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Two are better than one: Comparison influences infants' visual recognition memory

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Abstract

Despite a large literature on infants' memory for visually presented stimuli, the processes underlying visual memory are not well understood. Two studies with 4-month-old infants (N = 60) examined the effects of providing opportunities for comparison of items on infants' memory for those items. Experiment 1 revealed that 4-month-old infants failed to show evidence of memory for an item presented during familiarization in a standard task (i.e., when only one item was presented during familiarization). In Experiment 2, infants showed robust memory for one of two different items presented during familiarization. Thus, infants' memory for the distinctive features of individual items was enhanced when they could compare items.

Infants can form memories for visual scenes and, with development, encode them faster and retain information for longer (see Fagan, 1990, for a review). Following 10- to 60-s of exposure to an item, 6-month-old infants consistently look longer at a novel stimulus than at the now-familiar stimulus (i.e., exhibiting a *novelty preference*) (Fagan, 1990). Younger infants, however, are less consistent, exhibiting novelty preferences (e.g., Pascalis, de Haan, Nelson, & de Schonen, 1998; Slater, Morison, & Rose, 1982), familiarity preferences (e.g., Richards, 1997; Rose, Gottfried, Mello-Carmina, & Bridger, 1982), or no clear preference (e.g., Wetherford & Cohen, 1973). Whether or not young infants exhibit a novelty preference depends on factors such as the amount of familiarization (Courage & Howe, 2001; Rose et al., 1982) and the particular stimuli (Fagan, 1974). Further, over repeated testing, infants exhibit familiarity preferences early in learning, and exhibit null or novelty preferences with more study time (e.g., Roder, Bushnell, & Sasseville, 2000). Indeed, Fagan (1990) concluded that the question "Can young infants demonstrate recognition memory?" can only be answered with "What are they being asked to recognize?"

Because much or our knowledge about infants' visual memory comes from this task, it is critical to understand the processes that underlie novelty preferences. Rose and her colleagues (Rose, Feldman, & Jankowski, 2004) have shown not only developmental differences in infants' memory in this task (e.g., how much encoding time is necessary for infants to remember an item), but also similarities between infants' and adults' memory. Two seminal studies identified one potentially important factor that contributes to young infants' novelty preference (Fagan, 1978; Rose et al., 1982). Although each involved several manipulations, both studies reported the counter-intuitive finding that infants familiarized with *two different* items showed stronger memory than did infants familiarized with only *one* item. This finding is counter-intuitive

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because infants exhibited stronger memory when they actually had less exposure to each item, if that item was presented with a contrasting item.

If robust and general, this pattern suggests critical commonalities in memory processes across the lifespan: exposure to contrasting items increases later recognition of the items, and better memory is observed in contexts that enhance the distinctiveness of the individual items. For example, adults remember more details of pictures when they are compared with other, similar pictures (Markman & Gentner, 1997), remembering both similarities *and* differences of instances when contexts encourage comparison (Gentner & Gunn, 2001). In addition, older children and adults have better memory for distinctive items (e.g., Arndt & Reder, 2003; Healy, Shea, Kole, & Cunningham, 2008). Thus, the same processes seem to operate at very different points in development.

Before we can conclude that such continuity exists, however, Fagan's (1978) and Rose et al.'s (1982) results must be replicated and extended. Specifically, several methodological issues limit the conclusions from these studies. First, Fagan (1978) tested infants' response to the familiar objects in a new orientation (i.e., a square design rotated 45 degrees to be a diamond-shaped design), rather than to a new *item*. Second, in Fagan's experiments, the diamond-shaped design was always the novel stimulus, making it impossible to disentangle the contribution of stimulus factors and comparison on infants' responding.

Third, both Fagan (1982) and Rose et al. (1982) tested infants' memory for relatively simple abstract patterns, and thus we do not know how comparison influences infants' memory for complex realistic stimuli. When two complex items (e.g., photographs of novel animals) are presented side-by-side, infants may have difficulty encoding each, and thus robust recognition memory might not be observed. Infants often must remember such items. Moreover, comparison is central to categorization, memory and judging item similarity of complex items (Gentner & Medina, 1998). Thus, comparison should be particularly useful in remembering items that can be categorized (e.g., particular cars, dogs, or flowers). Therefore, it is important to determine whether the effects described earlier are found when infants are familiarized with complex items, particularly those that may be included in the same category. This extension will connect work on infants' memory for relatively impoverished stimuli to work on infants' categorization of realistic stimuli.

Most importantly, it is still unknown whether infants' memory for individual items is equivalently facilitated by familiarization with two different items presented in *succession* versus when such items are presented *simultaneously* (i.e., side-by-side). Although Rose et al. (1982) found that infants had more robust memory when familiarized with two different items presented side-by-side than when familiarized with a single item, they did not examine infants' memory for two different items presented on successive trials (i.e., one at a time). Fagan (1978) did assess in two separate experiments infants' memory both when contrasting items were presented side-by-side and when they were presented on successive trials. Thus, Fagan (1978) could not directly compare infants' memory in these two conditions. Moreover, differences in infants' interest during familiarization in the two conditions raise questions about whether encoding was equivalent.

Determining whether presenting contrasting items successively or simultaneously is important for understanding *why* familiarization with two different items should enhance infants' memory. One possibility is that infants discover distinctive features of items as they glance back-and-forth between two simultaneously presented items, perhaps engaging the kinds of comparison processes proposed by Gentner and her colleagues (e.g., Markman & Gentner, 1997). In this case, only simultaneous presentation of two different items will enhance memory. Alternatively, *any* exposure to contrasting items (even if each item is presented in isolation) may enhance their distinctiveness. In this case, infants will show enhanced memory even when the two different items are presented one-at-a-time.

We asked whether (1) infants' show more robust memory when familiarized with two items versus one, and (2) whether simultaneous and successive exposure to the items were equivalent. This study incorporated several methodological controls to remove the potential confounds in previous studies. And, in Experiment 2, we directly compared the successive and simultaneous presentation of two items.

Experiment 1

First we examined infants' memory when familiarization with just one item.

Method

Participants—Twenty 4-month-old infants (*M* = 123.15 days, *SD* = 7.41; 10 girls, 8 infants had pets at home) participated (16 were tested at The University of Iowa, 4 were tested at The University of California, Davis). Most infants were White (three were multiracial and/or Hispanic) and middle class (all mothers had graduated high school; 13 had earned at least a bachelor's degree). Eleven additional infants were excluded because of fussiness or lack of interest.

Infants' names were obtained from county birth records (Iowa) or professional list broker or state vital records (California). Parents were contacted by letters and phone or e-mail. Infants received a small gift for their participation. Across experiments, infants tested at the different institutions did not differ on the number with pets at home or SES, although more non-white and/or Hispanic infants were tested in California. The two groups did not differ in looking time during familiarization or novelty preference scores, *p*s > .30.

Stimuli—We used the 18 color pictures of cats from Kovack-Lesh, Horst, and Oakes (2008, see Figure 1A). The cats differed in breed and coloring; 8 were standing, 4 were sitting, and 6 were lying down. Images were approximately 19.0 by 14.5 cm (subtending 27 by 21 degrees visual angle from a distance of 40 cm), and were similar in contrast and brightness.

Apparatus—Stimuli were presented on two 17″ (43.2 cm) CRT monitors, situated side-by-side (52 cm center-to-center). A black curtain in front of the monitors had holes revealing the monitors, a blinking light between the monitors, and a video camera beneath the light. An observer, seated out of view, watched infants on a monitor (connected to a VCR or DVR) and used a computer program (Cohen, Atkinson, & Chaput, 2000–2002) on a Macintosh G4 or G5 computer to control the experiment and record infants' looking times.

Procedure—Infants sat on a parent's lap approximately 40 cm away from the monitors (parents wore opaque glasses to eliminate bias). Before each trial, the light between the monitors blinked and beeped at a rate of 3 Hz. When the infant fixated this light, the observer initiated a trial by pressing a computer key. On the first 6 trials (each 15-s in duration), identical images of one cat were presented on each monitor. Immediately following familiarization, infants received two 10-s test trials with the now-familiar cat paired with a randomly selected novel cat (the number of pairings of cats was maximized across infants, and the same pairings were used in both experiments), left-right position counterbalanced across trials. During each trial, the observer recorded look durations to each monitor by pressing keys on the computer. Across experiments, the correlation between this on-line coding and looking recorded off-line by a second observer for 14 infants was *r* = .97 (mean difference for the duration of looking on each trial was *M* = .53 s).

Results

During familiarization, infants' significantly decreased their looking from block 1 (trials 1 through 3) to block 2 (trials 4 through 6) (see Table 1). We calculated each infant's *novelty preference* by dividing the amount of looking at the novel item during test by the total amount of looking during test. This score was not different from chance (.50), $t(19) = .48$, $p = .96$, $d = .42$ (see Table 1 and Figure 1B).

Discussion

Following familiarization with one cat, 4-month-old infants failed to show a preference for a novel cat, in contrast to other reports that at this age infants show novelty preferences to new cats in nearly identical procedures with different sets of cats (e.g., Oakes & Ribar, 2005; Quinn, Eimas, & Rosenkrantz, 1993). However, as described earlier, young infants' responses in this task are inconsistent (e.g., see Cohen & Gelber, 1975) and highly dependent on a number of factors, including the stimuli used (Fagan, 1990). Thus, the lack of consistency in results is not surprising.

We predict that familiarizing infants with pairs of *different* items will enhance their memory for the distinctive feature of those items. Kovack-Lesh et al. (2008) observed that when 4-month-old infants were familiarized with pairs of different cats (the same cats used here), presented side-by-side, infants preferred the taller, thinner cat (this was not a preference for a specific item—an item was preferred if it was the taller and thinner one, but that same item would be non-preferred if it was the shorter and fatter one of the pair), suggesting that in this context infants do attend to the differences among the stimuli.

This prediction is supported both by the classic work of Fagan (1978) and Rose et al. (1982), and more recent work by Gentner (Gentner & Gunn, 2001; Markman & Gentner, 1997). Gentner argues that differences are detected in the context of commonalities as people compare representations (Markman & Gentner, 1997). For example, Markman and Gentner found that two non-identical items (e.g., a baby and a pig) that had the same role in their respective scenes (e.g., each was making a mess) provided better memory cues for those scenes than did objects in one scene that had no corresponding object in the other scene. Thus, when comparing items, people apparently first detect the commonalities that provide a foundation for noticing differences—for example, people may first notice that two animals have ears, increasing the salience of differences in the shape, size, or color of the ears.

In Experiment 2 we tested infants' memory following familiarization with two *different* items. We addressed the methodological issues in the work by Fagan (1978) and Rose et al. (1982) by (1) presenting a novel cat during test, thus assessing infants' memory for *items* not for particular *orientations of an item*, (2) using all cats both as familiarization and test items, thus eliminating the possibility that the effects reflected preferences for a particular cat, and (3) using photographs of real cats, thus determining whether the effect observed for the impoverished stimuli of previous experiments is replicated with more complex stimuli.

Most importantly, we directly compared infants' responses when familiarized with different items presented successively versus simultaneously. This manipulation is important because although presenting two different items side-by-side allows infants to compare items during a single trial by looking back-and-forth between them, this procedure introduces *two* differences from Experiment 1—(1) familiarization with two different items *and* (2) increasing the similarity between familiarization and test trials. Thus, opportunities to compare instances during familiarization are confounded with the fact that infants are presented with two different items both during familiarization and test. Presenting two different items one-at-a-time on successive trials eliminates this confound and tests infants' memory following familiarization with two different items while maintaining the differences between the test and familiarization trials in Experiment 1.

Comparing these two conditions is also important theoretically. If infants only detect distinctive features when different items are presented side-by-side—i.e., if this presentation induces comparison—we will only see enhancement in the simultaneous presentation, replicating Fagan's (1978) findings. However, if infants encode individual items in any context that increases the distinctiveness of the items, then we will see enhancement in both conditions.

Experiment 2

Method

Participants—Forty infants (*M* = 124.53 days, *SD* = 7.94; 21 girls; 19 infants had pets at home) participated. None had participated in Experiment 1. The sample was middle class (39 mothers had graduated high school and 23 had completed at least a Bachelor's degree) and racially/ethnically diverse (23 infants were White and not Hispanic). Eleven additional infants were tested but were excluded due to fussiness or a lack of interest (*N* = 9) or experimenter error (*N* = 2). Twelve infants were tested at The University of Iowa.

Stimuli, apparatus, and procedure—The stimuli, apparatus, and procedure were identical to Experiment 1 except that infants were familiarized with two different cats. Half of the infants were tested in the *simultaneous* condition in which the two cats were presented side-by-side during each familiarization trial (left-right position counterbalanced across trials). The other infants were tested in the *successive* condition in which pairs of identical pictures were presented on each trial (as in Experiment 1), but two different items were presented across the 6-familiarization trials (i.e., one cat was presented on three trials and the other cat was presented on the other trials). We used the same familiarization pairs in the two conditions (the pairs were chosen semi-randomly, with no constraints on which item was paired with which other item, except that we maximized the number of different pairs).

Results

An Analysis of Variance (ANOVA) conducted on infants' looking time during familiarization with Block (first, second) as the within-subjects factor and Condition (*simultaneous*, *successive*) as the between-subjects factor revealed no significant effects. Unlike Experiment 1, infants in this experiment failed to significantly decrease their looking across blocks (see Table 1).

Infants in Experiment 2 looked significantly more overall during familiarization than did infants in Experiment 1, $t(58) = 3.77$, $p = .0004$, $d = .99$, likely because they were familiarized with twice as many items. Note, however, that infants in Experiment 2 did not look twice as long as did infants in Experiment 1. Across the 6 familiarization trials, infants in Experiment 2 accumulated 56.85 s (*SD* = 11.93) of looking at *two* items (approximately 28 s per item), clearly less looking per item than the 43.75 s (*SD* = 14.16) accumulated by infants at *one* item in Experiment 1. Any difference between experiments, therefore, cannot be due to infants having accumulated more looking to each item during familiarization in Experiment 2.

The analyses of infants' preferences during test revealed that infants significantly preferred the novel item, $t(39) = 3.74$, $p < .0001$, $d = 1.20$ (Figure 1B); *simultaneous:* $M = .62$ ($SD = .18$), $t(19) = 2.83$, $p = .01$, $d = 1.30$, *successive:* $M = .58$ ($SD = .15$), $t(19) = 2.41$, $p = .03$, $d = 1.11$ (see Table 1). The novelty preferences for the two conditions did not differ, $t(38) = .66$, *ns*. Thus, infants who saw two items during familiarization preferred the novel item during test.

Discussion

Infants in Experiment 2 showed evidence of visual recognition memory—they preferred the novel item during test. Learning items in a context of a contrasting item apparently enhances infants' memory for those items (the novelty preference score of infants in Experiment 2 was marginally greater than that of infants in Experiment 1, $t(58) = 1.80$, $p = .08$, $d = .48$, two-tailed). Importantly, this effect was observed regardless of whether items were presented one-at-a-time or side-by-side. The important factor appears to be that infants were familiarized with *two different* items.

General Discussion

Four-month-old infants showed robust memory for individual items when familiarized with two different items but not when familiarized with one item. This study represents a tightly controlled replication of studies by Fagan (1978) and Rose et al. (1982), using more complex, realistic stimuli. Moreover, Experiment 2 shows that infants' memory is enhanced by exposure to contrasting stimuli, and not that performance is influenced by similarities between familiarization and test. Thus, we have definitive evidence that 4-month-old infants' visual recognition memory is enhanced by familiarization with contrasting items, and this effect is robust and general to a wide range of stimuli.

This work is not simply a tightly controlled replication of previous findings, however. These data suggest continuity across the lifespan in basic memory processes. Like the infants we observed, older children and adults have better memory for distinctive items (e.g., Arndt & Reder, 2003; Healy et al., 2008). Moreover, the mechanisms of comparison described by Gentner and her colleagues (Gentner & Gunn, 2001; Gentner & Namy, 1999; Markman & Gentner, 1997) contribute to cognitive processes in infancy. Providing infants with the opportunity to compare items—by presenting two different items—enhanced their memory for those items. Like adults, infants' detection and encoding of the distinctive features of items appears to be influenced by the ability to compare different items. This finding adds to a growing literature showing that categorization, word learning, and other cognitive processes are enhanced when infants and children are shown multiple items as compared to only one item (Namy & Gentner, 2002; Oakes & Ribar, 2005).

It is possible that the amount of familiarization infants received contributed to our effects. That is, the present results may reflect probing infants at different points in their learning about the stimuli, and novelty preferences may emerge earlier in learning. However, in contrast to our findings, several studies have reported that in this procedure infants with more familiarization show *novelty* preferences and infants given less familiarization time show *familiarity* preferences (Roder et al., 2000; Rose et al., 1982). Moreover, we tested a separate group of 4-month-old infants in a version of Experiment 1, except that they had a single familiarization trial (accumulating 8.53 s on average of study time). These infants failed to exhibit a significant novelty preference, $t(19) = .73$, $p = .48$, $d = .16$, suggesting that less exposure did not enhance infants' novelty preference. Therefore, this alternative does not appear to explain our results.

The present results also have implications for assessing infants' discrimination of to-be-categorized items (see, for example, Quinn et al., 1993). Clearly, in the visual recognition task, evidence of infants' discrimination reflects an interaction of developing memory and perceptual abilities. Thus, evidence from this task about discrimination abilities early in infancy when novelty preferences are fragile and highly context-dependent (Cohen & Gelber, 1975; Fagan, 1990) should be considered cautiously. Fortunately, alternative methods for assessing infants' discrimination of to-be-categorized items have been developed (Kovack-Lesh et al., 2008; Mareschal, Powell, & Volein, 2003) that can be adopted with young infants. The point is that visual familiarization and habituation engage many cognitive processes, and failure to show the expected response during test emerges from the interaction of all those processes (see also Oakes & Kovack-Lesh, 2007).

Thus, infants' visual recognition memory is complexly determined by multiple interacting factors. Here we provide definitive evidence that one factor—the opportunity to compare two different items—contributes to infants' visual recognition memory of complex realistic stimuli. The present results therefore add to our understanding of both how developing cognitive abilities interact with the methods used to test them and how cognitive abilities develop in infancy, more generally.

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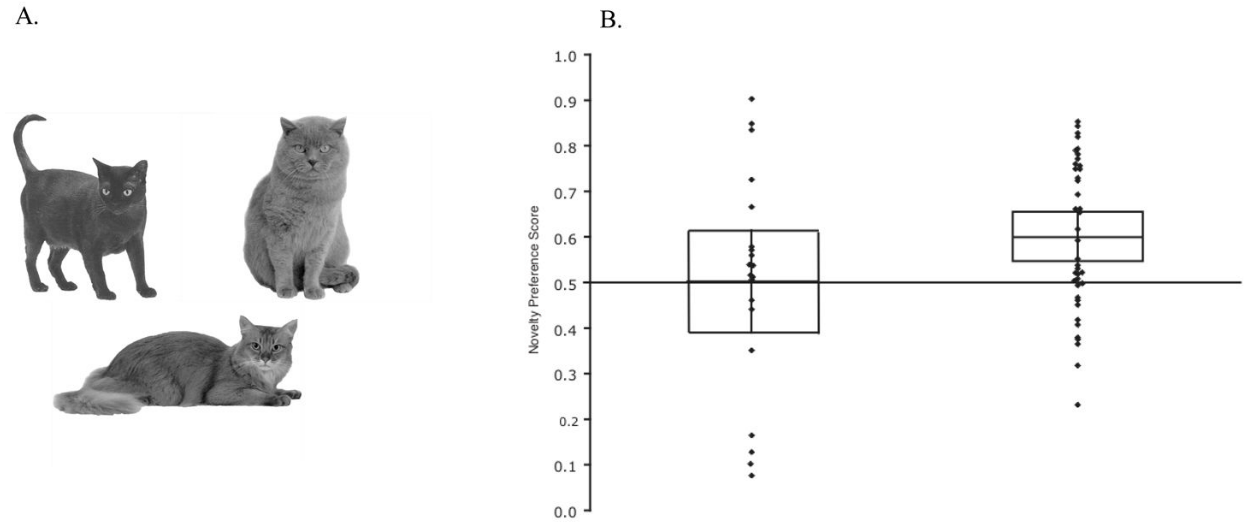

Figure 1.
A. Examples of pictures of cats used as stimuli in both experiments. B. Infant novelty preference scores (looking to the novel item divided by total looking during test) for Experiment 1 (left) and Experiment 2 (right). The box represents 95% confidence intervals; the average novelty preference score is the line bisecting the box. Each individual diamond represents the responding of a single infant.

Table 1

Duration of looking (in s) in the first and second familiarization blocks and test by experiment

		Familiarization			Test	
Experiment	N	Block 1	Block 2	t-value	Familiar	Novel
1 (one familiar item)	20	23.59 (7.40)	20.15 (7.77)	2.82*	5.10 (3.60)	4.93 (2.77)
2 (two familiar items)	40	29.28 (6.73)	27.58 (7.25)	1.47	4.94 (2.58)	7.38 (2.96)
Simultaneous	20	28.27 (7.89)	26.51 (7.54)	1.10	4.49 (2.66)	7.38 (3.34)
Successive	20	30.29 (5.35)	28.65 (6.98)	0.96	5.40 (2.47)	7.39 (2.62)

* *Note:* indicates $p \leq .01$.