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Brief Report

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-olds ($N = 60$) examined the effects of providing opportunities for comparison of items on infants' memory for those items. Experiment 1 revealed that 4-month-olds 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.

Introduction

Infants can form memories for visual scenes and, with development, encode them faster and retain information longer (see Fagan, 1990, for a review). Following 10 to 60 s of exposure to an item, 6-month-olds 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 a novelty preference (e.g., Pascalis, de Haan, Nelson, & de Schonen, 1998; Slater, Morison, & Rose, 1982), a familiarity preference (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). Furthermore, over repeated testing, infants

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exhibit a familiarity preference early in learning and exhibit a null or novelty preference with more study time (e.g., Roder, Bushnell, & Sasseville, 2000). Indeed, Fagan (1990) concluded that the question "Can young infants demonstrate recognition memory?" can be answered only with "What are they being asked to recognize?"

Because much of our knowledge about infants' visual memory comes from this task, it is critical to understand the processes that underlie novelty preference. 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' memories. 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 counterintuitive finding that infants familiarized with two different items showed stronger memory than did infants familiarized with only one item. This finding is counterintuitive 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 life span. 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 and colleagues' (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 (1978) and Rose and colleagues (1982) tested infants' memory for relatively simple abstract patterns; 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 in encoding each item; 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 important, 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 and colleagues (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 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 (a) infants' show more robust memory when familiarized with two items versus one item and (b) whether simultaneous and successive exposures to the items were equivalent. This study incorporated several methodological controls to remove the potential confounds in previous studies. In Experiment 2, we directly compared the successive and simultaneous presentations of two items.

Experiment 1

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

Method

Participants

Participants were 20 4-month-olds (mean age = 123.15 days, *SD* = 7.41, 10 girls and 10 boys, with 8 infants having pets at home). Of these infants, 16 were tested at the University of Iowa and 4 were tested at the University of California, Davis. Most of the infants were White (3 were multiracial and/or Hispanic) and middle class (all mothers had graduated from high school and 13 had earned at least a bachelor's degree). An additional 11 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 letter 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 on socioeconomic status, 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, *ps* > .30.

Stimuli

We used the 18 color pictures of cats from Kovack-Lesh, Horst, and Oakes (2008) (see Fig. 1A). The cats differed in breed and coloring; also, 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.

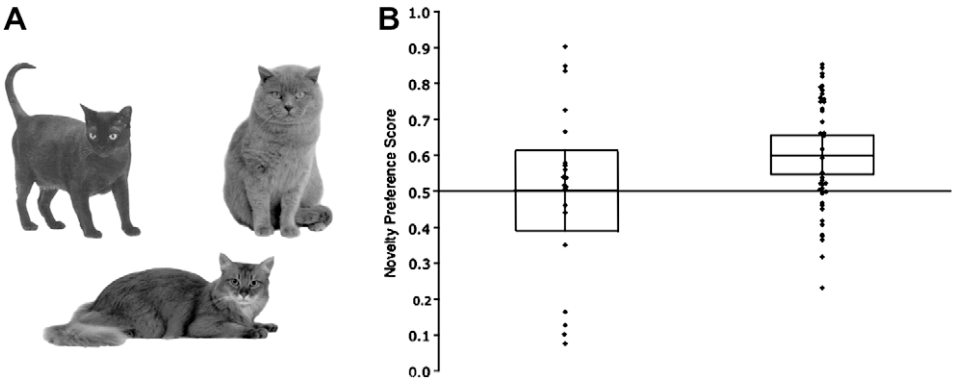

Fig. 1. (A) Examples of pictures of cats used as stimuli in both experiments. (B) Infant novelty preference scores (looking to the novel item divided by total looking during test) for Experiment 1 (left) and Experiment 2 (right). The box represents 95% confidence intervals; the average novelty preference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

Apparatus

Stimuli were presented on two 17-inch (43.2-cm) CRT monitors situated side by side (52 cm from 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

Each infant sat on a parent's lap approximately 40 cm away from the monitors (the parent 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 on this light, the observer initiated a trial by pressing a computer key. On the first six trials (each 15 s in duration), identical images of one cat were presented on each monitor. Immediately following familiarization, the infant 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) with 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 online coding and looking recorded offline by a second observer for 14 infants was $r = .97$ (the 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 1–3) to Block 2 (Trials 4–6) (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), $t(19) = 0.48$, $p = .96$, $d = .42$ (see Table 1 and Fig. 1B).

Discussion

Following familiarization with one cat, 4-month-olds failed to show a preference for a novel cat, in contrast to other reports that at this age infants show a novelty preference 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 features of those items. Kovack-Lesh and colleagues (2008) observed that when 4-month-olds were familiarized with pairs of different cats (the same cats as 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 nonpreferred if it was

Table 1
Duration of looking in the first and second familiarization blocks and test by experiment

Experiment	*N*	Familiarization			Test	
		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 ($n = 20$)		28.27 (7.89)	26.51 (7.54)	1.10	4.49 (2.66)	7.38 (3.34)
Successive ($n = 20$)		30.29 (5.35)	28.65 (6.98)	0.96	5.40 (2.47)	7.39 (2.62)

Note. Durations of looking values are in seconds (s). Standard deviations are in parentheses.
* $p \leqslant .01$.

the shorter and fatter one of the pair.) This suggested 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 and colleagues (1982) and by more recent work by Gentner and colleagues (Gentner & Gunn, 2001; Markman & Gentner, 1997). Gentner and colleagues argued that differences are detected in the context of commonalities as people compare representations (Markman & Gentner, 1997). For example, Markman and Gentner (1997) found that two nonidentical 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 objects 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, and/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 and colleagues (1982) by (a) presenting a novel cat during test, thereby assessing infants' memory for items and not for particular orientations of an item; (b) using all cats as both familiarization and test items, thereby eliminating the possibility that the effects reflected preferences for a particular cat; and (c) using photographs of real cats, thereby determining whether the effect observed for the impoverished stimuli of previous experiments is replicated with more complex stimuli.

Most important, 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: (a) familiarization with two different items and (b) 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 during both 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 detect distinctive features only when different items are presented side by side—that is, if this presentation induces comparison—we will see enhancement only 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, we will see enhancement in both conditions.

Experiment 2

Method

Participants

Participants were 40 infants (mean age = 124.53 days, *SD* = 7.94, 21 girls and 19 boys, with 19 infants having pets at home). None had participated in Experiment 1. The sample was middle class (39 mothers had graduated from high school and 23 had completed at least a bachelor's degree) and racially/ethnically diverse (23 infants were White and not Hispanic). An additional 11 infants were tested but excluded due to fussiness or lack of interest ($n = 9$) or experimenter error ($n = 2$). Of the participating infants, 12 were tested at the University of Iowa.

Stimuli, apparatus, and procedure

The stimuli, apparatus, and procedure were identical to those in Experiment 1 except that infants were familiarized with two different cats. Half of the infants were tested in the *simultaneous* condition, where the two cats were presented side by side during each familiarization trial (with the left–right position counterbalanced across trials). The other infants were tested in the *successive* condition, where pairs of identical pictures were presented on each trial (as in Experiment 1), but two different

items were presented across the six familiarization trials (i.e., one cat was presented on three trials and the other cat was presented on the other three trials). We used the same familiarization pairs in the two conditions (the pairs were chosen semirandomly 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 times during familiarization with block (first or second) as the within-participants factor and condition (simultaneous or successive) as the between-participants 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 six familiarization trials, infants in Experiment 2 accumulated 56.85 s ($SD = 11.93$) of looking at two items (~28 s/item), clearly less looking per item than the 43.75 s ($SD = 14.16$) accumulated by infants looking 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, $t(39) = 3.74$, $p < .0001$, $d = 1.20$ (Fig. 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, $t(38) = 0.66$, *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

The 4-month-olds in this study showed robust memory for individual items when familiarized with two different items but not when familiarized with one item. The study represents a tightly controlled replication of studies by Fagan (1978) and Rose and colleagues (1982) using more complex and realistic stimuli. Moreover, Experiment 2 showed 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-olds' visual recognition memory is enhanced by familiarization with contrasting items and that this effect is robust and general to a wide range of stimuli.

However, this work is not simply a tightly controlled replication of previous findings. These data suggest continuity across the life span 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 during 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 with 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 current 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-olds in a version of Experiment 1 except that they had a single familiarization trial (accumulating 8.53 s of study time on average). These infants failed to exhibit a significant novelty preference, $t(19) = 0.73$, $p = .48$, $d = .16$, suggesting that less exposure did not enhance infants' novelty preference. Therefore, this alternative does not appear to explain our results.

The current results also have implications for assessing infants' discrimination of to-be-categorized items (see, e.g., 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 that can be adopted with young infants have been developed (Kovack-Lesh et al., 2008; Mareschal, Powell, & Volein, 2003). 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 have provided definitive evidence that one factor—the opportunity to compare two different items—contributes to infants' visual recognition memory of complex realistic stimuli. The current 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 during infancy more generally.

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