Oakes & Spalding, 1997). Infants as young as 4 months attended to the distinction between dogs and cats when presented with pairs of pictures (Oakes & Ribar, 2005; Quinn et al., 1993), but it is not until 6 months or later that infants respond to this same distinction when tested with pictures presented one at a time (Oakes & Ribar, 2005) or in an object-examining task (Mareschal, Powell, & Volein, 2003).

One factor that influences infants' categorization is whether items are presented singly or in pairs. Oakes and Ribar (2005) observed that 4-month-old infants attended to an exclusive category of dogs or cats when two different pictures were presented on each trial, but not when only one picture was presented on each trial. Similarly, Reznick and Kagan (1983) found that 14-month-old infants familiarized with pairs of different airplanes, women, cars, or dogs in a visual familiarization task were more likely to dishabituate to an out-of-category stimulus than were infants familiarized with pairs of identical pictures. Finally, Younger and Furrer (2003) showed that presenting novel items from the familiar category and a contrasting category side-by-side during test enhanced 9-month-old infants' recognition of the exclusive categories *horses or dogs* in an object-examining task.

Why would presenting items in pairs facilitate infants' attention to exclusive categories? Obviously infants must compare items both when they are presented one-at-a-time and when they are presented in pairs. Despite the fact that some studies have shown infants attend to categorical distinctions only when items are presented in pairs (Oakes & Ribar, 2005; Reznick & Kagan, 1983; Younger & Furrer, 2003), many studies have shown that infants categorize stimuli presented one at a time (e.g., Mandler & McDonough, 1998; Mareschal et al., 2003; Oakes et al., 1997; Oakes & Ribar, 2005). In these studies, infants must have compared items presented on different trials or else they would not have detected the similarities or differences among them. Thus, presenting items in pairs facilitates infants' attention to some categorical contrasts (using some stimuli), but it is not necessary for them to compare items.

Presenting items side-by-side may facilitate infants' attention to exclusive categorical distinctions by reducing the amount of time they must remember one item before they compare it to another item. Detecting similarities and differences between items encountered at different times requires that the memory for one item is compared with a second item currently in view. Because young infants' shorter-term memory abilities are limited (Rose, Feldman, & Jankowski, 2001; Ross-Sheehy, Oakes, & Luck, 2003) and their longer-term memories are less detailed than are the longer-term memories of older infants (Wilk, Klein, & Rovee-Collier, 2001), young infants may not make effective comparisons between a remembered item and another item. Indeed, Needham and her colleagues observed that infants detected different commonalities among items as a function of the amount of time between encounters with those

items. When the time between encounters was short—i.e., multiple items were encountered in the same experimental session—infants noticed commonalities and differences in details, such as the color of elements of the objects (Needham, Dueker, & Lockhead, 2005). When the time between encounters was longer—i.e., a 24 hour delay between encounters with the different items—infants seemed to notice only more general commonalities and differences between those same items (Dueker, Modi, & Needham, 2003). Thus, whether infants make comparison of items encountered at different times based on general or detailed commonalities and differences among them is determined, in part, by the amount of time infants must remember the first item before they encounter the second one.

Consider, the consequences of this for infants' categorization. An infant comparing a Golden Retriever encountered yesterday with a Beagle currently in front of him or her, for example, may only remember general details of the Golden Retriever—e.g., has a tail, four legs, fur, and so on. Therefore, the infant will only notice similarities and differences in those details and he or she may form a relatively broad category of dogs that may include other four-legged animals (e.g., a cat or a horse). If the infant encountered those two items at the same time, in contrast, he or she need only remember the first item (e.g., the Golden Retriever) for the period of time that he or she looks from that item to the other (e.g., the Beagle). Thus, more details are likely to be remembered, and similarities in differences in those details (e.g., type of tail, body, or head shape) will be detected. As a result, more exclusive categorical contrasts, such as the category *dog* that excludes other four-legged animals, can be formed. Therefore, infants may respond differently in experimental procedures in which two items are presented at time than those in which only one item is presented at a time because of differences in the memory demands involved in comparing items.

Consistent with this hypothesis, Oakes and Ribar (2005) observed that when tested in a task in which items were presented one-at-a-time in a series of infant-controlled trials (i.e., trials were initiated when infants looked at an attention-getter and ended when infants looked away from the stimulus), not only did 6-month-old infants respond to a more exclusive category than did 4-month-old infants, but 6-month-old infants had shorter inter-trial intervals than did 4-month-old infants. Older infants may have more effectively compared the items presented on different trials because they had to remember the items over a shorter inter-trial interval. The difference in inter-trial interval has implications for infants' need to hold the information in short-term or working memory (see Oakes & Bauer, 2007 for a review of developments in these aspects of memory). Differences in the demands on working memory—or the amount of time infants had to keep information active in memory for comparison with information presented on a subsequent trial—may have contributed to the developmental differences observed in this study.

The present investigation tested the hypothesis that infants attend to more exclusive categories when presented with pairs of different items because the inter-stimulus-interval is reduced. We conducted four experiments examining 10-month-old infants' attention to the distinction between *dog* and *horse* in an object-examining task (Oakes, Madole, & Cohen, 1991). Results reported by Younger and Furrer (2003) suggest that attention to this exclusive categorical distinction in this task at this age is relatively fragile—infants attended to this distinction only if items were in pairs during *test*. We extended this work by assessing how presenting items in pairs—as compared to one-at-a-time—during *familiarization* trials influences infants' attention to this distinction. This extension is important because previous studies examining differences in infants' attention to pairs versus singly presented items during familiarization have used a visual familiarization task (Oakes & Ribar, 2005; Reznick & Kagan, 1983). In the object-examining task, infants are given the opportunity to manipulate the items as they are familiarized. Thus, this extension will demonstrate whether the effect of presenting items in pairs during familiarization is robust and general.

In Experiment 1, we confirmed that infants attend to more exclusive categories—in this case, a category of dogs that excluded horses and vice versa—when familiarized with pairs of different items than when familiarized with pairs of identical items in an object-examining task (Oakes et al., 1991). Experiment 2 addressed the possibility that the number of times individual items were presented, and not whether they are presented in pairs or singly, that influences infants' categorization. Together Experiments 1 and 2 confirm that exposure to pairs of different items, and not some other variable, influences infants' attention to the exclusive category. In Experiment 3, we tested precisely what infants familiarized with pairs of identical items learn about the stimuli (a broad categorical representation such as animal versus the individual items presented during familiarization). In Experiment 4, we examined infants' attention to the exclusive categorical contrast in the identical pairs condition when the inter-stimulus-interval was eliminated, and therefore reducing the retention interval between presentations with different items (i.e., the period between trials).

Experiment 1

Experiment 1 sought to replicate the general effect observed by Oakes and Ribar (2005) and Reznick and Kagan (1983) that infants respond to a more exclusive categorical contrast when familiarized with pairs of different items than when familiarized with items one at a time. We extended this work by testing the effect of opportunities to compare in 10-month-old infants' categorization of dogs versus horses in an object-examining task (Oakes et al., 1991).

Method

Participants—A total of 38 infants participated. In this and all the experiments reported here, infants were full-term, healthy at time of testing, and with no history of vision problems. Six infants were excluded from the final sample for fussiness ($n = 3$) or experimenter error ($n = 3$). The final sample consisted of 32 10-month-old infants ($M = 43.58$ weeks; $range = 41.57$ to 45.29 weeks; 13 boys and 19 girls). Infants' names were obtained from county birth records, and parents were contacted by letter and a follow-up phone call. Infants received a small gift for their participation. In each sample reported here, infants were predominately from white middle class families. In Experiment 1, all mothers had graduated from high school and 56.25% had completed a bachelor's degree or higher.

Stimuli—The stimulus set consisted of 8 realistic plastic replicas of dogs (Black Lab, German Shepard, Golden Lab, Golden Retriever, Great Dane, Irish Setter, Pointer, and St. Bernard) and 8 realistic plastic replicas of horses (Appaloosa, Chestnut, Clydesdale Colt, Dapple Gray, Falabella, Fjord, Iceland, and White Mare) (see Figure 1). These replicas were small enough for 10-month-old infants to grasp and manipulate. The dog set ranged in height from 6.0 cm to 8.0 cm ($M = 6.7$ cm) and in length from 8.6 cm to 11.2 cm ($M = 9.4$ cm). The horse set ranged in height from 6.0 cm to 10.0 cm ($M = 8.2$ cm) and in length from 7.3 cm to 12.1 cm ($M = 9.7$ cm). The variability within the categories was comparable. In addition, 8 replicas of vehicles (Acura MD-X, Audi TT Roadster, Chevrolet SSR, Jaguar XK180, Plymouth Pronto Spyder, Porsche Boxter, Porsche 911 Carrera, and PT Cruiser) were used as a *post-test* in each experiment. The vehicles ranged in height from 1.8 to 3.7 cm ($M = 2.8$ cm) and in length from 11.2 to 12.9 cm ($M = 11.7$ cm).

To test for discrimination of the within category items, a separate group of 24 10-month-old infants ($M = 43.99$ weeks; $range = 42.43$ to 45.71 weeks; 12 boys and 12 girls) were presented with two discrimination tasks (one with dogs and one with horses, order of tasks counterbalanced across infants), presented in succession, separated by a short break. Each task consisted of two 30-s familiarization trials with the same pair of identical items (e.g., two identical Golden Retrievers) followed by two 30-s test trials in which the now familiar item was paired with a novel within category item (left-right position of the novel item was

counterbalanced across trials). The left-right position of the novel item was different for the first trial of the first and the second tasks, counterbalanced across infants. In addition, across all of the infants tested, each item was compared to 6 of the items in the same category. On each trial, infants' looking was coded as described in the *coding* section below. To test for discrimination, we examined infants' novelty preference score (duration of looking to the novel item divided by total looking during test). Initial analyses revealed no effect for task (first, second), category (dog, horse) or sex of infant on novelty preference scores. Comparing infants' average preference for the novel item to chance (.50) revealed that infants did discriminate the items ($M = .56$, $SD = .12$), $t(23) = 2.43$, $p < .05$, two tailed.

To assess infants' *a priori* preferences for the dogs versus horses, another group of 16 10-month-old infants ($M = 43.87$ weeks; $range = 43.0$ to 45.4 weeks; 8 boys and 8 girls) were presented with two 30-s trials in which a horse was paired with a dog (left-right position counterbalanced across trials). A one sample t-test comparing infants' preference for dog ($M = .50$, $SD = .17$) to chance (.50) revealed that infants did not have any systematic preferences for dogs over horses (or vice versa), $t(15) = -.08$, $p = .94$, two-tailed.

Procedure, apparatus, and design—The experiments reported here used a version of the standard *object-examining* procedure (Oakes et al., 1991; Ribar et al., 2004). Infants were seated on their parent's lap at a rectangular table across from an experimenter (see Figure 2). The experiment consisted of 16 30-s trials. On each trial, the experimenter placed items two at a time on the table in front of the infant and said "Look at these!" to direct the infant's attention to the toys. After placing the items on the table, the experimenter started timing the trial using a handheld stopwatch. During the 30-s trial, infants were allowed to manipulate the items any way that they wanted. If an item was dropped on the floor, the experimenter or the parent picked it up and placed it back on the table without adjusting the trial duration (Mandler & McDonough, 1998; Oakes et al., 1991; Ribar et al., 2004; Younger & Fearing, 1998; Younger & Furrer, 2003). At the end of each trial, the experimenter removed the two items and placed them out of sight, and only then initiated the next trial. Therefore, infants never saw more than two items at one time on the table. The sessions were videotaped using a video camera placed on a tripod behind and above the experimenter's left shoulder. The camera was focused on the infant and the table top.

The 16 trials were divided into separate familiarization, test, and post-test phases (although the trials were presented without interruption). The first 12 trials were the *familiarization phase*, during which infants were familiarized with six different items. Half of the infants were familiarized with dogs and half with horses. In addition, infants were randomly assigned to either an *identical pairs* familiarization condition, in which pairs of identical items were presented during familiarization (e.g., two Black Labs followed by two Golden Retrievers, followed by two Great Danes, and so on), or a *different pairs* familiarization condition, in which pairs of different items were presented during familiarization (e.g., Black Lab and Golden Retriever, followed by Great Dane and St. Bernard, followed by Irish Setter and German Shepard, and so on). Crossing of familiarization category and familiarization condition resulted in four separate groups ($n = 8$ in each group): infants familiarized with pairs of identical dogs, infants familiarized with pairs of identical horses, infants familiarized with pairs of different dogs, and infants familiarized with pairs of different horses. All infants, regardless of condition, received a randomly selected set of six different items from the familiarization category. Thus, the design equated the number of items presented on each trial, the number of different items presented during familiarization, and the amount of exposure to each familiarization item.

Immediately following familiarization, the *test phase* was administered. During this phase, infants received two 30-s test trials in which a novel within-category item was paired with an out-of-category item. For all infants, therefore, the test trials consisted of a dog paired with a

horse. For half of the infants the dog was the out-of-category item and for half of the infants the horse was the out-of-category item. Importantly, the same pairs were shown to infants familiarized with dogs and horses; as a result significant preferences for the novel out-of-category item will only be observed if infants who see the same pairs prefer the dog if they were familiarized to horses and prefer the horse if they were familiarized with dogs. The items were counterbalanced for left-right position across the two test trials; (the novel item was on the right on the first trial for half the infants and on the left on the first trial for the other infants).

The last two trials were the *post-test phase*. On these trials, a novel within-category item (a horse or a dog) was paired with a novel vehicle. The same items were presented on each trial, and the left-right position was counterbalanced across trials.

Coding—First, we coded the duration of infants' looking on each trial from the videotapes of the sessions as described in Ribar et al. (2004). Coders observed infants' behavior on each trial and recorded the duration of infants' looking at the toy. Often, in this procedure, only the portion of looking judged to be *examining* or *focused attention* is coded (Mandler & McDonough, 1998; Mareschal et al., 2003). Here, we chose to code overall looking rather than examining for two reasons. First, both the duration of examining and total looking will lead to the same conclusions about infants' response to novelty. Oakes et al. (1991) and Oakes and Tellinghuisen (1994) found that although examining time changed with object or category familiarity, the non-examining portion of looking remained constant. Thus, the same pattern is observed whether one analyzes total looking time (examining time + non-examining time) or just examining time, and conclusions about response to novelty will be the same from analyses of each measure. Obviously, if we were interested in understanding the differences between examining and non-examining looking, it would be important to code both behaviors. Second, overall looking is more reliably coded than is examining. Coders require more training to learn to code examining as compared to looking, coders exhibit more “drift” (e.g., becoming more or less conservative in their judgments of examining), and reliability rarely achieves the same level as is easily obtained for overall looking. Thus, the more reliable measure, overall looking, may be a more sensitive measure of infants' responses to novelty.

The test trials and post-test trials were copied onto a separate tape for coding. Thus, as they coded looking during test trials, observers were unaware of the infants' familiarization condition or the category presented during familiarization. Coders used a program developed for the Macintosh (Cohen, Atkinson, & Chaput, 2000) to code the duration of looking on each familiarization trial and the duration of looking to each item on each test trial (thus we could determine the amount of looking time to each item from the novel and familiar categories during test). A second observer coded looking time for at least 25% of the infants for each sample reported here. Across all of the samples reported here, reliabilities were very good: mean inter-observer correlation for the duration of looking on each trial was high ($r \geq .96$ for familiarization and $r \geq .98$ for test) and mean absolute difference between observers for the duration of looking was low ($M \leq .92$ s for familiarization and $M \leq .86$ s for test). In addition, to determine whether coders not only agreed on the amount of looking, but on the relative amount of looking to the left and right toy during each test trial, we compared the novelty preference scores (duration of looking to novel divided by total looking duration) calculated from the two observers' coding for each trial. The correlation between the novelty preference scores was .90 across all the experiments; therefore not only did the observers agree on how long infants looked during test, they also had high agreement for the proportion of time infants looked at the relatively novel item.

Second, we coded the number of times infants switched their gaze from one toy to the other on each familiarization trial, a measure that is similar to the number of *vacillations* described by Reznick and Kagan (1983). We used this measure of “switching” as an indicator of infants'

level of engaging in active comparison. Although it is possible that infants actively compare items without frequent looking back and forth between them, we reasoned that such glances back and forth allowed infants to “sample” the two stimuli more frequently, and perhaps to compare different aspects of the stimuli on each glance (e.g., the ears, then the tails, then the feet). Thus, this measure provides one way of testing whether the infants in the two conditions were engaged in different types of comparison of the stimuli.

The videotaped sessions were digitized, and coders used QuickTime to watch the familiarization sessions on a Macintosh computer. Coders indicated frame-by-frame whether infants switched their looking from one toy to the other (individual looks had to be at least 2 frames, or 667 ms, to count as a look; looks of only 1 frame were judged to be a part of an eye movement passing over the toy). A second observer coded the number of switches for 25% of the infants for the sample reported here. As with looking time, reliabilities were very good: mean inter-observer correlation for the number of times infants switched was high ($r \geq .94$) and mean absolute difference between observers for the number of switches was low ($M \leq .37$).

Results

Familiarization—Infants' behavior during familiarization, test, and post-test were analyzed separately. First, to test the effects of category and condition on looking during familiarization, as well as to establish that infants decreased looking during familiarization, we analyzed changes in infants' duration of looking during each block of three familiarization trials. We entered the average duration of looking in each block into a 2 (Familiarization Category: Dogs versus Horses) $\times$ 2 (Familiarization Condition: Identical Pairs versus Different Pairs) $\times$ 2 (Gender: Male versus Female) $\times$ 4 (Trial Block) mixed-model Analysis of Variance (ANOVA). The only significant effect was the main effect of Trial Block, $F(3, 72) = 22.37, p < .0001$, partial eta squared = .47, indicating that the group of infants as a whole decreased their looking across familiarization blocks (see Table 1). Tukey/Kramer post-hoc comparisons among the means revealed that overall infants looked longer in blocks 1 and 2 than in blocks 3 and 4, $p < .05$. There were no effects of condition or category, suggesting that looking during familiarization by all groups of infants was similar.

We also examined whether infants looked back-and-forth between items more when familiarized with two different items as compared to when familiarized with two identical items. If familiarization with pairs of different items induces different kind of comparison, infants may engage in more glances back-and-forth between the items than when familiarized with pairs of identical items. We entered the average number of switches (i.e., glances between items) in each block of familiarization trials in a mixed-model ANOVA as described above. This analysis revealed only a main effect of block, $F(3, 72) = 5.90, p < .01$, partial eta squared = .20, due to infants exhibiting more switches during trials in block 1 ($M = 5.01, SD = 2.49$) than in block 2 ($M = 3.79, SD = 1.90$), block 3 ($M = 3.96, SD = 2.08$), or block 4 ($M = 3.30, SD = 2.06$), Tukey-Kramer $p < .05$. Interestingly, infants who received different pairs of items shifted their glance between items about the same number of times on each trial on average ($M = 4.15, SD = 2.36$) as did infants who received identical pairs of items ($M = 3.88, SD = 2.05$). Thus, presenting infants with pairs of different items did not induce more active looking back-and-forth between those items than did presenting infants with pairs of identical items.

Test—To determine whether infants attended to the exclusive category presented during familiarization, we evaluated their responding at test. Specifically, we calculated preference scores for the novel out-of-category item by dividing the looking time to the out-of-category item by the total looking time to the out-of-category and within category items for each of the two test trials. The mean preference scores for the identical pairs and different pairs conditions

are presented in the leftmost portion of Figure 3. Infants in the different pairs condition preferred the novel out-of-category item, but the infants in the identical pairs condition did not, replicating the pattern reported by Oakes and Ribar (2005) and by Reznick and Kagan (1983), and suggesting that familiarization with different pairs enhanced attention to the subtle similarities that define the exclusive category.

These conclusions were confirmed with a 2 (Familiarization Category: Dogs versus Horses) $\times$ 2 (Familiarization Condition: Identical Pairs versus Different Pairs) $\times$ 2 (Gender: Male versus Female) ANOVA conducted on infants' preference for the out-of-category item. This analysis revealed a significant main effect of familiarization condition, $F(1, 24) = 6.82, p < .05$, partial eta squared = .22, with the average preference score for those infants familiarized with different pairs ($M = .64$ s, $SD = .22$ s) being higher than infants familiarized with identical pairs ($M = .51$ s, $SD = .16$ s).

The analysis also revealed an unexpected familiarization category by gender interaction, $F(1, 24) = 5.34, p < .05$, partial eta squared = .18. Collapsed across condition (identical versus different pairs), girls familiarized with horses ($M = .64$ s, $SD = .16$ s) and boys familiarized with dogs ($M = .62$ s, $SD = .15$ s) had higher preference scores than did boys familiarized with horses ($M = .53$ s, $SD = .25$ s) and girls familiarized with dogs ($M = .50$ s, $SD = .24$ s). However, this effect did not interact with condition (recall that approximately half of the infants in each of these groups was familiarized with different pairs), and it was not observed in any of the other experiments reported here. In addition, there was no gender difference found in the preference control experiment. Therefore, we assume this effect is not robust, but rather reflects idiosyncratic responding of a few infants and it is not relevant to our main hypotheses.

Comparing preference scores in an ANOVA demonstrates that infants familiarized with different pairs responded differently during test than did infants familiarized with identical pairs—clear evidence that exposure to different items on the same trial influences infants' attention to the categorical distinction. However, this analysis does not provide any information about whether either group of infants attended to the novel out-of-category item more than would be expected by chance. To answer this question we also performed one sample t-tests comparing infants' preference scores for the out-of-category item to chance (.50), and these comparisons corroborated the results of the ANOVA: infants in the different pairs condition had a preference score that was significantly greater than chance, $t(15) = 2.65, p < .05$, two-tailed, Cohen's $d = .66$, and infants in the identical pairs condition did not have a preference score that significantly differed from chance, $t(15) = .34, p > .05$, two-tailed, Cohen's $d = .09$ (see left portion of Figure 3). Moreover, 13 of the 16 infants in the different pairs condition had a preference score above chance, one sample sign test $p < .05$, whereas only 9 of the 16 infants had a preference score above chance in the identical pairs condition, one sample sign test $p > .05$. Together, all of these results show that the infants familiarized with different pairs of items looked significantly longer at the novel out-of-category item at test. Infants familiarized with identical pairs of items looked equally to the dog and horse at test.

Although the analysis of the number of switches did not differentiate infants in the two conditions, it is possible that this behavior was predictive of infants' responding during test. We calculated the correlation between the average number of switches (across all 12 familiarization trials) and infants' novelty preference to the new out-of-category item. This correlation was not significant for either the identical pairs condition, $r = -.19$, or the different pairs condition, $r = .11$; moreover, these two correlations did not differ significantly from each other, $z = .76, p = .45$. In addition, approximately half of the infants in each condition exhibited at least one switch on each familiarization trial, and there were no differences in either condition between infants who consistently looked back and forth between the two stimuli and infants who did not look back and forth between the two stimuli. Thus, performance on the test did

not seem to reflect differences in how infants' engaged in active looking back-and-forth between the two items presented on each trial, regardless of those two items were different or identical.

Post-test—Finally, we evaluated infants' preferences for the vehicle during the post-test phase. Unlike infants' responding during tests, these preference scores were uniformly high (see Figure 3). The ANOVA conducted on the scores revealed no significant effects, and the score for infants in the different pairs condition was different from chance, $t(15) = 23.11$, $p < .001$, Cohen's $d = 5.78$, as was the score for the infant in the identical pairs condition, $t(15) = 22.44$, $p < .001$, Cohen's $d = 5.61$. Moreover, all 32 infants had preference scores that were greater than .50. Thus, although infants in the identical pairs condition failed to prefer a novel out-of-category item that was from within the same superordinate category (e.g., a horse if familiarized with dogs), they did prefer a novel item from a different superordinate category (e.g., a vehicle).

Discussion

The results of this experiment extend previous findings that have shown infants respond to more exclusive categories when items are presented in pairs than when those same items are presented one at a time (Oakes & Ribar, 2005; Reznick & Kagan, 1983; Younger & Furrer, 2003). Importantly, we observed a robust effect of familiarization with pairs of different items in this experiment in which all infants received the same number of different items during familiarization (six), the same number of familiarization trials (12), the same number of items presented on each trial (two), and the same amount of exposure to each item. Thus, this experiment confirms the results of previous studies in a more tightly controlled experimental design, providing strong evidence that presenting different items side-by-side helps infants discover the features that define exclusive categorical distinctions.

In addition, these results demonstrate that the effects of presenting pairs of different items are general and not restricted to tasks in which infants are presented with pictures of items. The results reported here are consistent with those reported by Oakes and Ribar (2005) and Reznick and Kagan (1983) in which infants were exposed to pictures of the category items. Thus, the effect is not specific to a particular task, stimulus presentation, or categorical contrast.

In Experiment 2 we tested a possible alternative explanation for the pattern we observed here. In Experiment 1, we controlled for the number of items presented on each trial, the number of individual items presented during familiarization, and the amount of time infants had (on average) to explore each item; but, each item in the different pairs condition was presented on 4 familiarization trials, whereas each item was presented on only 2 familiarization trials in the identical pairs condition. Because frequency of presentation of individual items can contribute to classification of items both in adults (Homa, Dunbar, & Nohre, 1991; Nosofsky & Palmeri, 1997) and in infants (Oakes & Spalding, 1997), it is possible that infants in the different pairs condition attended to the exclusive category because items were presented on more different trials. To test for this possibility in Experiment 2 we tested infants in the different pairs condition, but each item was presented on only 2 trials.

Experiment 2

Method

Participants—Eighteen infants who had not participated in Experiment 1 participated in Experiment 2. Two infants were excluded from the final sample for fussiness ($n = 1$) or experimenter error ($n = 1$), resulting in a final sample of 16 10-month-old infants ($M = 43.71$

weeks; *range* = 41.86 to 45.57 weeks; 6 boys and 10 girls). All mothers had at least completed high school and 72.22% had completed a bachelor's degree or higher.

Stimuli—Stimuli were identical to those used in Experiment 1.

Procedure, apparatus, and design—The procedure was the same as the different pairs condition except that during familiarization infants received 6 trials each 60-s in duration. Thus, each individual item was presented twice during familiarization, but the amount of exposure to each item was identical to that in Experiment 1. Half of the infants were familiarized with pairs of different dogs and the other half were familiarized with pairs of different horses. The test and post-test trials were identical to those of Experiment 1.

Coding—We coded for looking as described in Experiment 1.

Results

Familiarization—Infants' looking during familiarization, test, and post-test was analyzed separately. Looking times during familiarization were averaged across blocks of two consecutive familiarization trials and entered into a 2 (Familiarization Category: Dogs versus Horses) $\times$ 2 (Gender: Male versus Female) $\times$ 3 (Trial Block) mixed-model ANOVA. There was a significant main effect of Trial Block, $F(2, 24) = 4.03$, $p < .05$, partial eta squared = .25, indicating that infants decreased their looking between trial blocks. Post-hoc comparisons among the mean using Tukey/Kramer HSD revealed that overall infants looked longer in block 1 ($M = 36.27$, $SD = 7.30$) than in block 3 ($M = 29.43$, $SD = 9.11$), $p < .05$.

Test—Next, to assess whether or not infants responded to the exclusive category we performed a one-sample *t*-test comparing infants' average preference scores for the novel item to chance (.50). As was observed for the different pairs condition of Experiment 1, infants familiarized with different pairs in Experiment 2 significantly preferred the novel out-of-category item, $t(15) = 2.90$, $p = .01$, two-tailed, Cohen's $d = .73$ (see middle portion of Figure 3). In addition, 12 of the 16 infants had a preference score above .50, one sample sign test $p = .08$. Thus, when familiarized with six 60-s familiarization trials with pairs of different items, infants attended to the exclusive categories of dog and horse, as did the infants familiarized with 12 30-s familiarization trials with pairs of different items in Experiment 1.

Post-test—Finally, we evaluated infants' responding to the post-test trials. Infants preferred the novel vehicle to the novel within-category item, $t(15) = 9.83$, $p < .001$, two-tailed, Cohen's $d = 2.46$ (see Figure 3). All of the 16 infants had novelty preference scores greater than .50.

Discussion

These results indicate that infants in the identical pairs condition of Experiment 1 did not fail to differentiate dogs from horses simply because each item was presented on only two trials. In Experiment 2, when the frequency of presentation of each individual item was the same as that in the identical pairs condition of Experiment 1 but pairs of different items were presented on each trial, infants differentiated the categories. Together Experiments 1 and 2 demonstrate that when familiarized with pairs of different items, infants form an exclusive category, even when controlling for the number of items presented, the number and duration of trials, and the frequency of the presentation of individual exemplars.

Experiment 3

What did infants learn when familiarized with pairs of identical items? In Experiment 1, infants in the identical pairs condition looked equally at the novel within-category and the novel out-

of-category items, but they looked longer at a vehicle than at a within-category item. This pattern of looking is ambiguous and may reflect either that infants remembered the individual exemplars during familiarization (and thus both the novel within-category and the novel out-of-category items were novel) or that they responded to a very broad category that included both dogs and horses (and thus both items were familiar). In Experiment 3, we tested these alternatives by assessing infants' memory for the particular familiarization items following familiarization with pairs of identical items.

Method

Participants—Nineteen infants who had not participated in the previous experiments were tested. Three infants were excluded for fussiness ($n = 2$) or experimenter error ($n = 1$), yielding a final sample of 16 10-month-old infants ($M = 44.47$ weeks; $range = 43.43$ to 45.71 weeks; 6 boys and 10 girls). All mothers had completed at least a two year associate's degree and 68.75% had completed at least a bachelor's degree.

Stimuli—The stimuli were the same as in the previous experiments.

Procedure, apparatus, and design—All infants were familiarized in the identical pairs condition of Experiment 1 (half with dogs and half with horses). During the test phase, infants received an item that they had seen during familiarization paired with a novel item from within the same category (e.g., infants familiarized with dogs were tested with a dog that they had seen before paired with a new dog).

Coding—We coded for the duration of looking on each trial as described earlier.

Results

Familiarization—Looking times during familiarization were averaged across blocks of three consecutive familiarization trials and entered into 2 (Familiarization Category: Dogs versus Horses) $\times$ 2 (Gender: Male versus Female) $\times$ 4 (Trial Block) mixed-model ANOVA. There was a significant main effect of Trial Block, $F(3, 36) = 5.92$, $p < .01$, partial eta squared = .33, indicating that infants decreased their looking between trial blocks. Post-hoc comparisons among the means using Tukey/Kramer HSD revealed that overall infants looked longer in block 1 than in block 4, $p < .05$ (see Table 1).

This analysis also revealed unexpected significant main effects of category, $F(1, 12) = 7.66$, $p < .05$, partial eta squared = .39, and gender, $F(1, 12) = 14.68$, $p < .01$, partial eta squared = .55. The first effect was due to infants who were familiarized with dogs looking longer overall than did infants familiarized with horses ($M = 14.9$ s, $SD = 4.51$ s and $M = 13.1$ s, $SD = 3.86$ s respectively), and the second effect was due to girls looking less overall than boys ($M = 12.76$ s, $SD = 3.61$ s and $M = 16.03$ s, $SD = 4.56$ s respectively). Importantly, the magnitude of these effects was small and these effects were not observed in any of the other experiments reported here. Moreover neither familiarization category nor gender interacted with block. Thus although some groups of infants may have looked longer overall during familiarization, there is no evidence that some groups of infants decreased their looking to a greater degree than others.

Test—To assess whether or not infants remembered the individual exemplars presented during familiarization, we calculated preference scores by dividing the looking time to the novel item by the total looking time to the novel and familiar items for each of the two test trials. The preference scores are presented in the middle portion of Figure 3 and it can be seen that when familiarized with identical pairs, infants did not significantly prefer the novel item, $t(15) = .79$, $p > .05$, two-tailed, Cohen's $d = .20$. In addition, only 7 of the 16 infants had a preference

score above chance, one sample sign test $p > .05$. Thus, infants familiarized with identical pairs of dogs (or horses) looked approximately equally to the novel and the familiar items at test. Thus, we have no evidence that infants learned the individual items.

Post-test—These infants did prefer the novel vehicle to the novel within-category item, $t(15) = 22.53, p < .001$, two-tailed, Cohen's $d = 5.63$ (see middle portion of Figure 3). All the infants had novelty preference scores above .50. Thus, infants appeared to form a broad category that included dogs and horses but not vehicles.

Discussion

Familiarization with identical pairs of items does not appear to induce infants to remember the individual items. Importantly, both groups of infants familiarized with identical pairs (the infants in Experiment 3 and the infants in the identical pairs condition of Experiment 1) did exhibit a preference for a vehicle paired to a novel category item; we therefore have evidence that infants did learn something about the stimuli when familiarized with one exemplar at a time. However, infants did not appear to learn the features that define exclusive categories of dogs versus horses (Experiment 1), nor did they appear to learn the features that identify unique individual dogs or horses (Experiment 3). Instead, infants seemed to have formed a very broad category—one that includes both dogs and horses (but not vehicles). This findings is consistent with previous studies in which infants of this age in similar tasks (presented with one item at a time) tend to form broad categories (Mandler & McDonough, 1998; Oakes et al., 1997). It is possible that infants recognize the differences among the individual items and yet failed to find those differences compelling (therefore responding equivalently to the familiar and novel within-category items). Even in this case, however, Experiments 1 through 3 clearly show that infants more robustly attend to subtle commonalities and differences among items when familiarized with pairs of different items than when familiarized with pairs of identical items.

Experiment 4

Why does familiarization with pairs of different items facilitate infants' responding to more exclusive categorical contrasts? One possibility is that familiarization with pairs of different items reduces the memory demands required to compare the items, relative to familiarization with pairs of identical items. When items are presented in different pairs, the inter-stimulus-interval is effectively zero—infants can move their glance from one item to the other. When items are presented in identical pairs, in contrast, the inter-stimulus-interval is the inter-trial-interval—there is a several second retention interval between encounters with different items. As a result, infants must maintain a memory for items encountered on one trial during that inter-trial interval to compare them to items encountered on the next trial. Infants may more effectively notice the subtle commonalities and differences in the details of items when presented with pairs of different items because they do not have to hold one item in working or short-term memory for any period of time before they compare it to another item. In Experiment 4 we tested this hypothesis by familiarizing infants with identical pairs, but eliminated the inter-stimulus-interval, and thus the memory interval, between trials.

Method

Participants—A total of 19 infants who had not participated in the previous experiments participated in Experiment 4. Three infants were excluded from the final sample due to experimenter error. In addition, one infant had a novelty preference that was more than 2.5 standard deviations less than the mean (this infant exhibited a novelty preference that was well below that exhibited by all of the infants in all of the experiments reported here). The data from this infant was not included in any of the reported analyses. Thus, the final sample consisted of 15 10-month-old infants ($M = 43.73$ weeks; $range = 41.85$ to 45.86 weeks; 6 boys and 9

girls). All mothers had graduated from high school and 66.67% had completed a bachelor's degree or higher.

Stimuli—Stimuli were identical to those used in the other experiments.

Procedure, apparatus, and design—All infants were familiarized in the identical pairs condition of Experiment 1, half with dogs and half with horses. The procedure was the same as the identical pairs condition of Experiment 1 with one notable exception. Specifically, in-between trials instead of completely removing one set of items and only then presenting the next set of items, in this experiment at the end of the trial the experimenter presented one of the items from the next pair (and thus there were three items on the table), removed one of the old items (thus leaving one old item and one new item), presented the second new item, and then removed the final old item (see Figure 4). Note that this procedure allowed infants a brief exposure to different sets of items. This transition took 7.78 s ($SD = .74$) on average, during which time the experimenter was busy presenting and removing individual items (this period was comparable to the inter-trial-interval in Experiment 1, which was 5.59 s, $SD = 1.32$). An ANOVA conducted on the inter-trial-interval across the 11 trial transitions of this experiment revealed no effect of trial, $F(1, 10) = 1.48$, $p = .15$. Therefore, the inter-trial interval did not vary from the beginning to the end of the session (range from 7.25 to 8.33 s).

After the final familiarization trial, the experimenter removed each item one at a time before continuing with the test trials. During the test and post-test phases, the two new items were presented as in Experiments 1-3.

Coding—Coding for looking was as described in Experiment 1. In addition, we coded infants' looking behavior during the transitions between trials. The videotaped sessions were digitized, and coders used QuickTime to watch the familiarization sessions frame-by-frame on a Macintosh computer. Specifically, coders recorded how long during the transition between each pair of trials that infants looked at the toy versus looking at experimenter or around the room. A second coder recorded the looking for four infants (27% of the sample). Agreement between the two coders for the proportion of the inter-trial intervals that infants spent looking at the toys was good, average $r = .93$ and average mean difference in percentage score was 4%.

Results

Familiarization—The ANOVA conducted on infants' looking during familiarization revealed a significant interaction of Block by Familiarization Category interaction, $F(3, 33) = 2.994$, $p < .05$, partial eta squared = .21, driven by a decrease in looking by infants familiarized with horses (Block 1 $M = 18.69$ s, $SD = 4.88$; Block 2 $M = 14.13$ s, $SD = 4.02$; Block 3 $M = 12.33$ s, $SD = 3.36$; Block 4 $M = 11.96$ s, $SD = 4.11$) and no decrease in looking by infants familiarized with dogs (Block 1 $M = 12.73$ s, $SD = 5.47$; Block 2 $M = 9.90$ s, $SD = 5.39$; Block 3 $M = 12.43$ s, $SD = 3.85$; Block 4 $M = 13.48$ s, $SD = 6.82$). Indeed, separate ANOVAs conducted on the looking times for each familiarization group revealed a significant main effect of Block in the horse condition, $F(3, 15) = 4.918$, $p = .01$, but not for the dog condition, $F(3, 18) = .945$, $p > .05$. Note that this effect reflects infants who were familiarized with dogs looking less during the initial familiarization blocks than did infants who were familiarized with horses; at the end of familiarization, infants in the two groups exhibited approximately the same level of looking. Because no systematic preferences were observed across the all experiments, the discrimination task, and the preference task, we assume that there are no significant differences in a priori interest to the dogs and horses.

It is not clear why infants familiarized with dogs failed to decrease their looking as a group. In fact, across the whole sample 12 of 15 infants did decrease their looking from block 1 to

block 4, suggesting that the failure of the group of infants familiarized with dogs to significantly decrease their looking was due to a few infants showing an atypical pattern. Moreover, comparing infants' looking on the first trial ($M = 18.46$, $SD = 5.77$) to trial 12 ($M = 13.05$, $SD = 5.96$), revealed that infants in the group as a whole did decrease their looking, $t(14) = 2.89$, $p = .01$, two-tailed. Thus, there is some evidence that the infants in this experiment did decrease their looking during familiarization, and the apparent failure of infants to decrease looking (as measured by changes in looking over blocks of 3 trials) reflected the responding of a few infants.

Transition—To determine how infants behaved during the transitions between trials, we examined their looking during those trial transitions. Of the 7.78 s inter-trial-interval, infants looked at the toys for only 1.97 s, or 25% of the time. The duration and proportion of the time available that infants' spent looking at the toy did not vary across the session (range from 1.67 to 2.59 s, or 20% to 30%), $F's < 1.0$. Thus, rather than using the time when different toys were available to scrutinize the difference between them, infants spent this time looking at other things (usually the experimenter who was busily introducing and removing toys). Therefore, infants did not use the transition to look at the toys or to glance back and forth between the different toys presented at the same time.

Test—Next, we examined infants' responding during test. We conducted a one sample t-test for infants' preference scores for the out-of-category test item to chance (.50). As can be seen in the rightmost portion of Figure 3, the group of infants as a whole significantly preferred the out-of-category item, $t(14) = 2.76$, $p < .05$, two-tailed, Cohen's $d = .71$. In addition, 12 of the 15 infants had a preference score above chance, one sample sign test $p < .05$. Thus, the brief transition was sufficient to induce infants to learn the exclusive category. It should be pointed out that the preference scores for infants familiarized to dogs ($M = .57$, $SD = .16$) was not different from that for infants familiarized to horses ($M = .64$, $SD = .13$), $t(13) = .87$. Conducting the analyses without the 3 infants who failed to decrease their looking during familiarization did not change the overall results. Therefore, infants' significant preference for the novel out-of-category item during test is robust and characteristic of the sample as a whole. Experiment 4 suggests that familiarization with different pairs of items induces infants' attention to exclusive categorical contrasts because it reduces the amount of time infants need to remember one item before they investigate another item.

Post-test—Finally, we compared infants' preference for the vehicle during post-test to chance and observed once again that infants preferred the novel vehicle to the novel within-category item, $t(15) = 12.53$, $p < .001$, two-tailed, Cohen's $d = 3.23$ (see Figure 3). All 15 infants had preference scores greater than .50.

Discussion

Experiment 4 revealed that infants' recognized the exclusive categorical distinction in the identical pairs condition when the inter-stimulus interval was reduced to 0 s. Infants in Experiment 4 performed similarly to the infants in Experiments 1 and 2 who were presented with pairs of different items during familiarization. Indeed, an ANOVA comparing the preference for the out-of-category item of infants in the identical pairs condition of Experiment 1 with that of infants in Experiment 4 with Experiment (1, 4), Familiarization Category, and gender as factors revealed a main effect of Experiment, $F(1, 23) = 8.43$, $p < .01$, partial eta squared = .27, indicating that infants in Experiment 4 had significantly higher novelty preference scores than did infants in Experiment 1 (This ANOVA also revealed gender effects like those observed when comparing infants in the two conditions of Experiment 1. In this ANOVA, however, these gender effects were primarily restricted to the different condition of

Experiment 1, suggesting that those effects were not general, but were characteristic of the group of infants observed in Experiment 1).

Therefore, it appears that presenting items in pairs influences infants' categorization in part because this procedure reduces the memory demands of comparing items. When two different items are presented side-by-side, as in the different pairs conditions of Experiments 1 and 2, the inter-stimulus-interval can be extremely short—as long as it takes the infant to look from one object to the other. Experiment 4 approximated this situation in the identical pairs condition by providing an extremely short inter-stimulus-interval *between* trials. Recall that in Experiment 1, infants glanced back and forth between the two items presented on each trial equally often when presented with identical pairs and when presented with different pairs, and infants in Experiment 4 did not spend the brief transition looking at the toys. Thus, it does not appear that infants use the time when multiple items are together to look back-and-forth between stimuli, at least not anymore than they do when they see multiple identical items together. Thus, these results suggest that presenting items in pairs facilitates comparison by reducing the memory demands of comparison, not by inducing more looking back and forth between the objects.

General Discussion

These experiments contribute significantly to our understanding of how encountering different items at the same time influences infants' categorization. Although there is no question that infants must compare items to form categories when they encounter items one at a time (similarities and differences can only be detected by comparing items), these experiments confirm that presenting infants with different items side-by-side can facilitate their attention to an exclusive categorical distinction. Importantly, across experiments we controlled for the number of items presented on each trial, the number of different items presented, the amount of exposure to each item, and how frequently each item was encountered.

When familiarized with items one at a time (i.e., the identical pairs condition of Experiments 1 and 3), infants apparently responded to a relatively broad category (i.e., one that included both horses and dogs but not vehicles). However, because we tested infants' responding to only a few items it is impossible to know the exact boundaries of the category they formed. It should be pointed out that in other studies in our lab with infants at different ages and using different stimuli, we find that familiarization with items one at a time can induce infants to learn exclusive categories or individual items. Thus, infants' learning appears to be extremely context-dependent and is multiply determined by not only the experimental context, but also the infants' developmental level and the particular task used.

This investigation goes beyond demonstrating that presenting items in pairs facilitates infants' attention to exclusive categories and provides insight into the processes invoked by the familiarization conditions used here. Specifically, these results show that presenting different items side-by-side influences infants' categorization by reducing the memory demand of comparison. Under these conditions infants need not remember an item over a several second inter-trial-interval to compare it with another item—they need only to remember each item as long as it takes for them to glance at the other item. Recall that Oakes and Ribar (2005) observed that when items were presented one-at-a-time, not only did older infants respond to an exclusive category of dog versus cats whereas younger infants did not (they apparently responded to a more inclusive category such as *animal*), but that older infants also had shorter inter-trial-intervals than did younger infants. Thus, the older infants may have recognized the exclusive category when items were presented singly because they did not need to maintain in working memory for as long a representation of the item from one trial before the next item was presented. This conclusion is speculative, however, because the inter-trial-interval was

controlled by the infants' behavior. In Experiment 4 we experimentally induced exclusive categorical responding when infants were exposed to items one at a time (in this case in pairs of identical items) by eliminating the “empty,” or retention, period between trials. Thus, in this condition infants needed only to maintain in working memory a representation of the item as long as it takes to glance from the old item to the new item. In both of these conditions infants responded to a relatively exclusive category. Why would reducing the memory demands have this effect? Recall that when different items are presented on each trial, infants are required to compare items encountered at different times. When the delay between encounters increases, the basis of that comparison changes. This pattern is expected from results reported by Needham and her colleagues (Dueker et al., 2003; Needham et al., 2005). In those experiments, infants recognized similarities and differences in details such as the color of elements of the objects when items were encountered in the same experimental session (Needham et al., 2005), but they noticed only general similarities when items were encountered over a 24 hour delay (Dueker et al., 2003). Such findings are consistent with work revealing that infants' visual short-term memory capacity is limited (Ross-Sheehy et al., 2003) and their long-term memories are less detailed (Wilk et al., 2001). We cannot say for certain that the memory system responsible for these effects in short- or long-term memory, but the current manipulation of reducing the amount of time infants are required to remember an item from a few seconds to essentially zero is most compatible with theories of working or short-term memory (see Oakes & Bauer, 2007). Moreover, a common definition of *working memory* is that it is memory system that is used for the temporary storage and manipulation of information in the service of complex tasks (Baddeley & Hitch, 1974). The memory used in the present context—in which infants must maintain a memory of one item in order to compare it to a second item—seems to fit this definition. Therefore, the developmental changes observed for how infants categorize in tasks in which items are presented sequentially versus in pairs may reflect, in part, developmental changes in short-term or working memory systems (see Oakes, Ross-Sheehy, & Luck, 2007).

Note that it appears that at least one of the factors that influences whether or not infants respond to a more exclusive category is the same across different ages, categorical contrasts, and experimental procedures. The present results with 10-month-old infants' categorization of dogs and horses in object examining and the results reported by Oakes and Ribar (2005) with 4-month-old infants' categorization of dogs and cats in visual familiarization are both consistent with infants detecting more detailed and subtle commonalities when memory demands are reduced. Thus, the same kinds of processes seem to be operating at the two ages and in the two tasks. This conclusion clearly contrasts with other views that argue for different processes operating in these two tasks (visual presentation of stimuli versus object examining) at different points in development; according to such views, different factors are involved in young infants' attention to an exclusive category in a visual familiarization task and older infants' attention to an exclusive category in an object-examining task (Mandler, 2004). Clearly, additional research is needed to verify the role of memory demands at each age, but the present results in combination with previous results is consistent with the conclusion that there is continuity across development in the processes that are involved in infants' attention to exclusive categories.

It is likely that multiple factors contribute to why infants perform differently when exposed to two items versus one item at a time. The present results reveal that one factor—the time between presentations with different items—influences infants' attention to exclusive categories. We expect that different experiments involving infants of different ages, different stimuli, and different stimulus presentation formats, will reveal that other factors (e.g., the level of within-category variability, infants' history with similar items) also are important. These additional factors may influence infants' categorization also because they enhance the ability to compare items. Future research is needed to examine the influence of different factors, as well as the joint influence of multiple factors, on infants' attention to exclusive categories.

For example, exposure to different items side-by-side may more effectively induce comparison of the items than does exposure to two identical items side-by-side. As a result, when two different items are seen together, infants may attend to and learn different details of items (e.g., the ear shape, body type, etc.) than they do when encountering items one at a time (e.g., four legs, head, tail, etc.). Gentner and her colleagues (Gentner & Gunn, 2001; Gentner & Markman, 1994; Gentner & Namy, 1999; Markman & Gentner, 1997) argue that people detect commonalities and differences among items, events, and situations by *aligning* them, or by mapping the relationship between the features. Even a momentary exposure to two different items that are reasonably similar to each other may facilitate this process of alignment. Indeed, Gentner and her colleagues argue that presenting multiple items together at one time induces alignment (Gentner & Namy, 1999; Markman & Gentner, 1997). Therefore, presenting infants with multiple different items at one time—even for a brief period—may induce them to align the items, thus engaging a deeper level of comparison. In this case, the effect of seeing two items side-by-side should be moderated by how alignable the stimuli are.

Because infants did not glance back-and-forth between the two items more in the different pairs as compared to the identical pairs condition, the present results do not provide evidence that infants' engaging in more active comparison of items presented side-by-side. Although when encountering two different items at one time infants can actually scrutinize commonalities and differences by looking at one item, then the other, and then back at the first, in Experiment 1 infants in the different pairs condition did not engage in more looking back-and-forth of the two stimuli than did the infants in the identical pairs condition, and in Experiment 4 infants did not spend extensive time looking at the two different items side-by-side during the trial transitions. Thus, if infants do engage in more active comparison when different items are encountered together, it is not indicated by large differences in overt looking behavior.

In summary, the present results add to our understanding of infants' categorization by providing insight into why presenting items in pairs enhances their attention to exclusive categorical contrasts. They provide an important step in uncovering the role of encountering different items on infants' categorization, and represent a focus on the process of categorization. The results here are consistent with a general framework that infants create categories in the moment, and that context-dependencies in categorization observed during familiarization are due to differences in how infants are forming categories during the course of familiarization (Oakes, Horst, Kovack-Lesh, & Perone, in press), a perspective that has much in common with the view that even in infancy categories are dynamically created on-line (Jones & Smith, 1993; Schöner & Thelen, 2006; Smith, 2000), as well as the view that adults' categorization is context-dependent (Barsalou, 1993; Yamauchi et al., 2002). Importantly, therefore, the present results go beyond demonstrating that contextual differences induce the formation of different categories in infants, and begin show *how* those contextual differences engage and support different processes involved in category formation.

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Figure 1.
The stimuli used in all experiments.

Figure 2.
An infant being tested in the procedure used in all experiments.

Figure 3.

Average novelty preference scores (duration of looking to the novel $\div$ total duration of looking during test) for the test phase (grey bar) and post-test phase (white bar) for Experiments 1, 2, 3, and 4 (error bars represent 95% confidence intervals). For Experiments 1, 2, and 4, novelty preference during test reflects infants' preference for an item from a novel *category* (e.g., a horse if familiarized with dogs). This is the novelty preference calculated on test trials in which a novel item from within the familiar category is paired with a novel item from the contrasting category. For Experiment 3, novelty preference during test reflects infants' preference for a novel item from within the familiar category (e.g., a new horse if familiarized with horses). This is the novelty preference calculated on test trials in which a novel item from within the familiar category is paired with one of the items shown during familiarization. In all experiments, novelty preference during post-test indicates a preference for the vehicle to an item from the familiar category. Scores different from chance (.50) are indicated by * $p \leq .05$, two-tailed.

End of Trial N

E introduces first new toy

E introduces second new toy

Start of Trial N+1

Figure 4.

Sequence of events during the trial transitions in Experiment 4. The top panel is the end of one trial. In the next panel, the experimenter introduces one new toy and removes one old toy. In the third panel, the experimenter introduces the other new toy. The fourth panel is the start of the next trial.

Table 1

The mean duration of looking (in s) for each block of 3 familiarization trials in Experiments 1, 3, and 4 (*SD* are in the parentheses).

	Block 1 (Trials 1-3)	Block 2 (Trials 4-6)	Block 3 (Trials 7-9)	Block 4 (Trials 10-12)
Experiment 1	17.36 _a (5.76)	15.60 _a (5.23)	12.65 _b (3.97)	11.38 _b (4.84)
Experiment 3	16.35 _a (4.86)	14.73 (4.01)	13.31 (3.76)	11.56 _b (3.04)
Experiment 4	15.51 (5.89)	11.88 (5.12)	12.39 (3.50)	12.77 (5.58)

Note. Within each experiment, means that are significantly different from one another ($p < .05$) are indicated by different subscripts.