Published in final edited form as:

Memory. 2011 November ; 19(8): 871–878. doi:10.1080/09658211.2011.613842.

Effects of viewing ordered pictorial reminders on long-term memory in the first year of life

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Abstract

Previous research has shown that reminders can be effective for extending and enhancing a variety of kinds of memory in infants. We investigated the effects of viewing pictorial representations of actions that were included in imitation events used to measure long-term memory in young infants. Infants who saw the pictures of actions displayed in the order in which they comprised events showed evidence of memory for the events. Infants who saw the actions presented randomly did not. These results suggest that pictures presented during the consolidation and storage phase of memory formation can be effective reminders of events for young infants.

Keywords

Memory; Infancy; Reminders

Research in recent years has yielded a wealth of information on infants' memory abilities. Several studies have established that memory skills are fragile at the end of the first year of life, but become increasingly stable and robust as infants grow (Bauer, 2005; Bauer, Wenner, Dropik, & Wewerka, 2000; Carver & Bauer, 2001; Hartshorn et al., 1998). The main purpose of the present research was to investigate how reminders given during the post-encoding period influence memory performance in 9-month-olds as measured in a deferred imitation paradigm.

Reminders given during the post-learning interval can extend the interval over which infants can retrieve memories (e.g., Galluccio & Rovee-Collier, 2005; Hayne & Rovee-Collier, 1995; Rovee-Collier, 1999; Rovee-Collier, Evancio, & Earley, 1995). Reminders may work by enhancing consolidation (Wixted, 2004), which has been implicated in developmental improvements and individual differences in memory at the end of the first year of life (Bauer, 2004, 2005; Bauer et al., 2006; Bauer, Wiebe, Carver, Waters, & Nelson, 2003; Carver & Bauer, 1999, 2001; Carver, Bauer, & Nelson, 2000).

Various kinds of dynamic reminders have been shown to improve memory performance in visual recognition (Morgan & Hayne, 2005), and deferred imitation tasks (Barr, Rovee-Collier, & Campanella, 2005; Bauer, Wiebe, Waters, & Bangston, 2001; Hudson & Sheffield, 1998; Sheffield & Hudson, 1994). For example, Bauer and colleagues (2001) provided 9-month-olds with a recall test and live re-enactment as a reminder 1 week after initial exposure to events in a deferred imitation task. Infants in this reminder condition recalled more than infants who did not receive a re-exposure. This result reinforces the idea that some kinds of reminders are beneficial for enhancing long-term retention. However,

despite showing the benefits of live reminders, these studies do not provide information about whether pictorial reminders are effective in facilitating recall.

Some studies have compared pictorial reminders with videos or live reminders (Deocampo & Hudson, 2003). In a study of elicited imitation with 18-month-olds, videos were effective as reminders if they were presented close to a recall test. Pictures were not effective as reminders at this age (Sheffield & Hudson, 2006). One possible interpretation of this finding is that infants may lack a mature ability to understand the dual representational nature of pictures (e.g., DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998), and therefore fail to recognise that the pictures depict information that would be useful in recalling the events (Deocampo & Hudson, 2003). Developmental changes in representational ability, as have been documented by DeLoache and colleagues (see DeLoache, 2004, for review) may explain why 18-month-olds in this study were unable to use pictures as reminders (Sheffield & Hudson, 1994, 2006).

Another possibility suggested by Hudson and colleagues is that pictures do not provide enough information about the events to reinforce memories that are in the process of consolidation. Several deferred imitation studies in which infants have been shown pictures during the delay interval have used a large number of repetitions of pictures of the events, and showed that 9-month-olds under these conditions can recall events (Bauer et al., 2003, 2006; Carver & Bauer, 1999). However, there is no evidence of recall over the same delays when 9-month-olds are tested without reminders (e.g., Bauer et al., 2001). However, the effects of pictures as reminders and the characteristics of those pictures necessary to facilitate recall have not been systematically investigated in infants during the first year of life.

The present study was designed to determine what kind of pictorial reminders facilitate infants' recall after a long delay. We showed infants pictures of actions involved in an event to which they were first exposed at 9 months of age, and a new event that they had never seen before. In one group (Ordered), pictures of actions were presented in order, so that groups of three consecutive trials carried information about both the individual actions as well as the order of those actions. A second group (Random) saw pictures presented randomly, so that any three trials could include pictures of either the old or new event, in random order. A final group was included to control for the possibility that differences between the Ordered and Random group might be due to pictures from three consecutive trials being presented together, not necessarily from them being presented in order. In this group (Massed) infants saw pictures from events together during a given set of three trials, but the actions depicted in these trials were not presented in the previously modelled order.

METHOD

Participants

Participants were 62 infants aged 9 months (30 female; $M = 8.97$ months, $SD = .15$ at the time of the first session). Participants were involved in a larger study of the effects of different kinds of picture presentation on infants' recognition memory as measured by event-related potentials (ERP).¹ An additional 29 infants were tested, but their data were excluded because they did not return for all sessions ($n = 17$), because of experimenter error ($n = 2$), because of computer failure during the presentation of the picture stimuli ($n = 4$), because the parent prompted the child during recall testing ($n = 1$), or because the infants refused to watch the reminder stimuli and/or wear the caps that were required for the ERP

¹ERP data and specifics about ERP recording parameters are not reported here. Details are available from the author.

testing ($n = 5$). Participants were predominantly White ($n = 42$). Other participants were Hispanic ($n = 7$), Asian ($n = 8$), African American ($n = 1$), Native American ($n = 1$), or of mixed ethnicity ($n = 3$). Infants were recruited from a subject pool for which their parents volunteered at the time of birth. All infants were full term and had no known developmental problems. Informed consent was obtained from the parent prior to testing.

Infants were randomly assigned to three groups. One group ($n = 19$) viewed pictures in the reminder session in the same temporal order as during the initial exposure sessions. Infants in this group saw repetitions of pictures of the actions involved in each event in sets of three, and in each set of three, the actions were depicted in the previously modelled temporal order. A second group ($n = 21$) viewed pictures during the reminder session in random order. In this condition, any three trials contained pictures depicting actions from either or both events, with the constraint that no event was ever seen in the correct order. The third group ($n = 22$) viewed the pictures in a “massed” condition. For these infants, sets of three consecutive trials depicted the steps in any a single event together, but these steps were presented in random order.

Stimuli

Each infant viewed three novel two-step events characterised by enabling relations (Bauer, 1992). In events characterised by enabling relations the steps must be completed in the correct sequence in order to achieve the final, target state, but are physically possible out of order. Events additionally were constrained so that photographs could be taken of each of the steps as well as of the target state of the completed event. The events that infants viewed were randomly selected from a pool of six events. They were counterbalanced so that all events were seen an equal number of times, each served as familiar and unfamiliar events an equal number of times, and none were seen in any serial position more than any other event.

Photographs of each step of each event were displayed on a computer monitor. Images were presented against a grey background. Image size was held constant for all stimuli. Pictures showed an adult woman’s hand completing each of the steps, in addition to the final appearance of the event once both steps were completed in order, for a total of three pictures per event. Each infant saw pictures of one old event (to which they had previously been exposed) and one new event (that they had never seen before) in a within-participant manipulation of familiarity. Events were counterbalanced so that each was presented as old and new an equal number of times. Due to the number of categories and constraints of the stimulus presentation system (e.g., infants in the ordered group were required to see Step 1 of an event followed by Step 2, followed by the goal state), the order of presentation was pseudorandom, and each infant viewed the pictures in the same order as the other infants in their group.

Procedure

The same female experimenter conducted each of the sessions for each infant. Each infant participated in a total of five sessions: three exposure sessions, which occurred between 1 and 2 days apart ($M = 1.5$ days, $SD = .72$), a reminder session, which occurred 1 week ($M = 7.48$ days, $SD = 1.78$) after the final exposure session, and a recall session 1 month ($M = 30.97$ days, $SD = 6.58$) after the reminder session. Each session began with a warm-up period to allow the infant to become comfortable with the experimenter, during which the infant was allowed to play with toys that were unrelated to the experiment. Parents were asked not to assist or instruct their children during sessions or at home between sessions. All sessions were videotaped for coding purposes.

Exposure sessions—The exposure and recall sessions took place with the infant sitting in the parent's lap across the table from the experimenter. The initial visit began with an infant-controlled baseline period, in which the infant was allowed to manipulate props from each of the three events in turn. The baseline ended when the infants indicated that they were no longer interested by repeatedly banging, mouthing, or throwing the props.

The experimenter then modelled each event two times in succession, with narration. Following demonstration, the test props were put away and the infant was not allowed to manipulate them. Between events, infants were given a distractor toy to prevent them from becoming upset at not being allowed to play with the test props. The second and third sessions were identical, except for the elimination of the baseline interval. The infants viewed each of the three events a total of six times over the three sessions.

Reminder session—The reminder session took place with the infant sitting in the parent's lap in approximately 65 cm in front of a computer monitor on which picture stimuli were presented. A grey screen blocked the rest of the room from the view of the infant. A trained observer observed the infant through the screen and recorded, by button press, when the infant was not looking at the screen. When necessary, the observer behind the screen directed the infant's attention back to the monitor by tapping the back of the screen or shaking a rattle.

Each picture stimulus was presented for 500 ms. Trials were separated by an interval that varied between 2700 to 3200 ms. For each group, each picture was shown 20 times (for a total of 120 trials). If infants became bored or fussy, stimulus presentation was stopped before this number of presentations was reached. Infants looked at an average of 68.73 trials ($SD = 23.49$). There were no differences in the number of old versus new trials viewed (ordered group: M for old events, = 34.95, M for new events = 36.2; random group: M for old events = 32.33, M for new events = 33.1; massed group M for old events = 34.68, M for new events = 35.1; all $ps > .10$). In addition, there was no difference in the total number of trials infants looked at between groups, (M for ordered group = 71.16, $SD = 25.12$; M for random group = 65.43, $SD = 19.97$, M for massed group = 69.77, $SD = 25.79$; $p > .10$).

Recall session—The procedure for the recall session was identical to the first exposure session. Infants were given props from each of the six events (three old events and three new events) in turn. They were allowed to manipulate the props; the manipulation period ended when the infants showed that they were no longer interested. If the infant did not complete a target action, a verbal reminder ("show me how to ...") was given.

Coding

Each of the exposure sessions and the recall session were videotaped. Two coders who were blind to the specific hypothesis being tested were trained until they achieved 90% reliability with the author. The coders overlapped on 25% of the coded tapes and agreed on 89% of behaviours on which they overlapped. Disagreements were settled by consensus. Tapes from the recall session were always coded prior to tapes from the exposure sessions to prevent the coder from knowing which of the events were familiar and which were unfamiliar to the infant.

For each event a total number of target actions (maximum = 2 per event) and correctly ordered pairs of actions (maximum = 1 per event) were calculated. To avoid infants getting credit for completing correctly ordered pairs of actions by chance, infants were given credit only for the first instance of each step when determining correctly ordered pairs. For example, if infants produced Step 2 of an event, then Step 1, then Step 2 again, they were given credit for producing each of the individual target actions, but not for the correctly

ordered pair. This method reduced the chance of infants receiving credit for producing a correctly ordered pair by trial and error.

Analyses

Analyses were conducted using a 2 (Condition: Old, New) $\times$ 3 (Group: Ordered, Random, Massed) repeated measures ANOVA on the number of actions and correctly ordered pairs of actions produced after the delay. Planned *t*-tests were used to test *a priori* hypotheses concerning the production of old and new events by infants in each group. Because infants were 1 month older after the delay, with presumably more mature problem-solving skills than at baseline, this measure better reflects memory for the events than a comparison with baseline production.

RESULTS

Actions

Across all events, infants produced more actions for old than for new events, as evidenced by a significant effect of condition, $F(1, 59) = 12.69$, $p < .001$, $\eta^2 = .18$. There was no effect of group, $F(2, 59) = 1.82$, $MSE = 2.29$ or condition by group interaction, $F(2, 59) = 1.35$, $MSE = 1.09$. The effect of condition was due primarily to the infants who saw the reminders in the correct order. Planned comparisons showed that these infants produced more actions for old than for new events, $t(18) = 2.78$, $p < .01$. Production of target actions for old and new events did not differ for infants who saw the reminders in random order ($p > .10$). Infants in the massed group tended to produce more actions for old than new events, but this trend did not reach statistical significance, $t(21) = 1.87$, $p = .08$, see Figure 1a.

During the reminder session infants saw pictures of one old and one new event. We measured performance on the events depicted in this session as a test of the effects of reminding and previewing events shown in the pictures. There was no effect of group, $F(2, 59) = .97$, $MSE = .47$, or condition by group interaction, $F(2, 59) = .44$, $MSE = .49$, and only a trend towards a main effect of condition, $F(1, 59) = 2.85$, $p = .10$, $\eta^2 = .05$. Planned *t*-tests revealed no advantage for production of old versus new actions from events infants were reminded of in order ($p = .25$), randomly, $p = .80$, or in the massed condition ($p = .19$), see Table 1.

We also examined performance of actions on events infants did not see during the reminder session. Infants produced more actions for old than new events, $F(1, 59) = 8.09$, $p < .01$, $\eta^2 = .13$. There was no effect of group, $F(2, 59) = 1.56$, $MSE = .345$, or group by condition interaction, $F(2, 59) = .107$, $MSE = .16$. As shown in Table 2, planned follow up tests revealed that, whereas infants in the ordered group produced more actions for old than new events, $t(18) = 2.82$, $p < .01$, infants in the random and massed groups did not, $ps > .10$.

Pairs of actions

Collapsed across all events, infants produced more correctly ordered pairs of actions for old than for new events, $F(1, 59) = 5.20$, $p < .05$, $\eta^2 = .08$. There was no effect of group, $F(2, 59) = .38$, $MSE = .40$, or condition by group interaction, $F(2, 59) = 1.40$, $MSE = .20$. Planned *t*-tests revealed that infants who saw the reminders in order produced more correctly ordered pairs of actions for the old versus new events $t(28) = 2.05$, $p < .05$, whereas infants who saw the pictures in random order or in the massed presentation did not ($ps > .10$), see Figure 1b.

Infants produced more correctly ordered pairs of actions for old events that were depicted during the reminder session than new previewed events, $F(1, 59) = 4.22$, $p < .05$, $\eta^2 = .07$.

As can be seen in Table 1, this effect was primarily due to the infants who saw the pictures presented in order ($t(28) = 2.21, p < .05$). In contrast, infants who saw pictures in random order and in the massed condition did not produce more pairs of actions for reminded than for previewed events ($p > .10$). There was no effect of group, $F(2, 59) = .16, MSE = .13$, or Condition by Group interaction, $F(2, 59) = 1.49, MSE = .08$ for this variable.

For events infants did not see during the reminder session, there was no main effect of condition, $F(1, 59) = 1.52, MSE = .04$, or group, $F(2, 59) = .46, MSE = .05$, or Condition by Group interaction, $F(2, 59) = .43, MSE = .04$. Planned *t*-tests showed that none of the groups produced reliably more correctly ordered pairs of target actions for old versus new events they did not see during the reminder session (all $p > .10$).

DISCUSSION

Infants who observed pictorial reminders of events presented in order 1 week into the delay interval produced more actions and more correctly ordered pairs of actions for old than for new events 1 month after initial exposure to the events. Infants who saw the pictures displayed in random order, and those who saw massed but unordered presentations, did not show evidence of recall of temporal order. These data suggest that pictures can be effective reminders of events even for very young infants. The results are consistent with findings from studies using live re-enactments to measure effects of reminders (Barr et al., 2005; Bauer et al., 2001; Galluccio & Rovee-Collier, 2005; Hayne & Rovee-Collier, 1995; Morgan & Hayne, 2005; Rovee-Collier, Hartshorn, & DiRubbo, 1999). The results extend those findings to show that pictures, as well as live presentations, can facilitate memory in young infants.

Previous studies (Sheffield & Hudson, 1994, 2006) did not find that pictures were useful reminders of events for 18-month-olds. Our study and theirs varied in ways that may explain the different findings. In the present study infants saw multiple repetitions of the items involved in the events, the actions to be produced, and the goal state of the events, whereas Sheffield and Hudson showed pictures once. Repetition, in combination with information about the order in which actions are to be produced, may facilitate recall in a way that single presentations do not (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). If the present study were repeated with 18-month-olds we would expect improved performance, even though previous research has failed to find effects of pictorial reminders in that age group (Sheffield & Hudson, 2006).

The present results may explain differences in recall ability in studies where infants receive several pictorial reminders (e.g., Bauer et al., 2006) of imitation events versus studies in which they do not (Bauer et al., 2001). These results suggest that the way those pictures are presented is important: Infants benefited from pictures being presented in the correct order, but were not helped by seeing pictures out of order. The results suggest that infants can use reminders to enhance their recall of events, provided that those reminders are rich in detail and information provided.

When we considered only infants' performance on events they saw depicted during the reminder session, there was no difference in production of old versus new actions for any of the groups. Infants in all groups produced a similar number of actions for both the old and new events that they saw during the reminder session. This is a rather unexpected result, and suggests that when infants see actions depicted in pictures, they can learn something about what the objects depicted might afford.

In contrast, infants in the ordered group produced more correctly ordered pairs of actions for old versus new events that they saw depicted in the reminder session. Infants in the massed

and random groups did not. This suggests that, whereas information about the actions afforded by the props might be extracted from viewing pictures of them, order information is not easily obtained from picture reminders, unless those reminders also provide information about order. Thus, memory for order in previous imitation studies (Bauer, Hertsgaard, Dropik, & Daly, 1998; Bauer & Mandler, 1989; Bauer et al., 2001, 2006; Carver et al., 2000) is unlikely to be the result of infants “discovering” the order in which actions should be produced merely by seeing the objects or pictures of them.

When we considered only those events for which infants were *not* reminded, only infants in the ordered group produced more actions for old than for new events. This suggests that providing infants with order information facilitates their memory even for associated events for which they received no reminder. Ordered reminders might provide a structure around which infants can organise their memories. This may serve to enhance memory even for the actions for which infants were not reminded. This finding is reminiscent of that of Sheffield and Hudson (1994), who found that re-demonstration of some events facilitated memory for events that occurred in the same session, but that were not subject to reminding. Recall of order information was not enhanced for events for which infants did not see pictorial reminders. This suggests that recall of temporal order cannot be improved by association between a reminded and not reminded event, but instead is specific to events infants were explicitly reminded of the order.

The present results have implications for our understanding of representational development. DeLoache and colleagues have suggested that 9-month-olds have difficulty understand the representational nature of pictures. This conclusion is drawn from a long line of studies that show that 9-month-olds interact with pictures by manually exploring them as though they were objects (DeLoache & Burns, 1994; DeLoache, Pierroutsakos, & Troseth, 1996; Pierroutsakos & DeLoache, 2003). The present results add to this literature by suggesting that even when infants do not have a sophisticated understanding of the representational nature of pictures, given enough exposure and sufficient information in the pictorial presentation, they can be reminded of past events by viewing pictures of them. One possibility is that the effect seen here is an early precursor to later more sophisticated understanding of the representational nature of pictures. Infants may be able to learn from pictures, and be reminded of past events by them, without understanding their representational nature. Experience with using pictures for these purposes may contribute to infants’ emerging understanding of their representational nature.

There are several caveats that should be considered when interpreting the present results. Here, infants viewed many repetitions of the stimuli. Although the number of trials viewed per condition was about the same for the infants who saw the ordered, random, and massed presentations, it may be that seeing a large number of trials benefited infants in the ordered condition more than infants in the random condition. In future research it would be interesting to investigate whether viewing pictures of stimuli that make up events in order is effective if the stimuli are not repeated a large number of times. In the present study infants in the ordered group produced more actions as well as more pairs of actions for old versus new events. Given the small number of actions in each event, one possibility is that infants produced more pairs because they produced more actions. We think this is unlikely, given that there was not a significant difference between groups in the number of actions produced. Rather, the differences were in the relative production of actions and pairs for old and new events. Finally, we did not include a no-reminder control in this study. Given the results of Bauer and colleagues (2001), we would expect a no-reminder group to show poor memory performance.

The present results indicate that memory can be facilitated by pictures in infants much younger than has been shown previously. The results provide important information about the types of reminders that are useful in facilitating memory in young infants, and add to our understanding of the development of representation in infancy. In addition, these results suggest that although infants might be able to figure out individual actions by perceiving affordance, and can learn about actions from viewing pictures, order information is more difficult and likely requires more sophisticated representational abilities.

Acknowledgments

I would like to thank the infants and parents who participated in this research. Thanks also to Katherine Mosher, Rebecca Cunningham, and the members of the Developmental Social and Cognitive Neuroscience research group for their assistance with data collection and coding.

References

- Barr R, Rovee-Collier C, Campanella J. Retrieval protracts imitation by 6-month-olds. *Infancy*. 2005; 7:263–283.
- Bauer PJ. Holding it all together: How enabling relations facilitate young children's event recall. *Cognitive Development*. 1992; 7:1–28.
- Bauer PJ. Getting explicit memory off the ground: Steps toward construction of a neuro-developmental account of changes in the first two years of life. *Developmental Review*. 2004; 24:347–373.
- Bauer PJ. Developments in declarative memory: Decreasing susceptibility to storage failure over the second year of life. *Psychological Science*. 2005; 16:41–47. [PubMed: 15660850]
- Bauer PJ. Constructing a past in infancy: A neurodevelopmental account. *Trends in Cognitive Sciences*. 2006; 10:175–181. [PubMed: 16537115]
- Bauer PJ, Hertsgaard L, Dropik P, Daly BP. When even arbitrary order becomes important: Developments in reliable temporal sequencing of arbitrarily ordered events. *Memory*. 1998; 6:165–198. [PubMed: 9640427]
- Bauer PJ, Mandler JM. One thing follows another: Effects of temporal structure on 1- to 2-year-olds' recall of events. *Developmental Psychobiology*. 1989; 25:197–206.
- Bauer PJ, Wenner JA, Dropik PL, Wewerka SS. Parameters of remembering and forgetting in the transition from infancy to early childhood. *Monographs of the Society for Research in Child Development*. 2000; 65(4):1–204.
- Bauer PJ, Wiebe SA, Carver LJ, Lukowski AF, Haight JC, Waters JM, et al. Electro-physiological indices of encoding and behavioral indices of recall: Examining relations and developmental change late in the first year of life. *Developmental Neuropsychology*. 2006; 29:293–320. [PubMed: 16515408]
- Bauer PJ, Wiebe SA, Carver LJ, Waters JM, Nelson CA. Developments in long-term explicit memory late in the first year of life: Behavioral and electrophysiological indices. *Psychological Science*. 2003; 14:629–635. [PubMed: 14629697]
- Bauer PJ, Wiebe SA, Waters JM, Bangston SK. Reexposure breeds recall: Effects of experience on 9-month-olds' ordered recall. *Journal of Experimental Child Psychology*. 2001; 80:174–200. [PubMed: 11529674]
- Carver LJ, Bauer PJ. When the event is more than the sum of its parts: 9-month-olds' long-term ordered recall. *Memory*. 1999; 7:147–174. [PubMed: 10645377]
- Carver LJ, Bauer PJ. The dawning of a past: The emergence of long-term explicit memory in infancy. *Journal of Experimental Psychology: General*. 2001; 130:726–745. [PubMed: 11757877]
- Carver LJ, Bauer PJ, Nelson CA. Associations between infant brain activity and recall memory. *Developmental Science*. 2000; 3:234–246.
- Cepeda NJ, Pashler H, Vul E, Wixted JT, Rohrer D. Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin*. 2006; 132:354–380. [PubMed: 16719566]

- DeLoache JS. Becoming symbol-minded. *Trends in Cognitive Sciences*. 2004; 8:66–70. [PubMed: 15588810]
- DeLoache JS, Burns NM. Early understanding of the representational function of pictures. *Cognition*. 1994; 32:83–110. [PubMed: 7924202]
- DeLoache JS, Pierroutsakos SL, Troseth GL. The three ‘R’s of pictorial competence. *Annals of Child Development*. 1996; 12:1–48.
- DeLoache JS, Pierroutsakos SL, Uttal DH, Rosengren KS, Gottlieb A. Grasping the nature of pictures. *Psychological Science*. 1998; 9:205–210.
- Deocampo JA, Hudson JA. Reinstatement of 2-year-olds’ event memory using photographs. *Memory*. 2003; 11:13–25. [PubMed: 12653486]
- Galluccio L, Rovee-Collier C. Updating reactivated memories in infancy: II. Time passage and repetition effects. *Developmental Psychobiology*. 2005; 47:18–30. [PubMed: 15959894]
- Hartshorn K, Rovee-Collier C, Gerhardstein P, Bhatt RS, Wondoloski TL, Klein P, et al. The ontogeny of long-term memory over the first year-and-a-half of life. *Developmental Psychobiology*. 1998; 32:69–89. [PubMed: 9526683]
- Hayne H, Rovee-Collier C. The organization of reactivated memory in infancy. *Child Development*. 1995; 66:893–906. [PubMed: 7789205]
- Hudson JA, Sheffield EG. Deja vu all over again: Effects of re-enactment on toddlers’ event memory. *Child Development*. 1998; 69:52–67.
- Morgan K, Hayne H. Age-related changes in memory reactivation by 1- and 2-year-old human infants. *Developmental Psychobiology*. 2005; 48:48–57. [PubMed: 16381032]
- Pierroutsakos SL, DeLoache JS. Infants’ manual exploration of pictorial objects varying in realism. *Infancy*. 2003; 4:141–156.
- Rovee-Collier C. The development of infant memory. *Current Directions in Psychological Science*. 1999; 8:80–85.
- Rovee-Collier C, Evancio S, Earley L. The time window hypothesis: Spacing effects. *Infant Behavior and Development*. 1995; 18:69–78.
- Rovee-Collier C, Hartshorn K, DiRubbo M. Long-term maintenance of infant memory. *Developmental Psychobiology*. 1999; 35:91–102. [PubMed: 10461123]
- Sheffield EG, Hudson J. Reactivation of toddlers’ event memory. *Memory*. 1994; 2:447–465. [PubMed: 7584303]
- Sheffield EG, Hudson JA. You must remember this: Effects of video and photograph reminders on 18-month-olds’ event memory. *Journal of Cognition and Development*. 2006; 7:73–93.
- Wixted JT. The psychology and neuroscience of forgetting. *Annual Review of Psychology*. 2004; 55:235–269.

Figure 1.

(a) Production of target actions by infants who observed the reminder pictures in order, randomly, or massed (max = 6). (b) Production of correctly ordered pairs of actions by infants who observed the reminder pictures in order, randomly, or massed (max = 2).

TABLE 1

Production of individual actions and correctly ordered pairs of actions for events infants saw pictured during the reminder session

Group	Actions		Pairs of actions	
	Old event	New event	Old event	New event
Ordered	.94 (.18)	.63 (.13)	.21 (.10)	.00 (.00)
Random	.85 (.14)	.81 (.14)	.14 (.35)	.04 (.05)
Massed	.77 (.15)	.50 (.16)	.13 (.07)	.13 (.07)

Mean (*SE*).

* Old vs New; $p < .05$.

TABLE 2

Production of individual actions and correctly ordered pairs of actions for events infants did not see pictured during the reminder session

Group	Actions		Pairs of actions	
	Old event	New event	Old event	New event
Ordered	1.02	.66 [*]	.16	.11
Random	.80	.68	.13	.05
Massed	.69	.55	.11	.11

Mean (*SE*).

^{*} Old vs New; $p < .05$.